Analysis on the characteristics of precipitation changes in the Yangtze River Basin in recent years

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Abstract. The Yangtze River is China’s mother river. In the context of climate change, it is of great practical significance to study the changes in precipitation in the Yangtze River Basin, especially in the event of a catastrophic flood in the Yangtze River Basin in 2020. Based on the daily data of measured precipitation in the Yangtze River Basin, this study analyzed the trend and sudden change of precipitation, and also analyzed the intra-annual distribution during the year, and obtained the following conclusions: the change trend of the annual precipitation shows increase insignificantly, and the change-point occurred around 2015; the flood season accounts for 82.5% of the annual precipitation; the precipitation in the dry season has a slight increasing trend.

1. Introduction
The Yangtze River is the mother river of the Chinese nation and an important support for the development of China. With 18.8% of the country’s land area, the Yangtze River produces 33% of the country’s food, nurtures 32% of the country’s population, and creates 34% of the country’s GDP [1]. It is a strategic water source for China’s water resources allocation, an important clean energy strategic base, and the “golden waterway” that traverses east and west [2]. In addition, it is an important support point for improving China’s ecological environment, and has a very important strategic position in China’s economic and social development and ecological environment protection.

In 2020, the Yangtze River Basin was affected by precipitation, and there were catastrophic floods throughout the basin, which greatly affected the people's property and life safety [3]. In the context of global climate change, studying the characteristics of precipitation changes in the Yangtze River Basin is helpful to provide reference information for decision makers.

2. Study Area
The Yangtze River originates from the Tanggula Mountains on the Qinghai-Tibet Plateau in China. The main stream flows from west to east through 11 provinces (autonomous regions and municipalities) including Qinghai, Tibet, Yunnan, Sichuan, Chongqing, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, and Shanghai. The total length of the Yangtze River is about 6300km, its tributaries extend to 8 provinces including Gansu, Shaanxi, Henan, Guizhou, Guangxi, Guangdong, Fujian, and Zhejiang, with a basin area of about 1.8 million km².
The topographic features of the Yangtze River Basin are high in the northwest and low in the southeast, crossing the Chinese terrain from west to east. The basin generally belongs to the East Asian monsoon region and has a significant monsoon climate [4]. The vast area and complex land-forms determine the diversity of the Yangtze River Basin. The basin is rich in precipitation, and the annual precipitation distribution trend is that the south of the Yangtze River is larger than that of the north of the Yangtze River, and the middle and lower reaches are larger than the upper reaches, showing a downward trend from southeast to northwest. The average is 940mm in the upper reaches and 1440mm in the middle and lower reaches [5].

3. Data and Methodology

3.1. Data
The precipitation data of the Yangtze River Basin comes from the daily precipitation data of each station in the Yangtze River Hydrological Yearbook.

3.2. Methodology
The monthly and annual precipitation data were counted through mathematical statistics, and then the area average precipitation in the Yangtze River basin is counted through the method of Thiessen polygons. Linear trend method is used in trend analysis, while Mann-Kendall (M-K) method is used to detection change-points [6].

4. Results and Discussion

4.1. Analysis on the characteristics of annual precipitation

4.1.1. Trend analysis
Based on the characteristics of annual precipitation in the Yangtze River Basin from 1960 to 2018, the average precipitation was 1058.1mm, the maximum annual precipitation was 1222.9mm in 2006, and the minimum annual precipitation was 892.7mm in 1978, of which the 30-year average areal precipitation was 1049.2mm (1986-2015, the same below). According to Figure 1, the total areal precipitation in the Yangtze River Basin has no significant change trend (2.1mm/10a) in the past 60 years, but there has been a significant increasing trend since 2006. The inter-annual fluctuation of annual precipitation in the Yangtze River Basin in the past 60 years is very obvious.

Figure 1  Change trend of annual precipitation in the Yangtze River Basin from 1960 to 2018

4.1.2. Change-point detection
Figure 2 shows the M-K change-point analysis of the annual precipitation in the Yangtze River Basin. It can be seen from the UF curve that the annual precipitation in the Yangtze River Basin shows a decreasing trend in general, but it has not passed the significance test. Based on the the intersection of
the UF and UB curves, the annual precipitation change-point occurred around 2015, then showing a weak increasing trend, but not significant.

![Graph showing UF and UB curves with UF > UB around 2015](image)

Figure 2  M-K analysis of annual precipitation in the Yangtze River Basin (The black dashed line indicates the critical value of 95% significance level)

4.1.3. Intra-annual distribution characteristics

Figure 3 shows the intra-annual distribution characteristics of monthly average precipitation in the Yangtze River Basin. For the Yangtze River Basin, June has the most precipitation, with an average of 170.7mm, accounting for 16.1% of the annual precipitation; followed by July with an average of 163.2mm, accounting for 15.4% of the annual precipitation. The precipitation of the three months in the main flood season accounts for 44.7% of the annual precipitation, the precipitation of the flood season (April-October) accounts for 82.5% of the annual precipitation; the precipitation of the dry season (November-April) accounts for 26.4% of the annual precipitation.

![Bar chart showing monthly precipitation in the Yangtze River Basin](image)

Figure 3  Annual distribution characteristic of the monthly average precipitation in the Yangtze River Basin

| Month | Precipitation (mm) |
|-------|--------------------|
| 1     | 20                 |
| 2     | 30                 |
| 3     | 40                 |
| 4     | 50                 |
| 5     | 60                 |
| 6     | 70                 |
| 7     | 80                 |
| 8     | 90                 |
| 9     | 100                |
| 10    | 110                |
| 11    | 120                |
| 12    | 130                |

Table 1  Percentage of the monthly average precipitation to the total annual precipitation in the Yangtze River Basin (Unit:%)

| Month     | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
|-----------|----|----|----|----|----|----|----|----|----|----|----|----|
| Yangtze River Basin | 2.5 | 3.3 | 5.9 | 8.9 | 12.4 | 16.1 | 15.4 | 13.2 | 10.1 | 6.4 | 3.7 | 2.0 |
4.2. Analysis on precipitation change in the dry season

4.2.1. Trend change
Precipitation characteristics in the dry season (November-April of the following year) in the Yangtze River Basin from 1960 to 2018 was counted. The statistical year lasts 59 years from 1960 to 2018. Considering the completeness of the hydrological year, the dry season is from November to April of the following year.

The 30-year average precipitation in the dry season in the Yangtze River Basin is 280.8mm. From the perspective of the inter-annual variation of annual precipitation (Figure 4), the precipitation in the dry season in the Yangtze River Basin has a slight increasing trend (2.5mm/10a) in the past 60 years. From the perspective of amplitude, the inter-annual fluctuations of precipitation in the dry season in the Yangtze River Basin have been more obvious.

![Figure 4](image-url)

Figure 4 Change trend of precipitation in the dry season (November -April of the following year) in the Yangtze River Basin from 1960 to 2018

4.2.2. Change-point detection
Figure 5 shows the MK change-point analysis of the precipitation in the dry season in the Yangtze River Basin. It can be seen from the UF curve that the precipitation shows a trend of first decreasing and then increasing in general. The precipitation shows a fluctuatingly decreasing trend before 1990 and an increasing trend after 1990, but it has not passed the significance test.

![Figure 5](image-url)

Figure 5 M-K analysis of precipitation in the dry season in the Yangtze River Basin (The black dashed line indicates the critical value of 95% significance level)
5. Conclusions
(1) The change trend of the annual precipitation in the Yangtze River Basin is not obvious, the total precipitation in the dry season shows a slightly increasing trend, but change-point detection is not significant.
(2) The Yangtze River Basin has obvious characteristics of the flood season, in which the precipitation during the flood season (April to October) accounts for 82.5% of the annual precipitation.
(3) This study only briefly analyzed the precipitation trends and sudden changes in the Yangtze River Basin, as well as the intra-annual distribution characteristics. From the perspective of flood resistance, it is more necessary to study the change characteristics of extreme precipitation, and this is the content of the next step.

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