Research of Extreme Precipitation Variation in Shanxi Based on R/S Analysis

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Abstract: In this paper, the daily precipitation observation data collected from 21 meteorological stations in Shanxi Province from 1958 to 2018 by China meteorological data network were used. The R/S analysis method and MATLAB analysis were adopted to calculate and analyze the future trend of extreme precipitation in Shanxi Province in the past 60 years. According to the study, R/S prediction analysis show that in the last 6 decades, the indexes of changes of continuous dry period and heavy rainfall show a downward trend, the indexes of the changes of annual precipitation and heavy rain days shows an upward trend, and the indexes of the future change trend of continuous wet period, extreme heavy rainfall, rainfall intensity, daily maximum precipitation and 5-day maximum precipitation remain uncertain.

1. Preface
According to the fifth assessment report of the IPCC, the global average temperature rise in the 21st century may range from 1.4 °C to 5.8°C. The increase in the global average temperature will affect the earth's water cycle, leading to an increasing trend of extreme weather, climate events and extreme precipitation events, which has been confirmed by many studies. Alexander et al. pointed out that in the past 50 years, global extreme temperature events, especially the extreme temperature index related to the daily minimum temperature, have changed significantly. Over 70% of the global land surface temperature shows a significant decrease in cold nights and a significant increase in warm nights. Manton et al. found that hot days and warm nights increased significantly in southeast Asia and the south Pacific, while cold days and cold nights decreased significantly. Although the characteristics of climate change in large scale regions have high similarity and consistency, there are large differences and opposite change characteristics in precipitation change rules in medium and small scale regions, so relevant research and evaluation work should be carried out in specific regions. Therefore, it is necessary to study the extreme precipitation in the province and below.

Shanxi Province is located in the west of the north China plain and the loess plateau, which covers an area of 156,700 square kilometers and is a continental monsoon climate of the plateau. Most of Shanxi is a mountainous plateau extensively covered by loess, which is characterized by high terrain...
in northeast and low terrain in southwest. It belongs to the hilly gully landform area of the loess plateau. The terrain is dominated by loessfield, loessridge and loesshill. The altitude of most areas in the territory is over 1000 meters, which is the superposition area of latitudinal zone and vertical zone. That intensifies the change of climate factors, leading to the significant increase of extreme weather such as high temperature, drought and little rain, frequent meteorological disasters, and causing huge losses to agriculture and tourism. Most of the natural disasters caused serious influence are related to extreme precipitation Department.

Meteorological disasters occur frequently, causing huge losses to agriculture and tourism. Most of these severe natural disasters are related to extreme precipitation.

Although there have been studies on extreme weather and climate events in Shanxi Province in recent years, it is impossible to take the characteristics of extreme precipitation changes in Shanxi Province into account in many aspects due to the less selected precipitation index, shorter research span and no simulation and prediction of future extreme precipitation changes in Shanxi Province. This paper focuses on the spatial and temporal changes of several extreme precipitation indexes in Shanxi Province in the past 60 years, which is of great significance to the understanding of future extreme weather changes, disaster prevention and mitigation, and the scientific planning of social production distribution.

2. Research area data and methods

2.1. Source of information

The meteorological data selected in this paper are from the ground daily data set provided by the China meteorological science data sharing service network. Due to the different construction time of each meteorological station in the study area, the observation data showed different duration and lack of measurement, so the stations with more lack of measurement were removed. Finally, only 21 meteorological stations in Shanxi Province could be selected. The distribution of meteorological stations is shown in figure 1.

2.2. The research methods

The definition of extreme precipitation events is mainly determined according to the edge of different distribution patterns adopted commonly used by different climate elements. The most percentile method in the world is adopted in this paper to define extreme precipitation thresholds of different stations, and then the spatial and temporal distribution characteristics of annual extreme precipitation events in Shanxi Province are discussed.

![Fig.1 Map of meteorological stations in Shanxi Province](image)
In this paper, nine of the 21 extreme weather indexes published by WMO are selected, as defined in detail in table 1. Heavy precipitation can be referred to by R95p, Extreme precipitation can be referred to by R99p, 5days of maximum precipitation can be referred to by Rx5day, Maximum daily precipitation can be referred to by RX1d, Continuous dry period can be referred to by CDD, Continuous wet period can be referred to by CWD, Annual precipitation can be referred to by PRCPTOP, Precipitation tensity can be referred to by SDII, days of heavy precipitation can be referred to by R25. The extreme precipitation index for each weather station was calculated using the RClimDex software. The division of the season uses the meteorological season, that is, march to may for spring, June to September for summer, September to November for autumn, December to the next year in January, February for winter. Continuous dry period requires across years statistics, such as some station uses 1958 dry period in August 1, 1958 to August 31, 1959 as a benchmark. By R/S analysis, the Hurst exponent is obtained, which asserted the persistence characteristic or anti-persistence characteristic strength by means of the tendency component of future changes.

### 3. Results and analysis

#### 3.1. Future changes of extreme precipitation in Shanxi Province

R/S analysis method is the British scholar H.E. Hurst in 1965 put forward a method of processing time sequence, Hurst have been using this method of river flow, mud sedimentation volume, tree rings, precipitation and many other natural phenomenon studied. At the same time, this method in other areas, such as (physics, biology, etc.) also has been widely used. Take the characteristics of changes in extreme precipitation in Shanxi Province in nearly 60 years as an example, using R/S analysis method for dynamic process of extreme precipitation are analyzed, and satisfactory results were obtained. Through the R/S analysis to calculate the Hurst index, climate time series The statistical results of Hurst index H obtained by R/S prediction analysis of the extreme precipitation index in Shanxi Province in the past 60 years are shown in table 2.
It can be seen from table 2 that the Hurst exponent after random rearrangement of the sequence in the continuous dry period is close to that of the original sequence, indicating that the calculated Hurst exponent is stable and meets the requirements. Since \( H < 0.5 \), the longer-term correlation is characterized by anti-persistence, indicating that the change trend of the continuous dry period in the future is contrary to that in the past. The difference between the Hurst exponent of the original sequence after the random reordering of the sequence of continuous wet period, extreme heavy precipitation, precipitation intensity, daily maximum precipitation and 5-day maximum precipitation is relatively large, indicating that the calculated Hurst exponent is unstable, indicating that the change trend in the future is uncertain. The Hurst index after the random rearrangement of annual precipitation is close to that of the original sequence, indicating that the calculated Hurst index is stable and meets the requirements. Since \( H < 0.5 \), the long-term correlation is characterized by anti-persistence, indicating that the change trend of precipitation intensity in the future is contrary to that in the past. The Hurst exponent after the random rearrangement of the number of days of heavy rain is close to that of the original sequence, indicating that the calculated Hurst exponent is stable and meets the requirements. Since \( H < 0.5 \), the long-term correlation characteristic is anti-persistence, indicating that the change trend of the number of days of heavy rain in the future is contrary to that in the past. The Hurst index after random rearrangement of strong precipitation is close to that of the original sequence, indicating that the calculated Hurst index is stable and acceptable. Since \( H > 0.5 \), the long-term correlation is characterized by persistence, indicating that the change trend of daily maximum precipitation in the future is consistent with that in the past.

| Extreme precipitation index | The original sequence H value | Random rearrangement of H values |
|-----------------------------|-----------------------------|-------------------------------|
| CDD                         | 0.43                        | 0.45                          |
| CWD                         | 0.31                        | 0.49                          |
| SDII                        | 0.72                        | 0.35                          |
| R25                         | 0.43                        | 0.48                          |
| PRCPTOP                     | 0.46                        | 0.46                          |
| R95p                        | 0.68                        | 0.64                          |
| R99p                        | 0.64                        | 0.49                          |
| RX1d                        | 0.71                        | 0.42                          |
| Rx5day                      | 0.56                        | 0.47                          |

4. Conclusion and discussion

Through predicting and analyzing 9 kinds of extreme precipitation index R/S nearly 60 years in Shanxi Province, and carrying on the random rearrangement of time series, calculating of H value after reordering and H value of the original sequence, finally it is concluded that: the change trend of continuous dry period, precipitation intensity and the days of heavy precipitation in the future compared with the past on the contrary, daily maximum precipitation of the future and the past is consistent, continuous wet period, annual rainfall, 5 maximum precipitation, strong precipitation, extreme strong precipitation change trend of the future is uncertain.

There are temporal and spatial differences in the changes in extreme precipitation events in Shanxi Province, which may be caused by combined efforts of many factors, such as climate, topography and so on. The changes of extreme precipitation may also be related to the occurrence of ENSO and the global warming caused by industrialization and urbanization. R/S forecast analysis shows that the change of continuous dry period, precipitation intensity and number of days of heavy precipitation will increase in the future, but the increase in the short term is very limited, so the future drought in this
area is still a major meteorological disaster threatening agricultural production. In conclusion, the causes of extreme precipitation are complex and need to be further studied.

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