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The Study on Characteristics of Precipitation and Its Return Period Calculation in Wuhan in Recent 30 Years Based on Data Analysis

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Abstract. Meteorological big data has a wide geographical range, large space-time density, many data types and strong timeliness. It has become the requirement of the development of meteorological industry to quickly extract huge information and knowledge from big data to solve the problem of weather prediction. Based on the measured data of maximum one-hour rainfall from six representative rainfall stations in Wuhan from 1992 to 2021, the variation law, characteristic analysis and return period of different aging precipitation in Wuhan city in the past 30 years are analyzed. The results show that although the number of days of precipitation in Wuhan has increased year by year in the past 30 years, the days of rainstorm and more than rainstorm generally show a decreasing trend. The precipitation is mainly concentrated in spring (March-May) and summer (June-August), with the most in summer. The monthly precipitation is mainly concentrated in July, with the least precipitation in December. The maximum daily precipitation is between 55.1~285.7mm, and the average maximum hourly precipitation of 122.4mm reaches 98.6mm. At last, based on the parameters of GEV distribution, the maximum hourly precipitation, maximum 3h, 6h, 12h, 24h precipitation, continuous hourly precipitation, maximum daily precipitation and maximum continuous daily precipitation are fitted, and the values of different recurrence periods are estimated.

Keywords. Characteristic, meteorological, rainfall, return period, variation characteristics

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1. Introduction

Urbanization is an important symbol of national modernization. According to the data of the seventh national census, the resident population in cities and towns in China is 901.99 million, accounting for 63.89% of the total population. Under the background of the accelerating process of urbanization, the hydrological characteristics of urban areas have changed greatly under the influence of a series of factors, such as the continuous expansion of urban construction areas, the increase of impervious area, the construction of drainage system and so on [1-3]. With the continuous improvement of urban population and asset density, the disaster losses caused by flood and waterlogging disasters in cities of the same scale are obviously increased [4-5]. According to the statistics of China Flood and drought disaster Bulletin, during the period from 2006 to 2016, floods occurred in more than 160 cities across the country, with an average annual direct economic loss of more than 200 billion Yuan RMB. The degree of dependence of cities on lifeline system is gradually increasing, and the impact of flood disasters is obviously beyond the scope of flooding [6-8]. Prevention of urban flood disasters has become an important work to ensure the safety of lives and property of urban residents [9-10].

In view of the new characteristics of urban flood disasters, in order to further enhance the ability of urban flood prevention and control and reduce flood risk, Wuhan actively establishes a comprehensive and systematic flood control engineering system and promotes the defense standards of flood control projects. In order to effectively reduce the loss of flood disaster in the flood control standard. However, at present, there are still a series of problems in how to systematically manage and prevent and control urban flood disasters under complex natural and cultural conditions. For this reason, the Yangtze River Survey, Planning and Design Research Co., Ltd. have carried out research on the key technologies to improve the waterlogging prevention capacity of urban agglomeration. In view of the fact that urban waterlogging is closely related to precipitation, if rainfall of 80mm to 100mm occurs in some urban areas in a short period of time, there will be many local floods. The Yangtze River Survey, Planning and Design Research Co., Ltd. specially entrusts Wuhan rainstorm Research Institute of China Meteorological Administration to carry out the analysis of urban rainfall law in Wuhan based on the precipitation data of Wuhan in the past 30 years, in order to analyze the environmental causes of frequent urban floods in Wuhan. In order to formulate more scientific urban flood prevention measures.

2. Analysis of the Characteristics of Annual Precipitation

According to the statistics of Wuhan National basic Weather Station, from 1992 to 2021, the annual precipitation in Wuhan is increasing year by year, the average annual precipitation is 1290.4mm, the maximum annual precipitation is in 2020, the annual precipitation is 2012.4mm, and the minimum annual precipitation is 899.8mm in 2001. The average annual precipitation days are 121.6 days, with an average of 86.1 days of light rain, 21.7 days of moderate rain, 8.9 days of heavy rain, 3.7 days of heavy rain, 1.1 days of heavy rain, the longest days of precipitation in 2016 and 2020, and the shortest days of precipitation in 2005 and 2011. There is no heavy rain in 10 years, and the largest number of heavy rain days in 2016 is 4 days. In 30 years, there are at least 2 rainstorm days per year, with the largest number of rainstorm days in 2004, with 8 days. Although the number of precipitation days in Wuhan has increased year by year in the past 30 years, the number of rainstorm and more than rainstorm days showed an overall decreasing trend (see figure 1(a), 1(b), 1(c)).

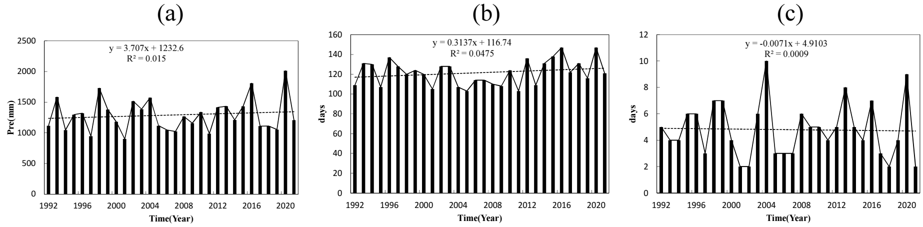


Fig.1 Distribution map of annual precipitation in Wuhan for many years (1992-2021) (a); Variation trend of annual precipitation days in Wuhan City for many years (1992-2021) (b); Variation trend of rainstorm and days above rainstorm in Wuhan City for many years (1992-2021) (c).

3. Analysis of Seasonal Precipitation Characteristics

The precipitation in Wuhan is mainly concentrated in spring (March-May) and summer (June-August) as shown in Figure2, with the most in summer, the average precipitation in spring is 345.2mm, the average precipitation in summer is 420.6mm, the average precipitation in autumn is 224.1mm, and the average precipitation in winter is 151.9mm. During the 30 years from 1992 to 2021, the maximum precipitation in spring appears in 2002, which is 653.8mm, and the minimum precipitation appears in 2011, which is 145.1mm; the maximum precipitation in summer appears in 2016, which is 1200.2mm, and the minimum precipitation appears in 2001, which is 214.4mm; the maximum precipitation in autumn appears in 2020, which is 424.4mm, and the minimum precipitation appears in 2007, which is 81.1mm. The maximum precipitation in winter is 220.1mm in 2020, and the minimum precipitation is 34.3mm in 1999.

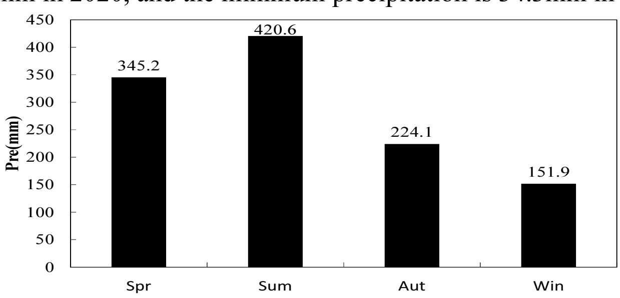


Fig. 2. Distribution of seasonal precipitation in Wuhan for many years (1992-2021).

4. Analysis of Monthly Precipitation Characteristics

The monthly precipitation in Wuhan is mainly concentrated in July as shown in Figure3, with an average annual precipitation of 235.6mm in July and the least in December, which is 29.4mm. The maximum value of multi-year monthly average precipitation is 758.4mm in July 1998, and the multi-year monthly minimum precipitation appeared in December 1999, which is 0mm (See Table 1 for details).

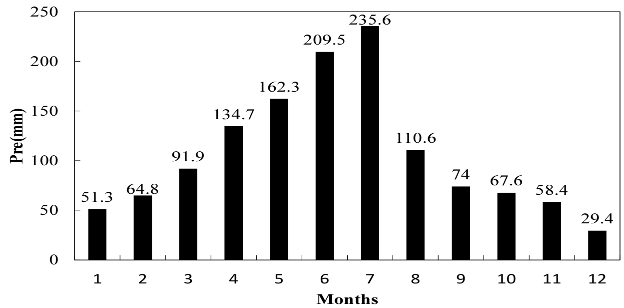


Fig. 3. Monthly precipitation distribution in Wuhan for many years (1992-2021).

Table 1. monthly precipitation statistics of Wuhan City.

January-June						
January-June Statistical content	1	2	3	4	5	6
Average monthly precipitation	51.3	64.8	91.9	134.7	162.3	209.5
Maximum monthly precipitation	113.2	122.9	225	333.6	344.2	469.1
Minimum monthly precipitation	15.6	8.4	23.9	22.9	70	53.2
July-December	7	8	9	10	11	12
Average monthly precipitation	235.6	110.6	74.0	67.6	58.4	29.4
Maximum monthly precipitation	758.4	244.1	207.8	173.1	143.4	88.9
Minimum monthly precipitation	39.6	14.4	1	1.3	0.2	0

5. Analysis of Daily Precipitation Characteristics

According to the precipitation data of Wuhan National basic Meteorological Station, during the 30 years from 1992 to 2021, the maximum daily precipitation in Wuhan is between 55.1~285.7mm, with an average of 122.4mm, among which the maximum daily precipitation in 1998 is the largest, reaching 285.7mm, and the minimum in 2017, which is 55.1mm. The maximum continuous daily precipitation in Wuhan is between 93.2~582.5mm, with an average of 218.93mm, in which the maximum sustained daily precipitation in 2016 is the most and that in 2018 is the least. The longest continuous precipitation days in Wuhan are 16 days (1992.03.13-1992.03.28) in 1992, and the process precipitation is 174.1mm. In 1995, the longest continuous precipitation days are only 4 days (1995.02.10- 995.02.13), and the process rainfall is 32.1mm. In the past 30 years, the process rainfall of the longest continuous precipitation in 2016 is the largest, reaching 582.5mm, and the process rainfall of the longest continuous precipitation in 2011 is the smallest, which is 9.7mm.

6. Analysis of the Characteristics of Short-Duration Precipitation

Affected by the effect of urbanization, the occurrence probability and rainfall intensity of high-intensity local torrential rain in urban central area are greatly increased, which increases the natural risk of flooding in the city. In recent years, extreme rainstorm events occur frequently in Wuhan, and the intensity of short-duration precipitation directly affects the degree of rainstorm waterlogging disaster. In order to better carry out the prevention and control of rainstorm and waterlogging disasters in Wuhan, according to the hourly precipitation data of the national basic weather station in Wuhan, the maximum hourly precipitation, maximum 3 h precipitation, maximum 6 h precipitation, maximum 12 h precipitation, maximum 24 h precipitation and maximum continuous hour precipitation in Wuhan are statistically analyzed. The results of statistical analysis show that from 1992 to 2021, the maximum hourly precipitation range of Wuhan City is 22.1mm-98.6mm, the maximum hourly precipitation is 98.6mm, the maximum continuous 3-hour precipitation range is 38.3-158.6mm, the maximum 3-hour cumulative precipitation is 158.6mm, the maximum 6-hour precipitation range is 46-221.2mm, and the maximum 6-hour cumulative precipitation is 221.2mm. The maximum 12-hour precipitation range is 62.4-276.7mm, the maximum 12-hour cumulative rainfall is 276.7 mm, the maximum 24-hour precipitation range is 70-293.3mm, the maximum 24-hour precipitation range is 293.3 mm, and the maximum continuous hourly precipitation range in Wuhan is 57.1-280mm.

7. Analysis of Return Period of Precipitation in Different Ages

The problem of extreme precipitation belongs to small probability events and belongs to the category of extreme value theory. In recent years, a variety of extreme value distribution models have been used to study extreme precipitation, flood and river runoff, and a variety of return period estimation methods have been derived. In general, the random variable X obeys the normal distribution. The extreme value is the maximum or minimum value selected from the random sequence, using $M_m = \max(x_1, x_2, \ldots, x_n)$, $M_n = \min(x_1, x_2, \ldots, x_n)$.The maximum and minimum values of n random variables are represented respectively, and their probability distribution characteristics can be fitted by the generalized extreme value model (GEV). There are extreme values in different aging precipitation, so they can also be fitted by GEV model. The distribution function of GEV model can be expressed as follows:

$$F(x) = \exp\left[-\left(1 + \frac{\varepsilon(x-\mu)}{\sigma}\right)^{-\frac{1}{\varepsilon}}\right] \qquad 1 + \frac{\varepsilon(x-\mu)}{\sigma} > 0 \qquad (1)$$

Where ε, μ and σ are shape parameters, position parameters and scale parameters, respectively. When the shape parameters take different values, three different extremely behaviors are corresponding.

The parameters of GEV distribution can be estimated by moment method, maximum likelihood method, Gumbel method, probability weighting method and so on. Because the maximum likelihood method is easy to adapt to complex models and the effect of parameter estimation is quite accurate, this paper uses the maximum likelihood method to estimate the model parameters. After the parameters are determined, given the return period T, the annual extreme precipitation of T is

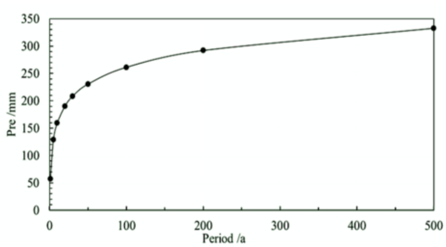
$$R_T = \mu - \frac{\sigma}{\varepsilon}\ln\left(1-(-\ln p)^{-\varepsilon}\right) \tag{2}$$

In the formula: R_T is the maximum hourly precipitation corresponding to the T-year recurrence period, and p is the probability corresponding to the return period.

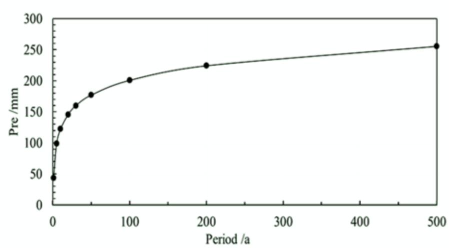
In order to better understand the influence of short-duration heavy precipitation on waterlogging in Wuhan, based on the statistical analysis results of the previous conclusion, according to Gumbel extreme value I distribution method, the maximum hourly precipitation, maximum 3h precipitation, maximum 6h precipitation, maximum 12h precipitation, maximum 24h precipitation, maximum continuous hourly precipitation, maximum daily precipitation and maximum continuous daily precipitation are fitted, and the values of different recurrence periods are estimated. Table 2 and figure 4(a)-4(f) show the maximum hourly precipitation, maximum 3h precipitation, maximum 6h precipitation, maximum 12h precipitation, maximum 24h precipitation, maximum continuous hourly precipitation

Table 2. precipitation with different aging characteristics under different return periods. (unit: mm)

Return period	1a	5a	10a	20a	30a	50a	100a	200a	500a
Max pre-1h	26	61.6	76.8	92.2	101.4	112.4	127.7	143	163.3
Max pre-3h	43.8	98.6	122.2	145.8	160.0	177.0	200.7	224.3	255.5
Max pre-6h	57.3	128.6	159.3	190.0	208.4	230.6	261.3	292.0	332.5
Max pre-12h	68	155.4	193.0	230.6	253.2	280.4	318.0	355.6	405.4
Max pre-24h	82	176.5	217.2	257.9	282.3	311.7	352.4	393.1	446.9



(a)



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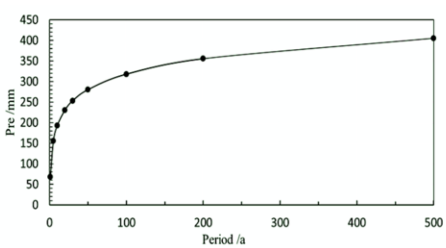

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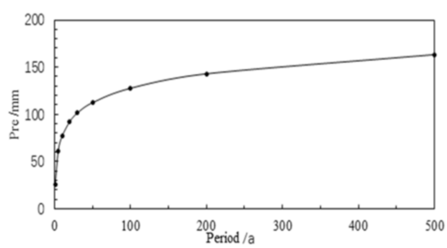

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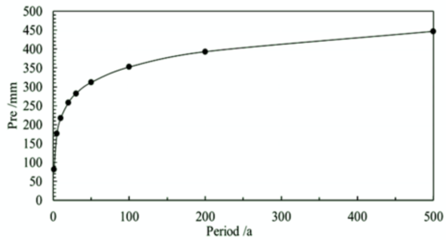

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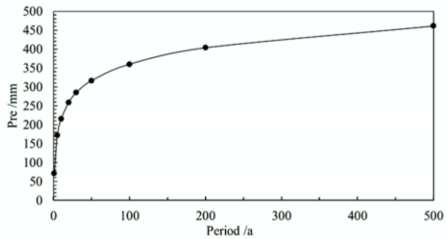

(f)

Fig.4 (a) return period distribution curve of maximum hourly precipitation in Wuhan; (b) return period distribution curve of maximum 3-hour precipitation in Wuhan; (c) return period distribution curve of maximum 6-hour precipitation in Wuhan; (d) return period distribution curve of maximum 12-hour precipitation in Wuhan; (e) return period distribution curve of maximum 24-hour precipitation in Wuhan; (f) return period distribution curve of maximum continuous hourly precipitation in Wuhan;

8. Conclusion

Based on the measured data of maximum one-hour rainfall from six representative rainfall stations in Wuhan from 1992 to 2021, the variation law, characteristic analysis and return period of different aging precipitation in Wuhan city in the past 30 years are analyzed. The results show that:

1) The average annual precipitation in Wuhan is 1290.4mm, and the maximum annual precipitation occurs in 2020. Although the annual precipitation days are increasing year by year, the annual rainstorm and the number of precipitation days above the rainstorm show a decreasing trend.

2) The precipitation in Wuhan is mainly concentrated in spring (March-May) and summer (June-August), with the most in summer, the average precipitation in spring is 345.2mm, the average precipitation in summer is 420.6mm, the average precipitation in autumn is 224.1mm, and the average precipitation in winter is 151.9mm.

3) The monthly precipitation in Wuhan is mainly concentrated in July, and the average annual precipitation in July is 235.6mm. The lowest precipitation is 29.4mm in December. The maximum monthly precipitation of many years appeared in July 1998, reaching 758.4mm.

4) Based on the parameters of GEV distribution, the maximum hourly precipitation, maximum 3h precipitation, maximum 6h precipitation, maximum 12h precipitation, maximum 24h precipitation, maximum continuous hourly precipitation, maximum daily precipitation and maximum continuous daily precipitation are fitted, and the values of different recurrence periods are estimated.

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