USING CLIMATE MODELS TO PREDICT EXTREME RAINFALL TREND IN YANHE RIVERBASIN, CHINA

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Reception: 03/11/2022 **Acceptance**: 26/12/2022 **Publication**: 17/01/2023

Suggested citation:

Y., Saiyu and D., Peng (2023). **Using climate models to predict extreme rainfall trend in Yanhe riverbasin, China**. *3C Tecnología. Glosas de innovación aplicada a la pyme, 12(1)*, 15-31. https://doi.org/10.17993/3ctecno.2023.v12n1e43.15-31

ABSTRACT

Climate model is an effective medium to study climate system and climate change. Its simulation results are essentially a crucial data basis for climate prediction and climate change risk assessment. With the acceleration of global warming, the surface ecological environment, hydrological dynamic cycle process, social and economic development are all affected thereupon, resulting in certain influence on the production and life of human beings. In this regard, this paper conducts a study on extreme precipitation events of different climate models with Yanhe River Basin as the study area. The results show that: 1. Yanhe River Basin is a sensitive area to climate change. In the future, the precipitation in this area, for a long time will not increase obviously, but fluctuate greatly; 2. The temporal and spatial difference of extreme precipitation events in the study area is significant. From 2000 to 2050, the interdecadal fluctuation of extreme precipitation events in the study area is significant. In the future, the area with the largest volume of precipitation above 12mm will be concentrated in the southeast part of the study area, followed by the western boundary area; 3. There are few areas with precipitation above 50mm in the Yanhe River Basin, and the occurrence frequency has decreased significantly; 4. The simulation results of different climate models are different. Alao, pursuant to the data analysis results, different models have certain differences in the spatial simulation of extreme precipitation. It is speculated that the terrain factors and Monsoon Simulation factors may affect the simulation results of extreme precipitation events.

KEYWORDS

Climate model; Statistical downscaling; Future climate change; Space-time difference; Extreme precipitation

https://doi.org/10.17993/3ctecno.2023.v12n1e43.15-31

PAPER INDEX

1. INTRODUCTION

Most cities in my country are located on the banks of rivers, lakes and seas, and are threatened by river floods to varying degrees. In the context of global warming, with the acceleration of urbanization, urban torrential rain events frequently occur, extreme flooding events increase, and the resulting disaster losses are also increasing. However, at present, the capacity of urban flood control in my country is generally low, and urban drainage standards are backward. In the event of upstream floods and urban torrential rains, supported by the long-term high water level of external river floods, it is difficult to discharge or even limit the discharge of internal waterlogging, which can easily cause serious flood disasters to the city.

The increase of extreme weather caused by climate change has had an important impact on the ecological environment, economic development and personal and property safety of countries all over the world [1], especially in the Loess Plateau of China, where geological disasters are seriously developed, the use of climate models to study future climate change can effectively deal with the risk of geological disasters caused by climate change. Climate model is a set of mathematical and physical equations that describe the behavior of climate system based on basic physical and chemical laws [2]. The data involved in this program are widely used to predict the characteristics of future climate change and analyze the trend of climate change. The research results of climate prediction based on climate models are an important basis for the government's Special Committee on Climate Change (IPCC) to assess future climate change [3]. At the same time, Representative Concentration Pathways (RCPs) scenarios fully consider the impact of future greenhouse gas emissions on climate change. Among them, RCP 2.6 scenario refers to that the radiation forcing reaches the peak before 2100 and drops to 2.6w/m2 by 2100, and the global average temperature rise is limited to 2.0 °C [4-5]. It can well simulate the average characteristics of large-scale and seasonal climate, but the PCPs spatial resolution (100~500km) is difficult to directly respond to the model to assess the impact of climate change or site scale environmental factors [6]. Therefore, improving the reliability of climate prediction is one of the important issues in the study of Watershed climate models [7].

In order to effectively improve the reliability of climate prediction, this paper introduces the climate model into the analysis of extreme rainfall trends along the river basin. The correction value and the daily precipitation data of future climate change are calculated, and the analysis of the extreme rainfall trend along the river basin in the future is finally completed.

2. CASE STUDIES AND DATA SOURCES

2.1. REGIONAL OVERVIEW AND SITE

Yanhe River Basin is the first-class tributary of the middle reaches of the Yellow River, between 36 ° 23 ′~37 ° 17 ′ N and 108 ° 45 ′~110 ° 28 ′ E. Yanhe River Basin is one of the serious soil and water loss areas in the Loess Hilly and gully region. It belongs to the warm temperate continental semi-arid climate zone [8-9]. The north is Qingjian River Basin, the southwest is Beiluo River Basin, and the south is connected with Yunyan River Basin [10]. The geographical location of the Yanhe River Basin is shown in Fig 1.

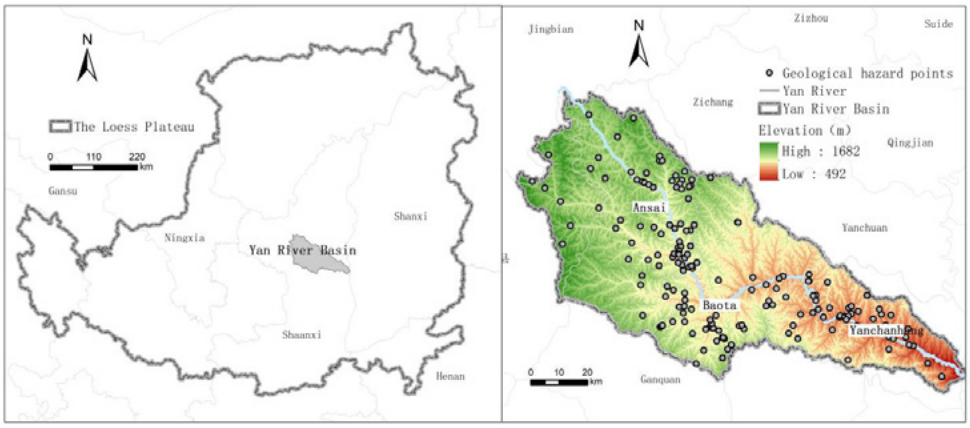

Figure.1. Geographical location of Yanhe River Basin

As shown in Figure 1,the main tributaries of Yanhe River include Xichuan, Xingzi River, Nanchuan and Panlong River, with a total length of 286.9 kilometers, an altitude of 958-1731m and an area of about 7725km2. The basin covers 6 counties and districts including Baota, Ansai and Yanchang, a total of 53 towns and townships, about 1027 administrative villages, with a total population of 990000 [11-12].

2.2. DATA SOURCES

Historical observational meteorological data of Yanhe River Basin is derived from the data of 154 surface meteorological stations covering Shaanxi Province from 1981 to 2013 and interpolated to 0.25 ° by thin disk spline × 0.25 ° horizontal resolution grid, generating multi-year daily precipitation data from China National Meteorological Information Center [13-14]. The global climate model is derived from the coupled multimodal global climate model prediction data set cmip5 in the nex-gddp project in the United States [15]. This data set is the main tool used by IPCC to predict future climate change by simulating earth systems such as atmosphere, ocean, land surface and vegetation, sea ice, etc [16]. Some studies show that cmip5 model has greatly improved the spatial resolution compared with the previous model, and significantly improved the simulation effect of extreme precipitation. Three GCMS in cmip5 are selected to predict future extreme precipitation changes, including the climate system model BCC of Beijing Climate Center_ CCSM, the multidisciplinary climate research model miroc5 jointly developed by the climate system research center of the University of Tokyo, Japan, the Japan Institute of environment and the Japan earth environment research center. It summarizes the earth system, spatial resolution and other parameters of the three climate model data. The model has been used to predict climate change and related extreme events in the Yangtze River Basin, and the model simulation results are good and close to the observed data [17-18]. Spatial resolution of mode data 0.25 ° × 0.25 °, the time resolution is day by day, and the time span is

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1981-2060. The typical concentration emission scenario rcp4.5, that is, the emission scenario is set to maintain the current level of population, economic and technological development. By 2100, the radiation forcing will be stable at 4.5w/m2, and the change of greenhouse gas emissions will increase first and then tend to be stable [19].

3. METHODOLOGY

3.1. ANUSPLIN METEOROLOGICAL INTERPOLATION

Meteorological element data is the basis of a variety of geoscience models and climatology models. Accurate climate element data can be obtained by establishing high-density meteorological observation sites. However, due to the limitations of economic level, technical means and terrain conditions, meteorological data in many places It is more difficult to obtain. In order to obtain meteorological data in areas outside meteorological observation sites, researchers usually combine statistical methods with geographic information systems to estimate based on the observed values of existing meteorological observation sites, that is, spatial interpolation of meteorological element data.

ANUSPLIN software is a classic meteorological interpolation software, based on thin disk spline function, suitable for interpolation of various natural station data. The accuracy is high, and the elevation can be considered as a covariate for difference [20-21]. The model formula is as follows:

$$z_i = f(x_i) + b^T y_i + e_i \quad (i = 1,\cdots,N) \qquad (3.\ \text{AUTONUM} \ \backslash * \ \text{Arabic})$$

Where, Z is the dependent variable at point I, f (XI) is the unknown smooth function to be estimated about Xi, Xi is the d-dimensional independent variable, BT is the p-dimensional coefficient about Yi, Yi is the p-dimensional independent covariate, EI is the random error, and N is the number of observations [22].

Where: function f and coefficient b are determined by least square estimation:

$$\sum_{i=1}^{N} \left[\frac{z_i - f(x_i) - b^T y_i}{w_i} \right]^2 + \rho J_m(f) \qquad (3.\ \text{AUTONUM} \ \backslash * \ \text{Arabic})$$

Where JM (f) is the roughness measure function of function f (x), which is defined as the m-order partial derivative of function f; ρ is a positive smoothing parameter.

3.2. STATISTICAL DOWNSCALING METHOD

The regional climate model is the result of the comprehensive action of the driving forces of the multi-scale general circulation model, such as latitude, sea land distribution, terrain and underlying surface conditions [23]. The assumptions for using statistical downscaling include: the climate state at different scales is stable and the statistical relationship is significant, and the large-scale climate model simulation is effective and the statistical relationship established is effective. Considering the

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complex terrain of the study area, in order to reduce the boundary impact, the north of Hengduan Mountain where the study area is located is taken as the prediction area.

Statistical downscaling adopts a numerical deviation correction method combining statistics and dynamics [24]. The method considers that the climate model of any scale is composed of stable long-term climate state and short-term weather fluctuation. The specific expression is as follows:

$$\alpha(t) = \bar{\alpha} + \alpha'(t) \qquad (3. \text{ AUTONUM } \backslash\text{* Arabic })$$

Where, $\alpha(t)$ represents the meteorological condition at any time,αrepresents the climate state corresponding to the scale where the meteorological condition is located, $\alpha'(t)$ represents the climate anomaly of the scale relative to the secondary scale, and $\bar{\alpha}$ indicates the average climate state [25]. The observation data and climate reanalysis data are divided in this way. For climate models with different spatial scales (such as global and regional), the expression of the linear correction value of the climate anomaly model of the cumulative distribution function is:

$$\frac{\partial \alpha_{LC}}{\partial c} - \frac{\partial \alpha_{\bar{RA}}}{\partial c} = \frac{\partial \alpha'_{GCM}}{\partial c} = k\left(\beta_{\bar{RA}} + \beta'_{GCM}\right) = k\beta_{LC} \qquad (3. \text{ AUTONUM } \backslash\text{* Arabic })$$

Where, K is a constant, ∂ is the horizontal and vertical correlation distance, $\beta_{\bar{RA}}$ is the climate state corresponding to the ground observation data at this spatial scale, and β'_{GCM} is the climate anomaly of the spatial scale corresponding to the global climate model relative to the spatial scale corresponding to the ground observation data. The equation is also applicable to global and regional climate models [26-27]. The equation is valid only when n>1 and $\bar{\alpha^n} = \bar{\alpha}^n$. Therefore, the deviation correction expression of daily precipitation data of future climate change is as follows:

$$Pr_d = M_{\bar{st_d}} + M_{\bar{prj_d}} - M_{st_d} \qquad (3. \text{ AUTONUM } \backslash\text{* Arabic })$$

In the formula, Pr_d represents the daily precipitation value after correction, D is 1-365, $M_{\bar{st\_d}}$ and $M_{\bar{prj\_d}}$ are the average value of historical daily climate data and climate change precipitation estimates. M_{st_d} represents the estimated precipitation of climate change [28]. The prediction of extreme rainfall trends along the river basin is realized by the revised daily precipitation value, the average value of historical daily climate data, the average value of climate change precipitation estimates, and the estimated precipitation amount of climate change.

4. 4 RESULT ANALYSIS

4.1. ANALYSIS ON OVERALL CHANGE TREND OF PRECIPITATION

Under the rcp4.5 emission scenario, during the 50 years from 2006 to 2056, the regional average precipitation of extreme precipitation in the study area is shown in Fig 2.

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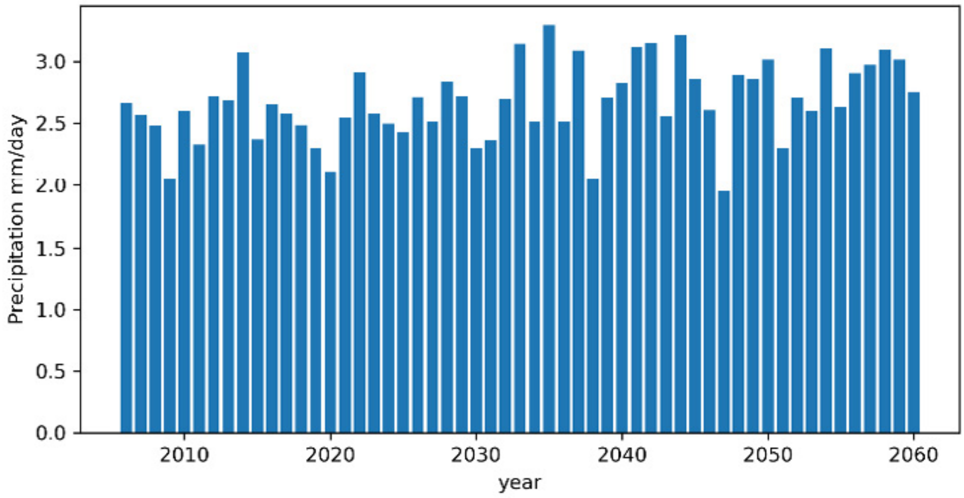
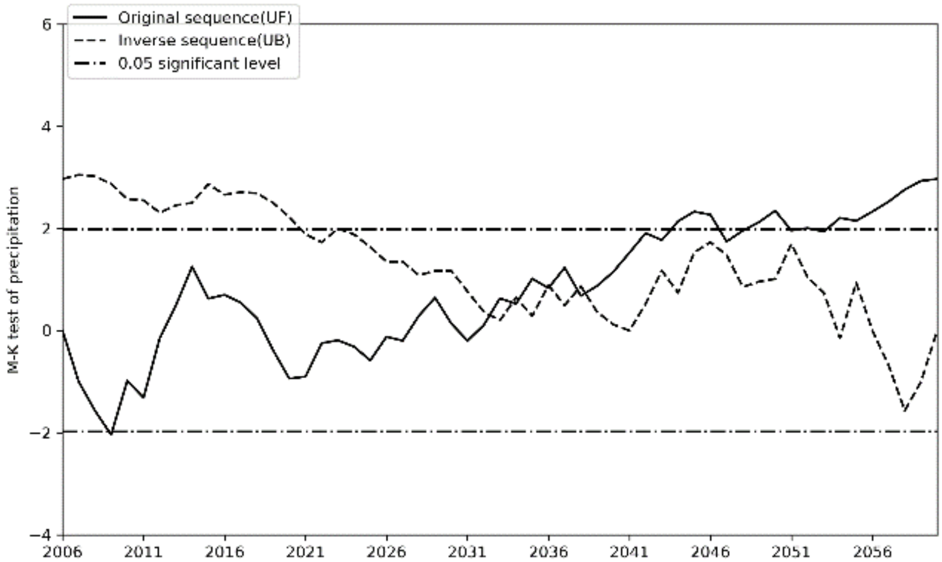
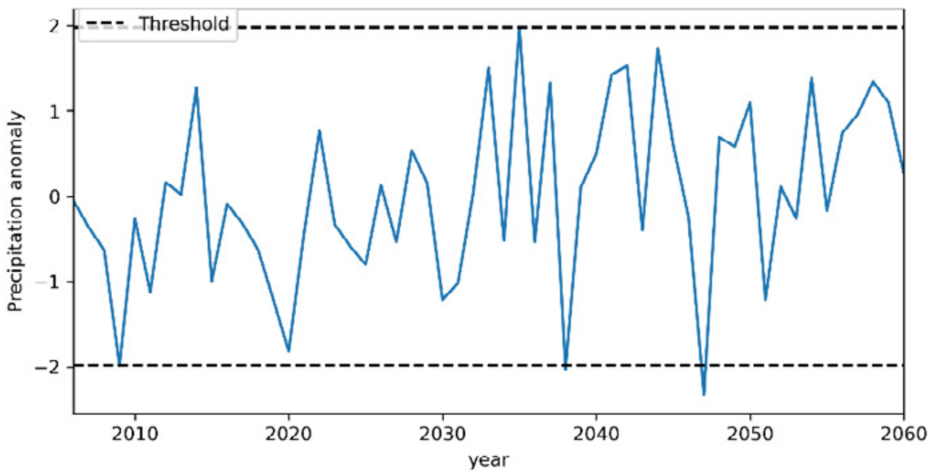


(a) Regional average precipitation.



(b) Precipitation Mann-Kendall test.



(c) Precipitation anomaly.

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Figure 2. Inter-annual departure of extreme precipitation in study area.

Fig 2(a) shows that the annual average daily precipitation in the study area fluctuates around 2.5 mm, with no obvious increase or decrease. Based on the Mann Kendall method, this paper conducted a test and analysis of the precipitation in the study area from 2000 to 2050, and found that the precipitation in the study area fluctuated greatly in the past 50 years. In Fig 2(b), the interannual fluctuations are relatively large around 2036, and the main mutation year in this region is around 2016. During the 50 years from 2000 to 2050, there were more abrupt changes, indicating the possibility of extreme climate events. In addition to the Mann Kendall rainfall test, precipitation anomalies are also analyzed in Fig2(c). The results show that the precipitation anomaly analysis results show a similar trend to the Mann Kendall test results, which more strongly indicate that under the background of future climate change, the rainfall in the study area will change greatly, and extreme precipitation events are more likely to occur [29].

4.2. SPATIAL AND TEMPORAL PATTERN AND ANALYSIS OF EXTREME PRECIPITATION INDEX

In this paper, absolute quantity index, intensity index and frequency index are selected to analyze the spatial and temporal distribution characteristics of extreme precipitation. The results show that there are significant differences in the frequency and distribution pattern of extreme precipitation in the study area. The absolute quantity index analysis results show that in the next 50 years, the precipitation in most parts of the study area may exceed 12mm, especially in the eastern and western parts of the study area. The spatial distribution of absolute indicators is shown in Fig 3.

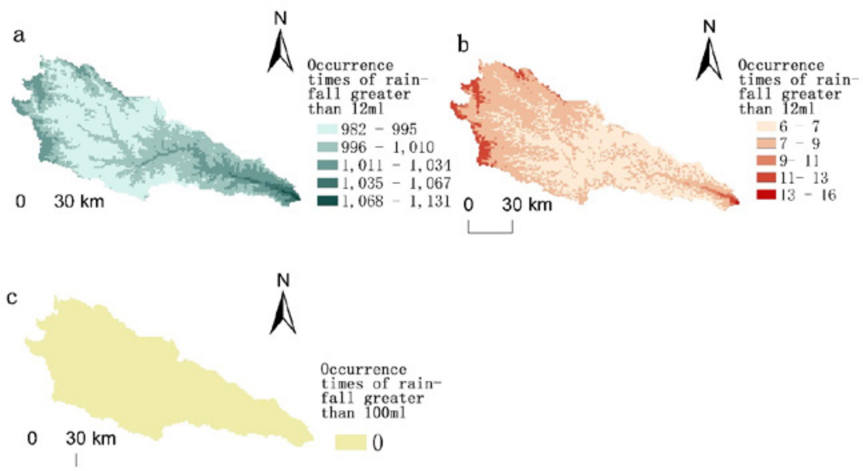

Figure 3. Spatial distribution of otherthe absolute indices: (a) Daily precipitation over 12 (mm); (b) Daily precipitation over 50 (mm); (c) Daily precipitation over 100 (mm).

In a of Fig 3, the number of days with precipitation exceeding 12 mm in some areas may exceed 1000 days, that is, more than 20 times a year. In the future, the areas with the most precipitation above 12 mm will be concentrated in the southeast of the

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study area, followed by the western border area. These areas will receive more than 21 times of precipitation above 12mm per year. The central region has the least precipitation, at least 19 times a year. Compared with the areas with precipitation greater than 12mm, there are fewer areas with precipitation greater than 50mm in b of Fig 3, and the frequency of occurrence is significantly lower. The high-value areas are distributed in the southeast border area and the northwest border area. Fig 3 c. For precipitation above 100mm, the study area will not appear. From the temporal and spatial distribution pattern of absolute precipitation index, it can be seen that the erosive precipitation in the study area is widely distributed, and the distribution of heavy rain precipitation is obviously localized, mainly in the junction of the northeast and southwest of the study area [30].

For the case where the daily precipitation of c in Fig 3 exceeds 100mm, the spatial distribution of the intensity index is analyzed, as shown in Fig 4.

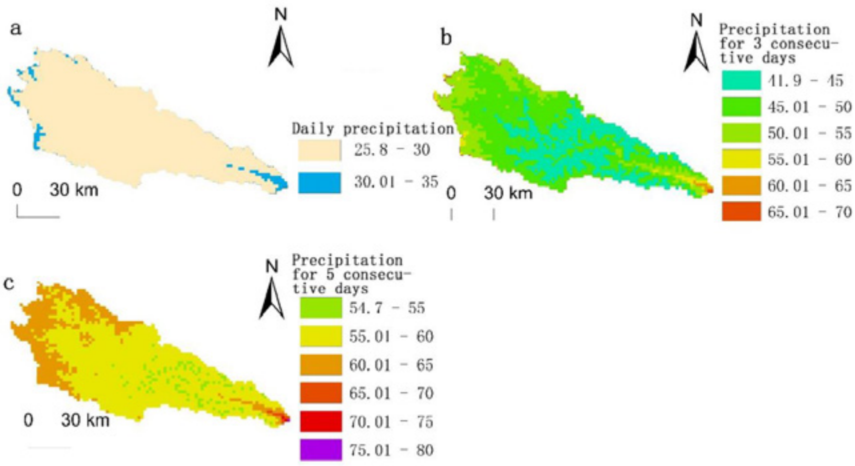

Figure 4. Spatial distribution of the intensity indices: (a) Daily precipitation; (b) Cumulative precipitation in 3 days; (c) Cumulative precipitation in 5 days.

Fig 4 shows that the analysis results of the intensity index show that single precipitation or continuous precipitation of more than 50 mm may occur in most areas, and more precautions should be taken against the risk of extreme rainstorms. In Fig 4a, it can be seen that the areas with daily precipitation rx1 higher than 30mm are only distributed in the southeast and northwest border areas of the study area[31-32]. The terrain in the southeast is lower. The daily precipitation in most areas of the study area is between 25 and 30 mm;

From (b) and (c) in Fig 4, we can see from the spatial distribution of RX3 and rx5 that the areas with precipitation exceeding 55mm for three consecutive days are mainly distributed in the southeast and northwest of the study area with precipitation exceeding 55mm for five consecutive days of the entire study area. In terms of precipitation, the accumulated precipitation in most parts of the study area may exceed 55mm, while the precipitation in the northwest and southeast of the study area may exceed 70mm.

The comparative analysis of the intensity indicators of different indicators shows that under the background of future climate change, extreme short-term sustained

https://doi.org/10.17993/3ctecno.2023.v12n1e43.15-31

high-intensity precipitation is very likely to occur in most areas of the study area, and the risk of mountain disasters cannot be reduced.

In order to reduce the uncertainty of climate change prediction and the possible model error of predicting a single precipitation, the frequency of extreme precipitation in the study area was analyzed for multiple consecutive days.

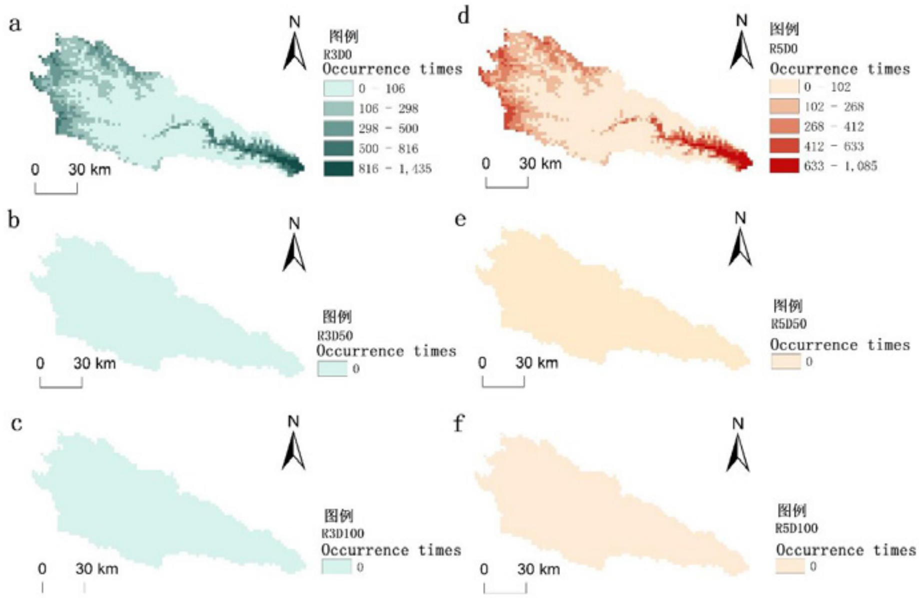

Figure 5. Spatial distribution of the duration indices: (a) The number of over 50 (mm) cumulative precipitation in 3 days; (b) The number of over 100 (mm) cumulative precipitation in 3 days; (c) The number of over 50 (mm) cumulative precipitation in 5 days; (d) The number of over 100 (mm) cumulative precipitation in 5 days.

From (a) and (b) in Fig 5, we can see that precipitation events may occur continuously for 3 days and 5 days in the study area, and the frequency of occurrence is higher in the southeast and northwest of the study area, and the prediction results of the spatial distribution of the intensity index. In addition, it can be seen from c in Fig 5 that due to being in a semi-arid area, the study area did not have extreme precipitation events with precipitation exceeding 50 mm and 100 mm for three consecutive days and five consecutive days, respectively.

4.3. COMPARISON OF DIFFERENT GCM MODELS OF EXTREME PRECIPITATION

Prediction of extreme precipitation events from a single climate model is uncertain. Therefore, this paper selects several representative extreme precipitation indicators for model comparison to reduce the uncertainty of a single climate model. The distribution of extreme precipitation under future climate change is shown in Fig 6.

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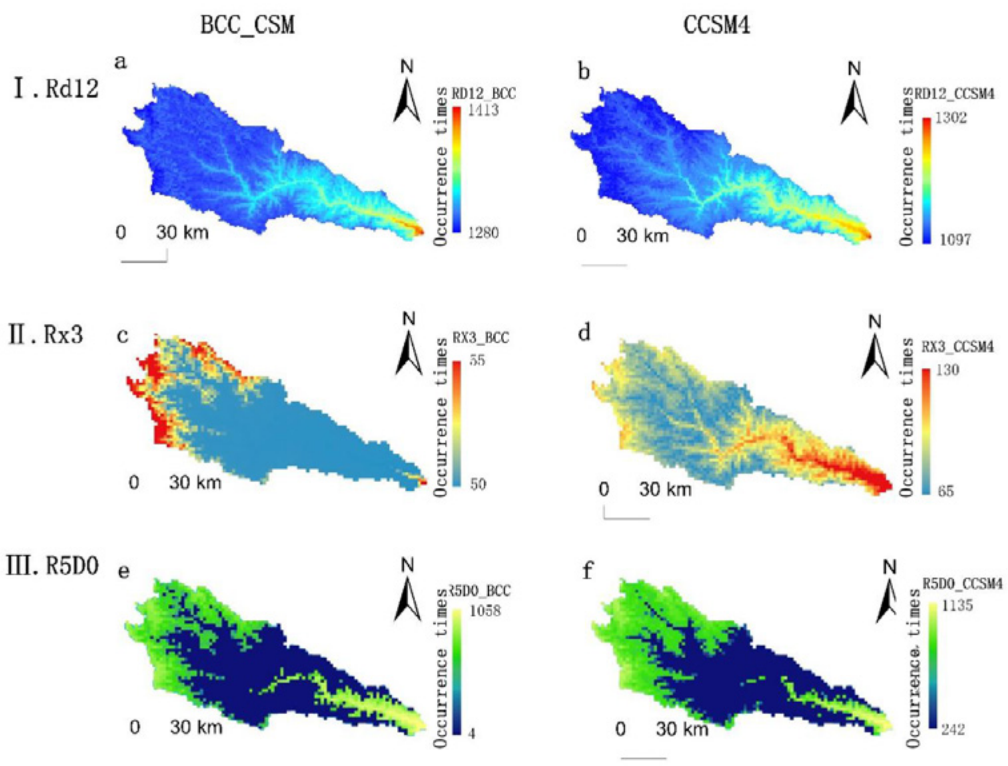

Figure 6. The distributions of extreme precipitation under climate change in the future

According to the data analysis results in Fig 6, there are certain differences in different spatial simulations of extreme precipitation. It is speculated that topographic factors and monsoon simulation factors may affect the simulation results of extreme precipitation events. According to the analysis of extreme precipitation index under different models, as shown in a and b in Fig. 6, the simulation results of absolute quantity index are not very different, while in the BCC_CS model and the miroc5 model, the two models are generally spatially consistent. The number of annual occurrences of absolute precipitation exceeding 12mm is higher than 21. In the BCC_CS mode, the annual occurrence of absolute precipitation exceeding 12mm can reach 28 times. The areas with more occurrences are mainly located in the southeastern part of the study, and the annual occurrence of absolute precipitation exceeding 12 mm in the western part of the study area is less frequent; as shown in c and d in Fig. 6, the precipitation is predicted and evaluated for three consecutive days under the BCC_CS model and the miroc5 model. . There is a certain difference in the amount of precipitation for three consecutive days under these two modes. The maximum precipitation for three consecutive days in the miroc5 mode can reach 130 mm, which is located in the southeastern part of the study area; the frequencies of precipitation events in the BCC_CS mode and the miroc5 mode for 5 consecutive days are shown in e and f in Fig 6. From the results, the precipitation frequency index shows that the average frequency of precipitation events for 5 consecutive days in the study area can reach 22 per year. The simulation results of these two modes also have certain continuity and spatial consistency.

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5. DISCUSSION

(1) The climate model with statistical downscaling can effectively reduce the model uncertainty. The terrain of the study area is complex, so it is more practical to select rcp4.5 to maintain the current greenhouse gas emission scenario. First, the simulation effect of different models of IPCC cmip5 on Precipitation in China decreases from the southeast coast to the northwest inland (Sun Jian, 2016). In terms of the simulation effect of average daily precipitation, the simulation effect may be better in some areas, but the overall simulation ability is weak. Therefore, based on the rcp4.5 emission scenario with high stability, statistical downscaling using the meteorological data of regional ground stations can eliminate the uncertainty of the climate model to a certain extent. In small areas with complex terrain, statistical downscaling technology is better than dynamic downscaling in rainfall prediction, because in small areas with complex terrain, extreme precipitation is not only affected by large-scale circulation factors such as monsoon and terrain, but also affected by small-scale climate and weather systems such as surface radiation and cloud, and is easily disturbed by human activities. The numerical deviation correction method combining statistics and dynamics can simulate single day precipitation to a certain extent and improve the accuracy of GCM data, but its long-term trend and extreme precipitation simulation effect need to be further tested in combination with ground data.

(2) The above results show that the frequency and distribution pattern of extreme precipitation in the Yanhe River Basin will be significantly different in the future. In terms of absolute quantity index, most areas in the study area may have more than 12mm of precipitation, and the number of 12mm of daily precipitation in some areas may exceed 20 times a year, mainly concentrated in the southeast, followed by the western region, and less in the central region. The results of intensity index show that most areas in the study area may have single precipitation or continuous precipitation with a daily precipitation of more than 50mm. Areas with a daily precipitation of more than 55mm for three consecutive days are mainly distributed in the southeast and northwest of the study area. Areas with a daily precipitation of more than 55mm for five consecutive days basically cover the whole study area. Precipitation events are likely to occur in the study area for 3 and 5 consecutive days, with more occurrences in the southeast and northwest regions, which is consistent with the predicted results of the spatial distribution of the intensity index. The comparison and analysis of different indexes show that the spatial and temporal distribution of extreme precipitation in the study area is closely related to the terrain, which may be the result of the joint action of regional terrain and climate change.

(3) Rainstorm and continuous precipitation are the main factors inducing geological disasters, and the disaster risk in the study area may be intensified in the future.Geological disasters in mountainous areas are the result of the joint action of extreme weather and disaster pregnant environment. The above analysis shows that under the background of future climate change, the intensity of extreme precipitation in most regions in the study area will increase, the number of precipitation days will increase, and the continuous precipitation for 3 or 5 consecutive days may be large, and the cumulative precipitation can reach 80 mm. The occurrence of continuous

precipitation may not only reduce the threshold of extreme precipitation, but also accelerate the development of disaster pregnant environment such as geological disasters. From the perspective of terrain, steep terrain areas are often prone to geological disasters. Especially in the southeast region where there may be multiple high-intensity extreme precipitation, it is necessary to formulate targeted geological disaster response strategies to adapt to climate change.

6. CONCLUSION

1. Yanhe River Basin is a sensitive area to climate change. In the future, the precipitation in this area will not increase significantly for a long time, but it will fluctuate greatly.
2. From 2000 to 2050, the interdecadal fluctuation of extreme precipitation events in the study area is significant. In the future, the area with the most precipitation above 12 mm will be concentrated in the southeast of the study area, followed by the western boundary area. Compared with the area with precipitation above 12 mm, the area with precipitation above 50 mm will be less, and the occurrence frequency will decrease significantly. According to the results of intensity index, single precipitation or continuous precipitation of more than 50mm may occur in most areas.
3. Different climate models have different simulation effects. According to the data analysis results, different models have certain differences in the spatial simulation of extreme precipitation. It is speculated that the terrain factors and Monsoon Simulation factors may affect the simulation results of extreme precipitation events. When simulating absolute index and continuous precipitation index, BCC_ CSM simulation results are on the high side; When simulating the intensity index for three consecutive days, the simulation result of ccsm4 is higher and is similar to that of BCC_ CSM simulation results have significant differences.

7. DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/ supplementary material, further in quiries can be directed to the corresponding author.

REFERENCES

(1) Compilation Committee of the second national assessment report on climate change. (2011). **The second national assessment report on climate change [m]**. *Beijing: Science Press.*

(2) Zeng Qingcun, zhangxuehong. (1989). **The concept, methods and current situation of climate models [j]**. *Advances in Geoscience*, 4 (3), 1-26.

(3) Cheng aifang, Feng Qi, Zhang Jiankai. (2015). **Review of research on the response process of climate change under future climate scenarios [j]**. *Geographic science*, 35(1), 84-90.

(4) Moss RH, Edmonds JA, hibbard KA. (2010). **The next generation of Scenarios for climate change research and assessment[J]**. *Nature*, 463(7282), 747.

(5) Flato G. (2017). **Evaluation of climate modes [g] climate change 2013.the physical science basis**. *Working groupI contribution to the fifth asassessment report of the intergovernmental panel on climate change.*

(6) R ISBEY J S, STONE P H. (1996). **A case study of the adequacy of GCM simulations for input to regional climate change assessments[J].** *Journal of Climate*, 9(7), 1441-1467.

(7) LIU Y H, GUO W D, FENG J M. (2011). **A summary of methods for statistical down scaling of meteorological data[J]** *Advances in Earth Science*, 26(8), 837-847.

(8) Zhu Qing, Zhou Zixiang, Liu Ting, Bai Jizhou. (2021). **Study on Some Random Place Somewhere vegetation restoration and ecosystem soil conservation service value gain: a case study of Yanhe Basin[J]**. *Journal of Ecology*, 41(07), 2557-2570.

(9) Wang Shuxia, Zhang Liping, Li Yi, she dunxian. (2019). **Extreme flood events in the Lancang River Basin under Climate Change Scenarios[J]**. *Progress in climate change research*, 15(01), 23-32.

(10) SCHMIDLI J, FREI C, VIDALE P L. (2006). **Downscaling from GCM precipitation: a benchmark for dynamical and statistical downscaling methods[J]**. *International Journal of Climatology,* 26(5), 679-689

(11) NGAI S T, TANGANG F, JUNENG L. (2017). **Bias correction of global and regional simulated daily precipitation and surface mean temperature over Southeast Asia using quantile mapping method [J]** . *Global and Planetary Change,* 149, 79-90.

(12) Sarita, Gajbhiye, Chandrashekhar. (2016). **Trend analysis of rainfall time series for Sindh river basin in India[J]**. *Theoretical & Applied Climatology.*

(13) Pawar P S, Rawat U, Yadav A, (2020). **Long Term Trend Analysis of Rainfall, Rainy Days and Drought for Sindh River Basin, Madhya Pradesh, India[J].** *International Journal of Current Microbiology and Applied Sciences,* 9(12), 2738-2749.

(14) Bera S. (2017). **Trend Analysis of Rainfall in Ganga Basin, India during 1901-2000[J].** *American Journal of Climate Change*, 116-131.

(15) [15]Kebede, Asfaw, Zeleke. 2017. **Analysis of rainfall trend and variability for agricultural water management in Awash River Basin, Ethiopia[J]**. *Journal of water and climate change*, 8(1), 127-141.

(16) Jiao P, Wei W, Bao H. (2020). V**ariation and Trend Analysis of Rainfall in Qingshui River Basin of Ningxia in China[J]**. *IOP Conference Series Earth and Environmental Science*, 526, 012040.

(17) Shah S A, Kiran M. (2021). **Mann-Kendall Test: Trend Analysis Of Temperature, Rainfall And Discharge Of Ghotki Feeder Canal In District Ghotki, Sindh, Pakistan[J]**. *Environment & Ecosystem Science (EES)*, 5.

 https://doi.org/10.17993/3ctecno.2023.v12n1e43.15-31

(18) Gao S, Wang H W, Sang X L. (2019). **Analyzing the Correlation of Time Series of Rainfall-runoff in Yuanjiang-Red River Basin[J]**. *Systems Engineering.*

(19) Doumouya F, Traore V, Sadio M. (2019). **Rainfall Variability in Sine Saloum River Basin in a Context of Climate Change and Variability[J]**. *Advances in Research*, 6(6), 1-12.

(20) Sinam R. (2019). **RAINFALL TREND ANALYSIS OF BAITARANI RIVER SUB-BASIN, ODISHA.[J]**. *International Journal of Advanced Research,* 7(10), 569-575.

(21) Shimola K, Krishnaveni M. (2018). **Statistical analysis of trend and change point in climate series for a semi-arid basin, Tamil Nadu, India[J]**. *Disaster Advances*, 11(10), 8-15.

(22) Bekele D, Alamirew T, Kebede A. (2018). **Analysis of rainfall trend and variability for agricultural water management in Awash River Basin, Ethiopia[J]**. *Journal of Water & Climate Change*, 8(1), 127-141.

(23) Noreen D N., Khan F., Dil S. (2020). **Trend Analysis of exponential increase of Covid-19 cases in Pakistan (Preprint).**

(24) Kiros G, Shetty A, Nandagiri L. (2017). **Trend Analysis of Temperature Time Series in Geba River Basin, Northern Ethiopia[C].** *HYDRO 2015 INTERNATIONAL 20th International Conference on Hydraulics, Water Resources and River Engineering, IIT Roorkee, India*, December 17-19.

(25) Singh G. (2018). **Analysis of Trend and Variability of Rainfall in the Mid-Mahanadi River Basin of Eastern India.**

(26) Kumar S, Santosh. (2019). **Non-Parametric and Parametric Analysis of Runoff in Satluj River Basin, Himachal Pradesh, India[J]**. *SciPress Ltd*.

(27) She D, Xia J, Zhang Y. (2018). **The trend analysis and statistical distribution of extreme rainfall events in the Huaihe river basin in the past 50 years[J]**. *Acta Geographica Sinica*.

(28) Thakural L N. (2018). **Trend Analysis of Rainfall for the Chaliyar Basin, South India.**

(29) Fernando S, AX Júnior, Stosic T. (2018). **A Brief multifractal analysis of rainfall dynamics in Piracicaba, So Paulo, Brazil[J]**. *Acta Scientiarum Technology*, 40(1).

(30) Tao D U, Xiong L H, Jiang C. (2018). **Nonstationary frequency analysis of rainfall time series in Weihe River Basin[J]**. *Arid Land Geography.*

(31) Singh, A. K., and Sora, M. (2021). **An optimized deep neural network-based financial statement fraud detection in text mining**. *3C Empresa. Investigación y pensamiento crítico*, 10(4), 77-105. https://doi.org/10.17993/3cemp.2021.100448.77-105

(32) Liu Yanwu. (2021). **Analysis and Prediction of College Students' Mental Health Based on K-means Clustering Algorithm**. *Applied Mathematics and Nonlinear Sciences,* 7(1), 501-512. https://doi.org/10.2478/AMNS.2021.1.00099.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.