

Change characteristics of observed precipitation extremes in the Weihe River Basin of China

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Abstract. The flood disaster has a higher frequency and more influences under the impacts of global climate change and urbanization for the past several decades. The primary objective of this study is to provide more comprehensively the change characteristics in observed precipitation extremes for the period of 1969-2016 in the Weihe River Basin (WRB) of China. Fourteen extreme precipitation indices (EPIs) were defined to describe the precipitation extremes. Daily observed precipitation from 35 surface meteorological stations in the WRB was used to calculate EPIs. The RCLimRex software was used to calculate 14 EPIs, and the trends were analyzed using the Mann-Kendall non-parametric method. The spatial distribution of the typical EPIs was also presented. The results showed that: 1) Generally, the spatial and temporal variations of precipitation extremes varied for different EPIs and different regions. More EPIs were mainly increasing trends dominated. Few stations exhibited statistically significant trends at significant levels of both 5% and 10%. 2) The spatial distributions of increasing and decreasing trends for the 14 EPIs were scattered. The stations which had statistically significant trends were mainly located at the northern and southeast regions, some of which were outside the WRB borders. 3) The reasons of the spatial and temporal variability need to be further investigated from the aspects of climate change and urbanization, which will be our further works.

1. Introduction

The global and regional climate change has attached widespread notice all over the world for the last few decades. The frequency and magnitude of extreme climatic events were mainly detected increasing trends. Due to the global warming and possible related effects, the torrential rain flood and heat wave events have increased regionally [1,2]. The Fifth Assessment Report of IPCC showed that more land regions were detected positive than negative trends of heavy precipitation events. High credible evidence suggested that the increasing trends of precipitation extreme mainly caused by the warming trend of the globally averaged combined surface temperature [3].

Many previous researches have investigated spatiotemporal change patterns of extreme precipitation events at different regions, such as, globally scale, and in different parts of China [4-6]. However, few studies investigated the variations of precipitation extremes in Weihe River Basin (WRB), the largest branch of the Yellow River. Our study focuses on the WRB, the Mother River of Shaanxi Province. Most previous studies on the long-term climate change have mainly focused on



trends of mean or total precipitation for the past several decades [4]. However, we used the extreme precipitation indices (EPIs) based on the observed precipitation because the EPIs are more appropriate to analyze the change characteristics than mean precipitation. The EPIs were widely used to investigate the climate change effects in the previous studies [5]. Especially, the CCI/WCRP ETCCDMI coordinated efforts to propose a suite of EPIs including a series of indices. An easy-to-use software was also developed to compute the EPIs, which provide great convenience for the users.

The primary objective of this paper is to study the spatiotemporal change patterns of EPIs during 1969-2016 in the WRB, which will help to understand the climate change effects on the extreme climate events, such as rainstorm, waterlogging and heat wave.

2. Material and methods

2.1. Study area

The WRB locates between 33.68°N-37.39°N latitude and 103.94°W-110.03°W longitude (figure 1), situated in the west-central of China. The length of the WRB is 818 kilometers and it covers 135 000 square kilometers. 44.1% of the basin area is in the Gansu province, 6.1% in the Ningxia Hui autonomous region, and 49.8% in the Shaanxi province. The main tributaries of WRB include the Jing River, Beiluo River and Feng River. The main stream of WRB originated from the Gansu province and trends eastward, through Tianshui city in Gansu province, Baoji, Xianyang, Xi'an, Weinan cities in Shaanxi province. According to the river morphology, the WRB can be divided into three parts. The upstream of WRB is about 430 km, rising from the Qin Mountains. The midstream of the WRB located from Baoji gorge to Xianyang, nearly 180 km. The downstream of the WRB is about 208 km, from Xianyang to join the Yellow River.

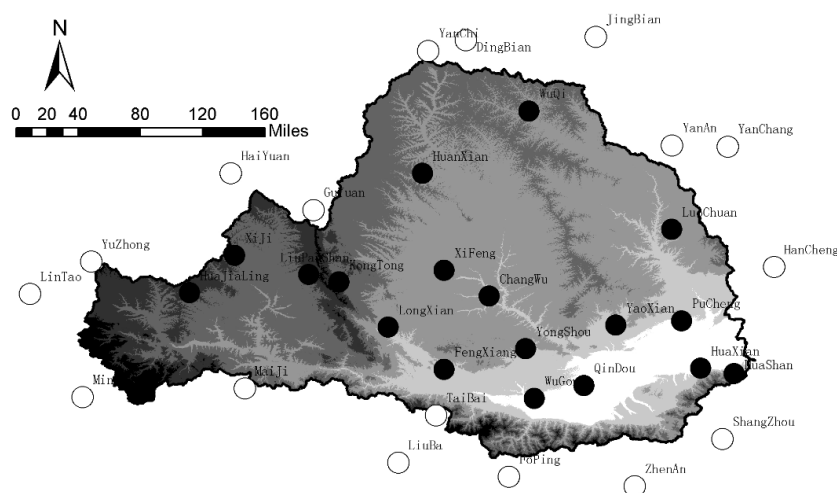


Figure 1. WRB and locations of meteorological stations.

The meteorological and hydrological features have great differences for different seasons and different regions over the WRB because of the diversity of its multifarious geological, geographic and climate conditions. The multi-year average annual precipitation is nearly 570 millimeters in the last several decades. More than 60% of the annual precipitation concentrates from July to October. The multi-year average annual natural runoff in the WRB is nearly 10 billion m^3 , nearly 17.3% of total natural runoff of Yellow River. However, both the precipitation and runoff varied for different regions, from the upstream to downstream, and from south bank to north bank of WRB, which caused severe flood and drought events in the history [7].

2.2. Daily precipitation data

Spatial and temporal variability of the EPIs were analyzed for 35 meteorological stations in the WRB. The daily precipitation data can be downloaded from the China Meteorological Administration. Table 1 shows the basic information of 35 stations (the WMO numbers of station outside the WRB are underlined). The 35 stations have an irregularly spatial distribution, located at the upstream, midstream and downstream of the WRB. It helps to reveal the spatiotemporal variability of the extreme precipitation events over the study area.

Table 1. Characteristics of the meteorological stations in the WRB.

WMO No.	STNM	Lon(°E)	Lat(°N)	Ele(m)
52983	YuZhong	104.09	35.52	1874.4
52986	LinTao	103.52	35.22	1893.8
52996	HuaJiaLing	105.01	35.23	2450.6
53723	YanChi	107.23	37.48	1349.3
53725	DingBian	107.58	37.58	1360.3
53735	JingBian	108.79	37.61	1325.0
53738	WuQi	108.17	36.92	1331.4
53806	HaiYuan	105.39	36.34	1854.2
53817	GuYuan	106.16	36.00	1753.0
53821	HuanXian	107.18	36.34	1255.6
53845	YanAn	109.50	36.60	958.5
53854	YanChang	110.02	36.59	901.0
53903	XiJi	105.43	35.58	1916.5
53910	LiuPanShan	106.12	35.40	2841.2
53915	KongTong	106.40	35.33	1346.6
53923	XiFeng	107.38	35.44	1421.0
53929	ChangWu	107.80	35.20	1206.5
53942	LuoChuan	109.50	35.82	1159.8
53948	PuCheng	109.59	34.97	489.0
53955	HanCheng	110.45	35.47	434.0
56093	MinXian	104.01	34.26	2315.0
57003	LongXian	106.86	34.91	1018.0
57014	MaiJi	105.52	34.34	1085.2
57025	YongShou	108.14	34.71	1018.0
57028	WuGong	108.22	34.25	447.8
57030	YaoXian	108.98	34.93	710.0
57034	HuaShan	110.08	34.48	2064.9
57037	QinDou	108.68	34.37	466.0
57046	HuaXian	109.77	34.53	335.0
57049	FengXiang	107.38	34.52	782.6
57106	TaiBai	107.30	34.09	1680.0
57124	LiuBa	106.95	33.65	1415.0
57134	FoPing	107.98	33.52	827.2
57143	ShangZhou	109.97	33.87	742.2
57144	ZhenAn	109.15	33.43	693.7

The EPIs were calculated using the RClimDex software. It can be downloaded from the following website of <http://etccdi.pacificclimate.org>. The RClimDex was developed using R programe. When the RClimDex is used to compute the EPIs, the observed daily precipitation should go through strict data quality control including identifying the unreasonable data or missing values, to make the results reasonable [6].

2.3. Methods

Fourteen EPIs were defined and investigated in the paper. These EPIs were got or modified from the ETCCDMI index set. The 14 EPIs were divided into three types according to the thresholds. Eight fixed thresholds EPIs include consecutive dry (CDD) and wet days (CWD), and other six indices of precipitation days, i.e., R10 mm, R20 mm, R25 mm, R50 mm, R100 mm and R150 mm. The R10 mm indicates heavy precipitation. The R20 mm is for very heavy precipitation. The R25 mm is on behalf of extremely heavy precipitation. The R50 mm represent rainstorm. The R100 indicates heavy rainstorm. The last EPI named R150 mm is for extreme heavy rainstorm days. Station-related thresholds EPIs were identified based on the proportion of annual total runoff when $RR >$ certain proportion. The R95p is 95th proportion, and the R99p is 99th proportion, respectively. Non-threshold EPIs, i.e., Rx1day, Rx5day, RPCPTOT and SDII were analyzed in the paper. These EPIs were computed based on daily precipitation data. More details including the definition and meaning of the EPIs can be found in our previous paper [5,6].

The Mann-Kendall nonparametric method was used to analyze the trends of the above 14 EPIs, due to its nonparametric characteristic. Details of Mann-Kendall nonparametric method refer to our previous study [8].

3. Results and discussion

3.1. General variations of fourteen EPIs in the WRB

Figure 2 is the boxplot of the trends for 14 EPIs based on 35 observed stations' daily precipitation data during 1969-2016 in the WRB. Four red dotted lines in the figure indicate that EPIs are statistically significant increase (or decrease) at significant levels of 5% or 10%. The positive values represent increasing trends, and the negative values indicate decreasing trends. For past 48 year (1969-2016), more stations were negative trends dominated for four EPIs, i.e., CDD, CWD, R10 mm and PRCPTOT. Other nine EPIs were increasing trends dominated. One EPI named R150 mm was stationary. The reason is that R150 mm does not exist for most stations during 1969-2016.

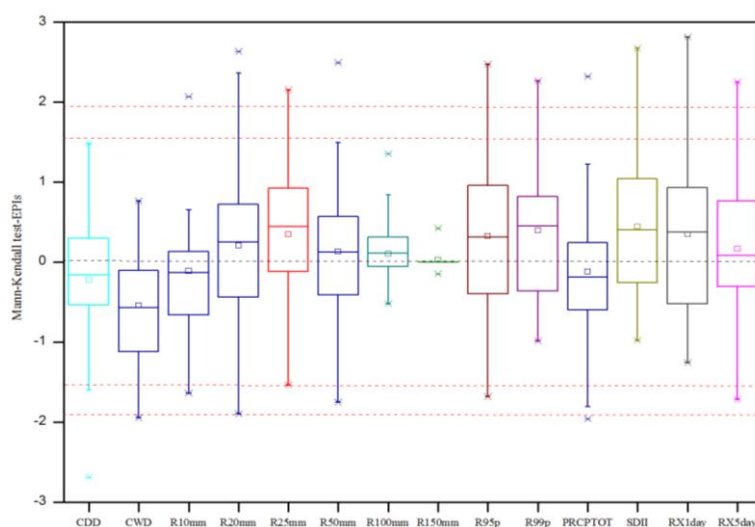


Figure 2. Boxplot of Mann-Kendall trends.

In case of CWD, the trends of 27 stations had decreased. The proportion of 77.14% was the highest, followed by 62.86% for PRCPTOT. In contrast, the highest proportion of stations with positive trends was 65.71% for R99p, followed by 62.86% for SDII, and 60% for other four EPIs including R25 mm, R550mm, R95p and RX1day.

As shown in figure 2, few stations had statistically significant trends at 5% significant level. Three stations (8.57%) had statistically significant positive trends for R95p and R99p. Two out of 35 stations had statistically significant positive trends. However, two EPIs including CDD and PRCPTOT exhibited statistically significant negative trends at 5% significant level.

3.2. Spatial distributions of two typical fixed thresholds EPIs in the WRB

Figure 3 shows trends of two typical fixed thresholds EPIs including CWD and R50 mm. For CWD, more decreasing trends (77.14%) were detected than increasing trends (22.86%). Eight stations had increasing trends and twenty seven stations had decreasing trends. The decreasing trends of above two EPIs mainly distributed in the mainstream of WRB. Three stations that exhibited statistically significant negative trends were found in the downstream of WRB. Six EPIs consisting of R10 mm-R250 mm were specially identified using the Julian day number with precipitation above 10 mm-250 mm, respectively. Taking R50mm for an example, 21 stations had positive trends and the rest of 14 stations had decreasing trends. The trend of Shangzhou station was significantly increasing at significant level of 5%. The trend of Yanchang station was significantly decreasing at significant level of 10%. Coincidentally, both Shangzhou and Yanchang stations were located outside the boundary of the WRB.

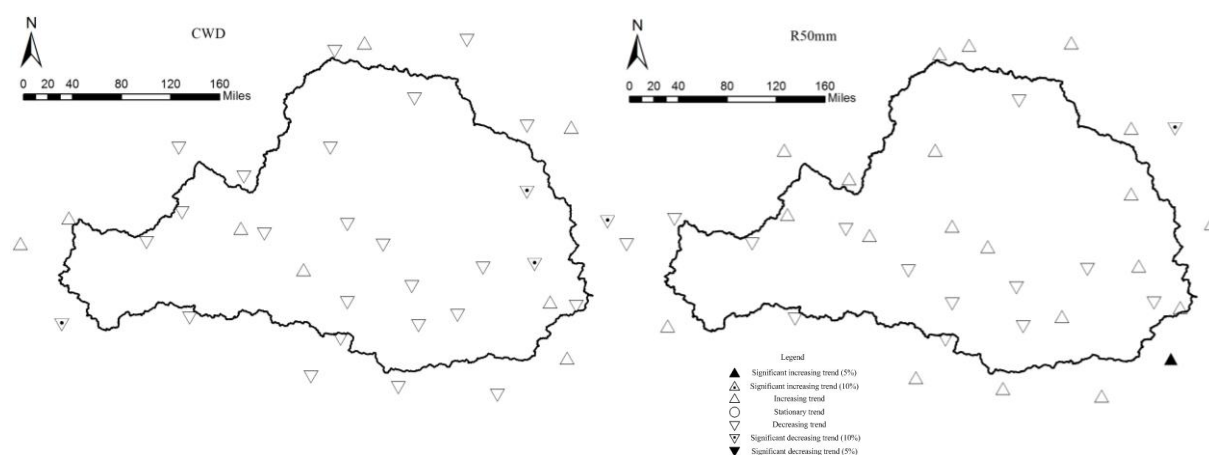


Figure 3. Trends of two typical fixed thresholds EPIs, CWD and R50 mm.

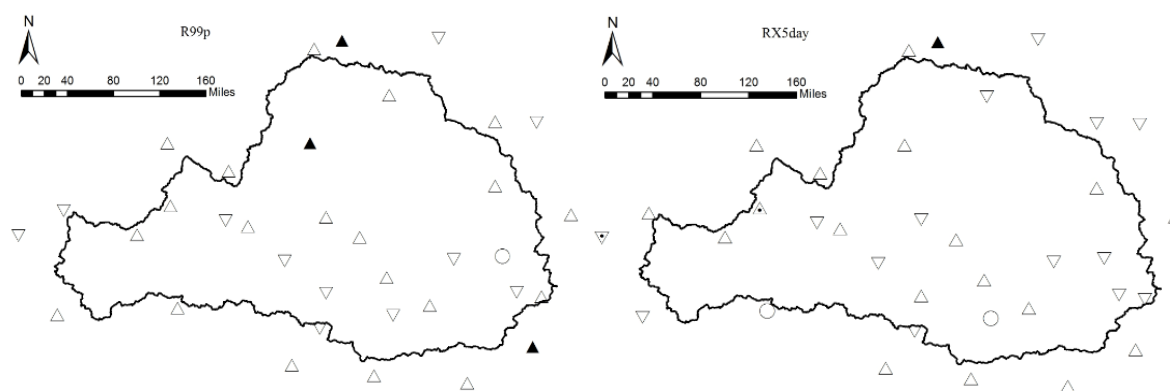


Figure 4. Trends of two typical station-related and no thresholds EPIs, R99p and Rx5day.

3.3. Spatial distributions of two typical station-related and no thresholds EPIs in the WRB

In case of two station-related thresholds EPIs, taking R99p as an example, as shown in figure 4. The R99p was increasing trends dominated (65.71%), and 11 out of 35 stations had decreasing trends. Two stations exhibited statistically significant increasing trends located outside the WRB border, and another station located in the Jing River.

In case of four no thresholds EPIs, taking Rx5day for an example, 19 stations had increasing trends and 14 stations had decreasing trends. The positive and negative trends were spatially distributed and scattered over the study area. Moreover, two stations located at the south of the WRB were stationary.

4. Conclusions

The paper used the Mann-Kendall method to investigate the spatial and temporal variability of the precipitation extremes with 14 EPIs during 1969-2016 in the WRB. Generally, the variations of precipitation extremes varied for different EPIs and different regions. More EPIs (nine with respect to four) were increasing trends dominated, and few stations (0-4) exhibited statistically significant trends, which also varied for different EPIs. The spatial distributions of increasing and decreasing trends for different EPIs were irregular. The stations had statistically significant trends were detected in the northern and southeast regions.

Notwithstanding the variations of 14 EPIs were studied, the reasons of the spatial and temporal variability need to be further investigated from the aspects of climate change and urbanization. The physical mechanisms for the change characteristics of the EPIs over the study area are our future works.

Acknowledgments

The study was partly funded by the National Key Research and Development Program of China (2016YFC0401409), National Natural Science Foundation of China (51509201, 51679188, 41471451), Natural Science Basic Research Plan in Shaanxi Province of China (2018JM5031). Thanks for the suggestions of the two anonymous reviewers.

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