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Spatial and temporal variations of precipitation in Haihe River basin in the recent 53 years

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Abstract In the context of climate change, the precipitation of the Haihe River basin undergoes significant changes. Based on the daily precipitation data from 58 stations over 53 years in and around Haihe River basin, the spatial and temporal variation of precipitation was analysed by the M-K test method using the ArcGIS platform. The results showed that there is a descending trend in the annual precipitation and after the mutations, 97.9% of the area experiences a precipitation reduction by the amount of 0–200 mm. The proportion of precipitation in the flood season demonstrates a decreasing tendency, in which the proportion of precipitation in July declines significantly. Meanwhile, precipitation in July also experiences a downward tendency and after the mutations, the decrement of precipitation in July amounts to 0–84 mm. However, annual precipitation and the proportion of precipitation in June all experience a rising trend. After the mutations, the added precipitation concentrates in 0–36 mm. With the increase of the proportion of non-flood season precipitation, the precipitation and proportion of precipitation in May both exhibit an increasing tendency. After the mutations, the added value of precipitation concentrates as 0–29 mm.

Key words Haihe River basin; precipitation, M-K test method; spatial–temporal variation

1 INTRODUCTION

Haihe River basin, whose catchment is 317 900 km^2 is located between 112°–120°E, and 35°–43°N, and includes the Haihe River and Luan River water system. Because of its special geographical position (arid to humid transition zone) there are obviously zonal seasonal and inter-annual differences in its precipitation. Haihe River basin experiences frequent floods and water shortages (Guo and Liu, 2004). Since precipitation is the main source of water supply, analysis of the spatial and temporal variation of precipitation in Haihe River basin is of great importance. In recent years, some scholars have conducted a series of studies on the precipitation of Haihe River basin (Xu *et al.* 2009; Liu and Shen 2010; Liu, *et al.* 2010; Wang, *et al.* 2010, 2012), however most of these studies concentrate on the trends of precipitation variation. In view of this, this paper analysed the proportion of precipitation in different periods of time and the variation of precipitation in space so as to provide some references for the water resources manager.

2 MATERIALS AND METHOD

2.1 Data sources

Daily meteorological data from 58 weather stations in the Haihe River basin and its surrounding areas for 1958–2010 (53 years) was selected as the base data for analysis of the spatial and temporal variation of precipitation. The distribution of the weather stations is shown in Fig. 1.

2.2 Method

The Mann-Kendall test method (Wei, 1999; Wang *et al.* 2011) and precipitation concentration were used to analysis the temporal variation of precipitation and determine precipitation mutations in different time periods. Based on this, the paper analysed the spatial variation of precipitation. The calculation procedure of M-K test method is described in Wei (1999) and Wang *et al.* (2011).

3 RESULTS ANALYSIS

Using the single site data, surface rainfall was calculated by the method of tessellation polygons. The annual average precipitation of Haihe River basin is 525.3 mm, which is below the national average annual precipitation (800 mm). In the study area, the maximum annual rainfall is 813.8 mm which is 2.32 times larger than the smallest annual precipitation (350.1mm).

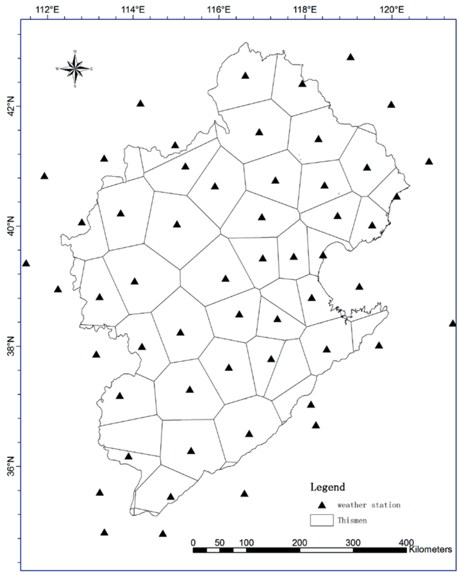


Fig. 1 Distribution of the weather stations.

However, there is an unobvious declining trend on the annual precipitation because the standardized statistic Z_c is below 0, but larger than –1.96. The annual precipitation UF_k curve shows that after 1968, annual precipitation in Haihe River basin show a sustained reduction trend, but this is not significant. Annual precipitation mutation took place in about 1978, after which the decreasing trend of precipitation increases, but does not exceed a confidence level of 95%.

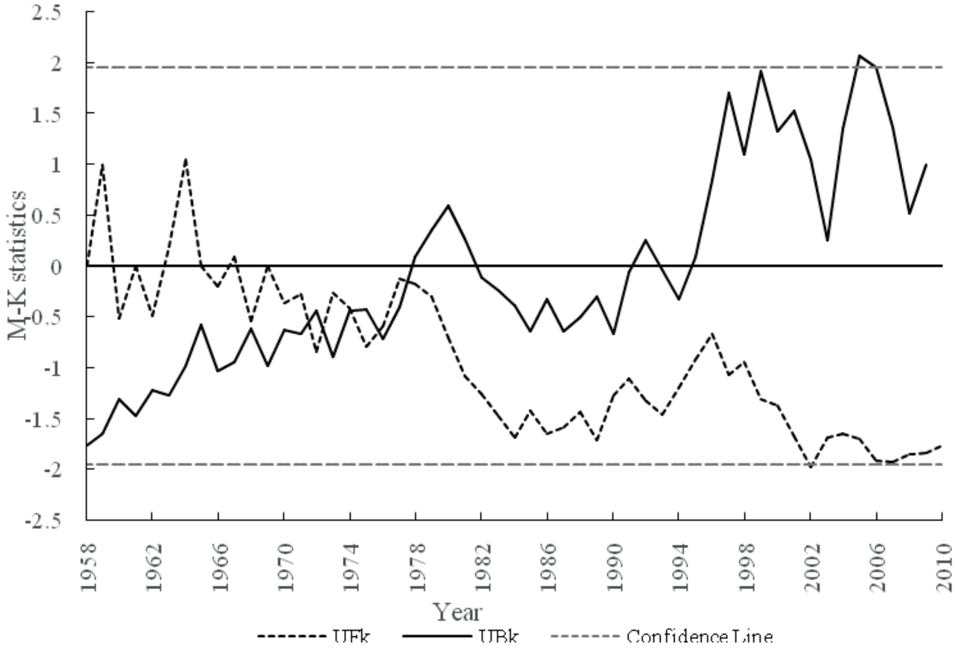


Fig. 2 M-K test curve of Haihe River basin.

3.1 Changes of precipitation concentration

Calculation shows that the annual precipitation concentration is 0.67 and there is a downward trend in it, but it is not significant. The concentration of rainfall varies during the years, alternating between high and low, and bringing some challenges to rainwater use and water resources management in Haihe River basin.

The concentration of precipitation is affected not only by the precipitation of specific periods of time, but also be affected by total precipitation. Therefore, the analysis of monthly precipitation and annual precipitation seem of equal importance. As we know, the proportion of the monthly precipitation is affected not only by monthly precipitation but also by annual precipitation, so this paper analysed the trend of the proportion of the monthly precipitation first, and based on this, the paper analysed the affect of variation of monthly precipitation on precipitation concentration.

3.2 Variation of precipitation in different time periods

The proportion of monthly precipitation was analysed by the M-K test method and the results are shown in Fig. 3.

The result shows that the proportions of precipitation in March, April, May, June, September and October all have an increasing trend. In May and June the trend is significant. However, the proportion of precipitation in other months all display a decreasing tendency, and in July the trend is very obvious.

The proportion of precipitation in the flood season was also tested by the M-K method and the result of Zc is –1.95. It shows that proportion of precipitation in summer also has a decreasing trend. That is to say the proportion of precipitation in the non-flood season has an increasing trend. However, the decreasing trend in the flood season is not significant. So far it can be said that the reduction of the precipitation proportion in the non-flood season is a direct factor that leads to the decline of precipitation concentration.

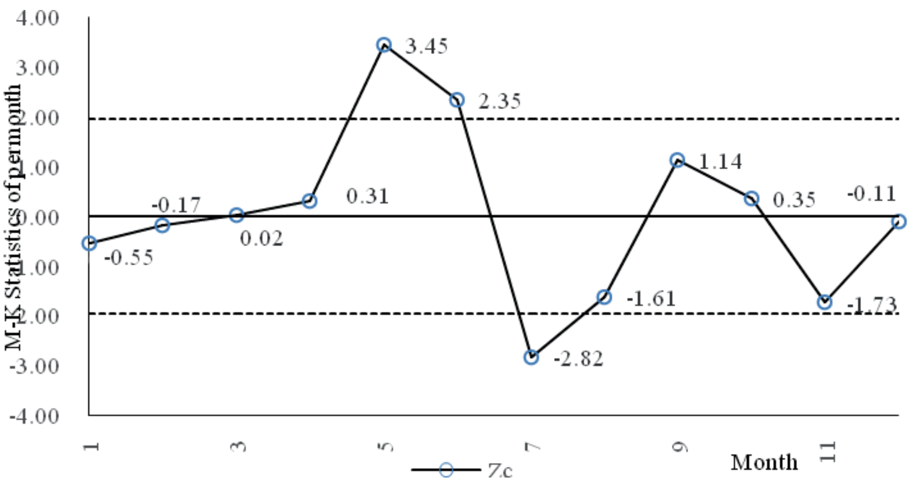


Fig. 3 M-K test of the proportion of the monthly precipitation in Haihe River basin.

3.2.1 Temporal variation Precipitation in May, June and July, whose proportion of precipitation show an obvious trend was analysed by the M-K test method. The results show: (1) Precipitation in May experiences a process of increase first, and then declines, but it shows an increasing trend overall. In 1958–1970, precipitation in May exhibits a not obvious decreasing trend, however, in 1971–2010 it displays an increasing tendency. What is more, in 1990–1993 and 2005–2009, the tendency is significant because the standardized statistics exceed the confidence level. Precipitation mutation occurs in about 1982. (2) After 1975, precipitation in June exhibits a continued rise and the mutation occurs in about 1976. (3) Precipitation in July shows a decreasing trend overall and can be divided into two phases: first, in 1958–1965 the tendency is not clear; second, in 1965–2010 precipitation shows a decreasing trend. What is more, in 1982–1993 and 2001–2009 the tendency is very significant. Mutation occurs twice, in 1978 and 1995.

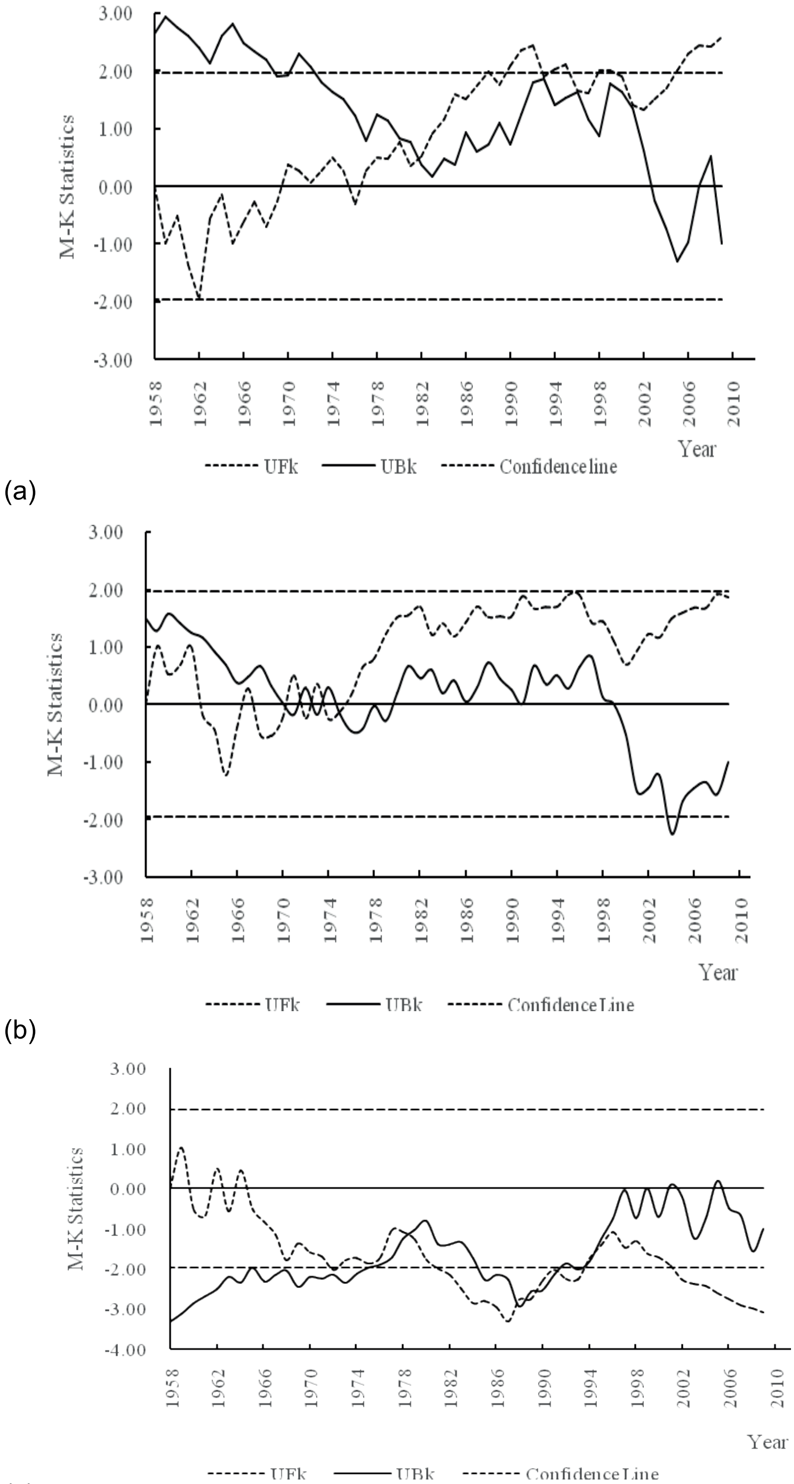


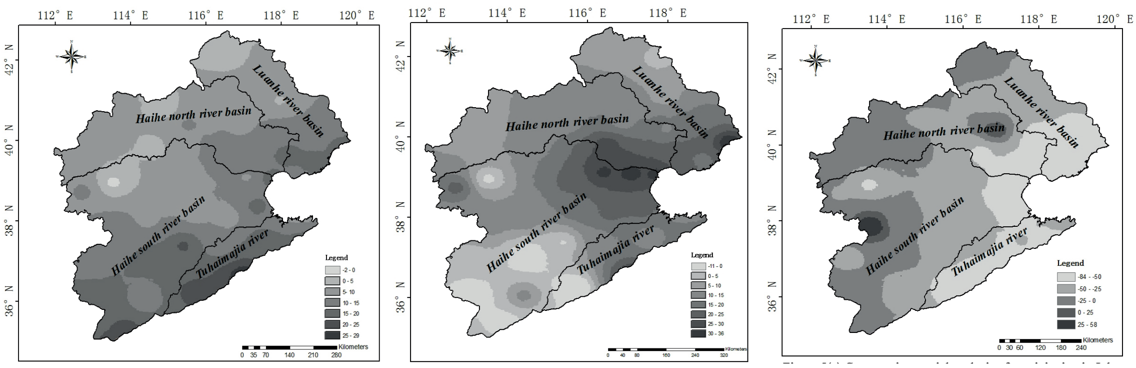
Fig. 4 M-K curve of precipitation in: (a) May, (b) June, and (c) July.

3.2.2 Spatial variation Precipitation of May, June and July, whose proportions of precipitation change obviously, were analysed in space. Precipitation mutation in May and July occurs in about 1982 and 1976, respectively. Since there were two mutations in June, we chose 1978 as an example.

The spatial comparison of precipitation before and after the mutation in May shows: (1) precipitation after the mutation is larger than before on the whole, and the area whose precipitation experienced an increasing trend is 28.96 km^2, and accounts for 90.8% of the watershed area. (2) Overall, the increase gradually increases from north to south, and from west to east. (3) The second grade of water was selected as a unit to analyse the spatial variation of precipitation and the result shows: Precipitation increase in Luanhe watershed and Hehai north basin concentrate in 0–20 mm and increases gradually from north to south and west to east. Precipitation in Haihe south basin exhibits an increasing trend but in Wutai Mountain and the increase concentrates in 0–25 mm. Compared with other district precipitation in the Tuhaimajiahe River basin experienced an obviously increasing trend, the increase concentrates in 10-30mm and the increase increases obviously from north to south.

Table 1 Spatial variation of precipitation in May.

Trend	Reduction	Increase					
Precipitation variation (mm)	–1.2~0	0~5	5~10	10~15	15~20	20~25	25~29
Area (10^4 km^2)	0.06	2.76	12.39	9.51	5.88	1.14	0.03
Percentage of watershed area (%)	0.2	8.7	39.0	29.9	18.5	3.6	0.1



(a) (b) (c)

Fig. 5 Comparative spatial analysis of precipitation in (a) May, (b) June, and (c) July.

Spatial analysis of precipitation before and after the mutation in June shows: (1) After the mutation, precipitation is larger than before on the whole and the area whose precipitation experienced an increasing trend is 29.52 km^2, accounting for 92.9% of the watershed area. (2) Precipitation increase exhibits an obvious increase from west to east and concentrates in 0–29 mm, but in different area it differs a lot. (3) Most of the region whose precipitation shows a decreasing trend is located in the south and the reduction of precipitation less than 10.5 mm. (4) After the mutation, precipitation in Luanhe River basin and Haihe North River basin experience an increasing tendency and the increase increases obviously from west to east. But, precipitation of Weichang shows a decreasing trend and the reduction is 0–10.5 mm. What is more, precipitation increase of Haihe South basin and Tuhaimajia River basin all show a decrease from north to south. Precipitation of Changzhi Xinxian and Xingtai all exhibit a downward trend and the reduction is less than 10.5 mm.

Table 2 Spatial variation of precipitation in June.

Trend	Reduction	Increase			
Precipitation variation (mm)	–10.5~0	0~10	10~20	20~30	30~36
Area (10^4 km^2)	2.26	9.90	14.22	5.08	0.32
Percentage of watershed area (%)	7.1	31.1	44.8	16.0	1.0

Table 3 Spatial variation of precipitation in July.

Trend	Reduction			Increase	
Precipitation variation (mm)	–84 to –50	–50 to –25	–25 to 0	0~25	25~58
Area (10^4 km^2)	7.17	13.32	10.56	0.50	0.22
Percentage of watershed area (%)	22.6	41.9	33.2	1.6	0.7

Spatial comparison of precipitation before and after the mutation in July shows: (1) After the mutation, precipitation is larger than before, on the whole, and the area whose precipitation experienced an increasing trend is 31.05 km^2, accounting for 97.7% of the watershed area. (2) Most of the increased precipitation area is located around Yangquan and Miyun. (3) Reduction of precipitation shows an obvious increasing trend from west to east and concentrates around 0–84 mm. (4) Precipitation reduction of Tuhaimajiahe River basin concentrates in 50–84 mm and precipitation variation of other second zone of water is similar to Haihe River basin.

4 CONCLUSIONS

The analysis of precipitation in Haihe River basin during 1958–2010 gives the following conclusions:

(1) Annual precipitation in the Haihe River basin shows an unobvious decreasing trend and precipitation mutation occurs at about 1978. After the mutation, precipitation of the whole basin shows a decreasing trend and the spatial distribution is very different.

(2) Concentration of precipitation of Haihe River basin presents a downward trend, but this is not significant. Not only the proportion of precipitation in May and June, but also the precipitation of May and June all exhibit an obvious upward tendency. However, annual precipitation and the proportion of precipitation in July all present a significant decreasing trend. After the precipitation mutation in May and June, the precipitation increases gradually from west to east and the increase concentrates between 0–25 mm and 0–35 mm, respectively. However, July precipitation decreases significantly. The reduction of precipitation increases gradually from west to east on the whole and the rate of decrease concentrates between 0–84 mm.

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