Analysis on the Characteristics of Extreme Weather Events in Kunming City during Recent 20 Years

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Abstract. Extreme weather events will change the current situation and distribution of the water cycle in the region, resulting in reallocation of time-space distribution of water resources, and directly affect precipitation, and runoff. In recent 20 years, it has experienced drought for three consecutive years from 2009 to 2011 in Kunming, in addition, serious urban waterlogging happened in almost every year which cause by the extreme precipitation events, this article selects 1998-2011 monitoring stations in kunming. The time, frequency and variation characteristics of rainstorm are studied. Through the study we found the formation of storm floods of factors in addition to natural factors, the change of the underlying surface conditions of urban waterlogging has played a more important role.

1. Introduction

Extreme weather events refer to the state of weather (climate) seriously deviates from its average state, which is a statistically unlikely event. Generally speaking, extreme weather events refer to small probability events that occur once every 50 years or once every 100 years. According to the assessment report of the United Nations intergovernmental panel on climate change (IPCC), over the past 50 years, extreme weather events, especially heavy precipitation, heat wave and other extreme events, have been on the rise and are expected to become more frequent in the future. At present, extreme weather events are studied mainly from the two aspects of extreme drought and extreme rainfall. Through the analysis of extreme weather events, relevant laws are found to predict the frequency, influence range and guide production practice. [1]

Extreme weather events are one of the natural disasters that have the greatest impact on the production and life of human society. The occurrence of extreme weather events in the past two decades has brought about a great impact on people's production and life in Kunming.

In general, absolute threshold method is adopted. For extreme precipitation events, daily precipitation of more than 50mm is taken as a rainstorm day. [2]
2. Background

Kunming is located in the central part of Yunnan province, the low-latitude plateau mountain monsoon climate zone, high in the north and low in the south. Most areas are between 1,500 and 2,800 meters above sea level. The urban area is located in the north of Dianchi basin, surrounded by mountains on the three sides in the south. It is a typical city of plateau basin, it is known as "spring city". In spring, it is warm and dry with little rain, high winds, high evaporation, and large daily temperature changes, it is not hot in summer, and rainfall is concentrated, it is warm and cold in autumn, less rain. In winter, there is no severe cold, plenty of sunshine and little rain. The wet and dry seasons are distinct, and the precipitation is concentrated from May to October, accounting for about 85% of the annual precipitation. The dry seasons runs from November to April, and rainfall accounts for only about 15% of the year.

Yunnan suffered three years of drought from 2009 to 2011. The drought has greatly affected on the water security of Yunnan province. Urban waterlogging caused by heavy rains also severely affected Kunming almost every year. In 1988, for example, there was a severe spring drought, and the rainy season experience flooding. These disasters caused by abnormal weather events have seriously affected people’s production and life. Therefore, it is of great significance to study extreme weather events to forecast disasters, make plans in advance, mitigate disaster losses and maintain normal production and living order.

3. Data and Methods

This paper studies the urban extreme weather events in Kunming-southwest plateau basin. This paper selects the monitoring data of Kunming monitoring station, they are from 1988 to 2011 of the meteorological and hydrological data, study in Kunming the laws between the precipitation, runoff and climate change, and according to the data analysis of the correlation of extreme events and meteorological factors.

There are two main definitions of extreme climate: one is the absolute threshold method. If the maximum (low) daily temperature is defined, the maximum daily precipitation greater than 50mm is a rainstorm day; another is the relative threshold, which is different from place to place based on the centenary value as the extreme threshold, such as 90% percentile of all precipitation or 95% percentile as the extreme precipitation value. The extreme events in this study are mainly defined according to the absolute threshold method.

A rainfall greater than 50mm within 24 hours is defined as a rainstorm in meteorology. This paper adopts this partition method.

4. Result and analysis

4.1. Extreme precipitation event.

The division of rainstorm days in kunming is consistent with that of meteorology. Because of the special geographical location and underlying conditions, extreme precipitation events are the main cause of urban waterlogging in kunming. Therefore, extreme precipitation events are analyzed as a series in this paper, analyzed the precipitation data and annual mean runoff data from 1988 to 2011 (Table 1). It can be seen from table 2 that there are a total of 48 storm events that are qualified. The occurrence number of each year and the maximum rainfall on a rainstorm day are shown in the table 1.
Table 1. More than 50mm daily rainfall scale at kunming station (1988-2011) (mm)

| Data   | Rainfall | Data   | Rainfall | Data   | Rainfall |
|--------|----------|--------|----------|--------|----------|
| 6/19/1988 | 8.07 | 7/27/1988 | 74.9 | 8/3/1989 | 6.79 |
| 6/26/1990 | 53.5 | 7/16/1990 | 53.2 | 8/23/1990 | 58.9 |
| 9/18/1990 | 76.1 | 10/4/1990 | 63.4 | 8/11/1990 | 65.5 |

| Data   | Rainfall | Data   | Rainfall | Data   | Rainfall |
|--------|----------|--------|----------|--------|----------|
| 6/17/1994 | 6.65 | 6/21/1994 | 6.04 | 7/7/1994 | 69.7 |
| 6/21/1994 | 6.17 | 7/16/1994 | 75.5 | 8/23/1994 | 60.6 |
| 9/18/1994 | 65.8 | 10/4/1994 | 56.5 | 8/11/1994 | 63.1 |
| 7/20/1994 | 84.5 |

Table 2. Number of annual rainstorms and maximum daily precipitation (1988-2011) (mm)

| Year   | Number | Maximum daily precipitation |
|--------|--------|-----------------------------|
| 1988   | 1      | 80.7                        |
| 1989   | 2      | 74.9                        |
| 1990   | 1      | 76.9                        |
| 1991   | 4      | 76.2                        |
| 1992   | 1      | 58.9                        |
| 1993   | 1      | 76.1                        |
| 1994   | 5      | 63.4                        |
| 1995   | 1      | 65.5                        |
| 1996   | 1      | 75.5                        |
| 1997   | 4      | 69.6                        |
| 1998   | 8      | 65.8                        |
| 1999   | 6      | 84.5                        |

It can be seen from table 2 that the number of rainstorms tends to decrease gradually. The maximum daily precipitation occurred from 1997 to 1999, among which the flood occurrence frequency and flood volume in 1998 were the largest, which was consistent with the occurrence of major floods in all parts of China in 1998.

Table 3. Statistics on the number of rainstorms in the rainy season (1988-2011)

| Month | Frequency | Early | Mid | Late |
|-------|-----------|-------|-----|------|
| 5     | 3         | 1     | 1   | 1    |
| 6     | 14        | 5     | 5   | 4    |
| 7     | 15        | 7     | 5   | 3    |
| 8     | 11        | 5     | 2   | 4    |
| 9     | 4         | 2     | 1   | 1    |
| 10    | 1         | 1     | 0   | 0    |
As shown in table 3, the rainstorm events were concentrated from June to August in 1988-2011, the number of occurrences was more average, mid-to-late June, and more occurred in early July, it occurs more frequently in early and late August. The heavy rain was concentrated in early September. Since the rainy season in Kunming is mainly focus on June, July, and August, the torrential rain event in Kunming was mainly from June to August that is, the flood control and disaster relief work was mainly concentrated in June, July, and August.

4.2. Extreme drought events.
Meteorological drought mainly refers to the imbalance between precipitation and evapotranspiration which leads to abnormal water shortage, that is, precipitation is less than evapotranspiration. The main indicators studied are dryness and humidity, and it is closely related to. By analyzing the daily rainfall data in Kunming, it can be seen that the drought events mainly occur in the dry season. According to the climatic conditions in Kunming, it can be seen that: There is no obvious relationship between water shortage in the dry season and weather changes, so we need to analyze the shortage of water in the rainy season. It can be seen from figure 1: The rainfall was relatively low in 1988, 1989 and 2008, but significantly low in 2009-2011. Therefore, the drought events were mainly analyzed in the three years of 2009-2011.

![Figure 1. Relationship diagram of annual rainfall, average temperature and relative humidity (1988-2015)](image)

According to figure 1, the annual average temperature has a gradual upward trend. From 2005 to 2011, the average annual temperature change was slightly. It has to do with global warming. The average annual relative humidity is decreasing. In 2005 and 2011 they changed slightly. Annual rainfall tends to decrease with the year, and annual rainfall fluctuations are relatively large. From 2009 to 2011, there was a trough was a trough of severe rainfall and drought.
4.3. The Annual rainfall and annual average river flow.

Figure 2 is drawn from precipitation and average annual average flow in 1988-2011. The calculation of regional runoff and confluence involves regional confluence area, confluence time, precipitation intensity, underlying surface condition, etc. As the research area is Kunming, the regional conditions are basically the same, compared the change of the index value of each year. Therefore, this paper does not do the production confluence calculation, but only analyzes the trend presented in the calculated year.

![Relationship diagram of annual rainfall and average flow (1988-2011)](image)

Figure 2. Relationship diagram of annual rainfall and average flow (1988-2011)

From figure 2, there is a partial correlation between precipitation and annual average flow of rivers, but the correlation is not strong. From the trend line, precipitation has a trend of gradually decreasing, while the annual average flow has a trend of gradually increasing. The reason is that with climate change, extreme weather events are increasing. This is reflected in the increase of the frequency of single rainstorm and the increase of rainfall, which shortens the time of runoff and confluence and reduces the soil infiltration. In addition, with the acceleration of urbanization, the underlying surface conditions have changed, and the impervious area has increased, so that precipitation can be converted into surface runoff more quickly.

Extreme weather events have a significant impact on the catchment runoff, it has a greater impact on regional hydrological elements. Leading to the transformation of the development and utilization of water resources. For example, Many cities have begun to build underground reservoirs to store flood waters during the flood season in order to use when the dry season coming.

4.4. Analysis of cause of extreme events.

Extreme climatic events have various extreme results. In general, the effects of flood and drought are analyzed. The main factor is precipitation, and the factors affecting precipitation include:

1. Changes in height field: after the 1970s, the height field of potential in mainland China has been increasing. Due to the influence of human activities, the surface temperature rises and the sensible heat increases. It also raises the potential height field. The potential height field also strengthens the ground temperature rise, and the increase of height field leads to the increase of rainfall.
2. Changes of vorticity field: The vorticity field in the region has an upward movement, which will lead to an increase in precipitation and a slow upward trend of temperature.

3. Changes of water vapour field: Increased convergence of water vapour field result in the increased rainfall.

In conclusion, the cause of extreme weather events are mainly three aspects on above. With the global temperatures changing, the analysis of extreme weather events mainly focuses on local areas. At present, different regions of the world are affected by various kinds of extreme events. Different regions are affected differently. In recent years, Kunming has witnessed a rise in temperature, a decrease in precipitation and a frequent occurrence of extreme events. As the water circulation water vapor decreases, evaporation decreases, coupled with human activities to make the climate warmer, adverse factors continue to increase. Therefore, the extreme events in Kunming are mainly caused by changes in height field.

4.5. Analysis of the impact of extreme events.
Statistics of the number of floods and the degree of disaster, it can be found that the disaster caused by extreme precipitation events is urban waterlogging. Severe storms and floods can flood large areas of farmland, destroy crops, reduce or even destroy crops. During the 24 years from 1988 to 2011, serious waterlogging occurred in the main urban area of Kunming almost every year due to the problem of terrain, which brought serious economic losses. The suburban areas were also affected by the impact of heavy rain and mud flows, landslides and other natural disasters.

From 2009 to 2011, Kunming suffered severe drought for several years, mainly due to extreme low precipitation. According to the statistics of the meteorological department, the precipitation rainy season of the city in the past three years is around 550mm, about 40% less than that of the year.

5. Discussion
The occurrence of rainstorms in kunming has obvious seasonality, that is, they are mainly concentrated in june-august, and short-term rainstorms are extremely easy to occur, which cause urban waterlogging, affect traffic and flood living areas, especially in the main urban area. In addition to meteorological factors, the influencing factors are also related to the capacity of urban flood discharge and insufficient capacity of municipal drainage system.

Local climate change is subject to major climate change. In the context of global climate change, the probability of regional extreme events significantly increases.

Therefore, it is necessary to improve the forecast accuracy, take preventive measures in advance, and renovate the urban drainage pipe network.

Urban waterlogging caused by heavy rain often happens in a very short time, which requires people to respond to it quickly and timely. In order to solve the problem of urban waterlogging, We rely on more than accurate forecasts, that it is not enough to rely solely on engineering means. On the one hand, the maximum flood amount of rainstorm flood cannot be accurately predicted; on the other hand, all urban drainage pipes cannot be replaced to improve flood discharge capacity. Therefore, we must rely on ecological methods and ecological means to change the underlying surface conditions. In case of rainstorm, partial rainfall can be intercepted, confluence process can be slowed down, and peak value can be cut down. In normal times, water resources can be conserving and water quantity can be saved. For example, to build the ecological section of the river course, to recover winding function of the river course and the sponge city project are being implemented.

Results
Through the analysis of the impact of extreme weather events in kunming, the following conclusions are drawn:

(1) Kunming rainstorm occurrence frequency in the past 20 years have gradually reduce the trend, it is related to global climate change, because the information collected by in 2011, just after three years of drought in 2009-2011, remove the influence of the drought, rainstorm floods frequency is basic in
reducing trend, illustrates the construction of water conservancy projects and the implementation of ecological engineering is effective;

(2) In the past 20 years, the rainstorm season in Kunming is generally from June to August, in which July of each year is the high frequency of rainstorm flood, which is related to the distinct dry and wet season characteristics of Kunming. With the vigorous development of disaster prevention and reduction work, the loss of urban waterlogging caused by rainstorm flood will be reduced correspondingly.

Focus on ecological changes, adopting ecological methods and the corresponding institutional measures mitigate the changing trend of global warming and meteorological factors, they also will reduce the impact of extreme weather events on hydrological and social elements. Therefore, rational planning, development and management of water resources, making full use of existing water conservancy projects and developing new forms of water conservancy projects, such as, building underground reservoirs, they can play a role in flood season storage, dry season access. In order to achieve the purpose of combined surface-water and groundwater scheduling. In addition, through scientific and accurate weather forecasts, we should formulate relevant disaster response plans to improve the ability to deal with disasters and achieve harmony between human and nature.

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