Problem Chosen	2021 ShuWei Cup Summary Sheet	Team Control Number
B		202111036817

Summary

Global precipitation is expected to increase by about 10% by the end of the century, with a significant increase in extreme weather. In recent years, many parts of the country have been hit by sudden heavy rains, and Henan, Shaanxi and Hubei provinces have been hit by extreme weather. Therefore, it is necessary to establish the prediction of future extreme rainfall and disaster models.

For question 1, the difference value of the data was removed and the average sliding model was smoothen. Then the **correlation analysis** of Zhengzhou meteorological data was carried out through prayer double-tail correlation, and the periodic analysis of zhengzhou annual precipitation was carried out through **wavelet analysis**. At the same time, the visual processing was carried out. Based on the analysis of annual precipitation anomaly, annual mean precipitation distribution diagram and **M-K analysis**, the relation, periodicity and mutation of precipitation in Zhengzhou are analyzed intuitively. The years with higher precipitation were 1992, 2003, 2016 and 2021. The extreme rainfall in Zhengzhou was quantified by analyzing the accumulated precipitation and real-time precipitation during the rainstorm.

For question 2, the **NOAA (https://www.noaa.gov)** obtained meteorological data of 9081 stations throughout China. We used wavelet analysis to analyze the precipitation periodicity, and analyzed the characteristics of annual precipitation change through the annual and quarterly average precipitation. At the same time, the city is selected to consider the factors of landform and climate type.

For question 3, as precipitation has the characteristic of internal periodic change, the neural network Timing sequence Prediction **(WNN)** based on wavelet analysis and **ARIMA** model are used to construct the prediction model, and the extreme rainfall weather in Beijing and Wuhan is analyzed in question 2. The results of different predictions are compared and analyzed. It is found that the neural network based on wavelet analysis has an obvious effect on time series prediction.

For question 4, we find that the characteristics of heavy rain in Zhengzhou in July 2021 and heavy rain in Shanxi in October 2021 are significantly different: occurrence time of rainfall and maximum precipitation, duration and range of rainfall, and important factors affecting rainfall. Zhengzhou suffered the heaviest loss of public facilities due to the impact of topography, while Shanxi suffered the heaviest loss due to the heavy circulation, resulting in several river dikes breaking, building collapse, cultural relics damage, casualties and other heavy losses, among which agriculture suffered the heaviest loss.

For problem 5, under objective conditions, we should adopt "**sponge system**" and "s**elf-cooling system**" according to local conditions, and the multi-faceted disaster resistance system can provide a more comprehensive disaster prevention effect. Environmental protection should be specific to every citizen. Only we make concerted efforts to prevent the further deterioration of global warming, to protect the environment, is to protect ourselves.

Key word：WNN; ARIMA; Movement smoothing; NOAA; Wavelet analysis;M-K mutation

Content

1. Introduction

1.1 Background

Climate scientists expect extreme storms to bring more rain as global temperatures rise. The warmer the atmosphere, the more water it can hold, which means storms get wetter. In the context of global warming, some extreme weather events are indeed increasing and increasing. It is expected that by the end of this century, global precipitation will increase by about 10%, indicating a significant increase in extreme weather. China is one of the countries most seriously affected by rainstorm disaster.

In recent years, many parts of China have been faced with sudden and extreme heavy rains, and Henan, Shaanxi, Hubei and other places have suffered extreme weather. In particular, this year's heavy rain in Zhengzhou, Henan province, from 18:00 on July 18 to 0:00 on July 21, A rare and sustained heavy rainfall weather process occurred in Zhengzhou, with heavy rain and extremely heavy rain all over the city, and the cumulative average precipitation was 449 mm. From 16:00 to 17:00 on The 20th, the rainfall in Zhengzhou reached 201.9 mm in one hour, which has exceeded the maximum rainfall per hour on land in China. From 20 o 'clock on The 19th to 20 o 'clock on the 20th, the single-day rainfall was 552.5mm; From 20 o 'clock on The 17th to 20 o 'clock on the 20th, the process rainfall of three days was 617.1mm. Hourly precipitation and single-day precipitation have exceeded the historical record of 60 years since zhengzhou station was established in 1951. The average annual rainfall in Zhengzhou is 640.8mm, which is equivalent to the amount of the previous year in these three days. Sudden torrential rain caused heavy casualties and losses in Zhengzhou.

In recent 10 years, the impact of rainstorm on national economy and people's life is increasing day by day, and rainstorm disaster is a great threat to national security in peacetime. Although China has made great progress in rainstorm forecasting system construction and capacity improvement, there are still some shortcomings that cannot be ignored. First, the mechanism of heavy rain is insufficient. We have a qualitative improvement in the understanding of macro meteorological system, but lack of understanding of the impact of local terrain and climate background on heavy rain disasters. Secondly, there is still room for improvement in meteorological disaster forecasting techniques and personnel training. Third, the application of new technologies in meteorological forecasting is insufficient, and it will take some time for the platform to consolidate data and improve its analysis ability. Therefore, we should make up for shortcomings and rise to the challenges. In particular, information exchange between meteorological professionals and the general public should be formed so as to enhance public awareness of meteorological disasters and extreme weather and minimize human and property losses. At the same time, due to the phenomenon that China has a large land area, diverse terrain and great climate difference in different regions, it is necessary to establish urban extreme precipitation models and preventive measures for different cities and regions facing different impacts of extreme rainfall. This is our immediate task.

1.2 Work

In order to establish an accurate and reliable prediction model, we collected a lot of data and preliminarily sorted out a lot of data. The annual precipitation of Zhengzhou is processed to obtain the characteristics of monthly average precipitation in Zhengzhou.

Second, we sorted out the rainfall detected by 9081 stations in China in the past 18 years, and selected several cities with different topography, landform and climate for analysis. However, some missing meteorological data affected our analysis and judgment, so we deleted and interpolated the data.

After that, we made a preliminary statistics based on the harm caused by extreme rainfall: extreme rainfall directly brings urban waterlogging, production stagnation, production reduction of agricultural products, inconvenience for people to travel, etc., followed by floods, debris flows, landslides, coastal cities may also face typhoons, etc. We establish neural network of wavelet analysis and ARIMA model to predict the analysis.

In the end, we summarize a set of long-term construction planning of the city under extreme rainfall conditions according to the results of the analysis and judgment of the first four questions.

2. Problem analysis

2.1 Data analysis

We made a data synthesis based on the rainfall status of Zhengzhou in recent 41 years given in Attachment 1. We found that the missing data file would be replaced with 999.99, which brought great trouble to our data analysis and processing. Therefore, we removed the difference points, and then interpolated and smoothed the remaining values. The correlation analysis was carried out using these data. Because of the lack of data, the correlation is not obvious, so we only forecast rainfall.

2.2 Analysis of question one

According to the title, we should conduct correlation analysis on the interannual changes in Zhengzhou to determine whether there are relevant factors that have an impact on precipitation. Because the cause of extreme precipitation weather is not only affected by meteorological factors, but also by geographical topographic factors. Therefore, in question 1, we should also analyze topographic and geomorphic factors. After that, the precipitation of each year was analyzed and compared to screen out the year with more precipitation.
At the same time, by analyzing the real-time precipitation and accumulated precipitation in Zhengzhou on July 20, the specific quantitative analysis results of zhengzhou flood

events were obtained.

2.3 Analysis of question two

Through the NOAA website **(https://www.noaa.gov)**, we obtained the meteorological data of 9081 stations throughout China. We used wavelet analysis to analyze the precipitation periodicity, and analyzed the characteristics of annual precipitation change through the annual and quarterly average precipitation. At the same time, the city is selected to consider the factors of landform and climate type.

2.4 Analysis of question three

As the precipitation has the characteristic of interannual periodic change, the neural network time series prediction based on wavelet analysis and ARIMA model are used to build the prediction model to analyze the cities that may have extreme rainfall weather in the future in question 2. The results of different predictions are compared and analyzed.

2.5 Analysis of question four

In view of the characteristics of heavy rain in Shanxi and Zhengzhou, we have carried out a series of mathematical analysis, respectively from precipitation, climate and other aspects. Through consulting the data, we have a general idea in advance: taiyuan and Zhengzhou have the same extreme weather, stable atmospheric circulation situation, abundant water vapor conditions. But there are more differences, for example, the topography is different, the timing of rainfall is different from when the maximum rainfall occurs. For the loss caused: Zhengzhou: train suspension, scenic spot closure, express damage, property loss, casualties; Shanxi: train stops, landslides, property losses, cultural relics collapse and so on.

2.6 Analysis of question five

In view of the future urban development planning under extreme precipitation conditions, the combination of "sponge system" and "self-cooling system" should be adopted according to local conditions, and the multi-faceted disaster resistance system can provide a more comprehensive disaster prevention effect. In the short term, artificial protection is needed to minimize the harm caused by extreme precipitation. In the long run, many aspects of the city need to be improved.

3. Symbol and Assumptions

3. 1 Symbol Description

NO.	Symbol	Symbol meaning
1	**d**	Annual precipitation statistics
2	$\boldsymbol{m_i}$	The ith sample accumulation
3	$\boldsymbol{x_i}$	The i annual precipitation
4	i	The ith sample variable
5	k	Total sample statistics
6	$\boldsymbol{R^2}$	The model was fitted with statistical variance values

3.2 Fundamental assumptions

✧ Firstly, precipitation is assumed to be related to some meteorological factors, as well as local topography, landform, altitude and other geographical factors, so local meteorological and geographical factors should be taken into account when analyzing precipitation related factors.

✧ Anyway, data can screen out factors with high correlation as much as possible during correlation analysis. If the correlation of detected factors is low, precipitation can be used as the judgment basis for subsequent modeling.

✧ Secondly, due to flaws in the data collected by the weather station and missing data searched, it is necessary to remove and interpolate some special error codes and error data when analyzing the characteristics of local precipitation.

✧ Thirdly, we can get data will inevitably exist error, so the data when processing the data should be no distortion.

✧ Fourth, due to the interannual, quarterly, monthly and diurnal variations in precipitation, periodic data analysis should also be done, which is also to prepare for the subsequent extreme rainfall prediction. At the same time, smoothing the data is also necessary.

✧ Finally, we built a prediction model based on monthly variation due to the complexity of daily precipitation variation and weak periodicality. Finally, the sensitivity of the model is analyzed.

4. Model

4.1MANN-KENDALmutation analysis

Mann-kendall nonparametric statistical method can effectively distinguish whether a certain natural process is in natural fluctuation or has definite change trend. The mann-Kendall rank-order correlation test is more suitable for non-normal hydrometeorological data. Mann-kendall is also often used to detect the trend of precipitation and drought frequency under the influence of climate change.

Mann-kendall nonparametric rank test is extremely useful in trend detection of data. Its characteristics are as follows :(1) there is no need to conduct specific distribution test for data series, and trend test can also be performed for extreme values; (2) The series is allowed to have missing values; (3) The analysis is mainly about the relative order of magnitude rather than the number itself, which enables the analysis of trace values or values below the detection range; (4) In time series analysis, there is no need to specify whether it is a linear trend. The correlation number between two variables is the Mann-Kendall correlation number, also known as the Mann-Kendall statistical number S.

Analysis process:
1. Let the original time series be y1， y2， …， yn， mi represents the cumulative number of the ith sample yi greater than yj (1≤j≤ I), and defines the statistic:
2. Under the assumption of random independence of the original sequence, the mean and variance of DK are:
3. Standardize the of the above formula, so:

$$d_k = \sum_{i=1}^{k} m_i, (2 \le k \le n)$$

$$UF_k = \frac{d_k - E(d_k)}{\sqrt{\operatorname{var}(d_k)}}$$

$$E(d_k) = k(k-1)/4 \quad \operatorname{var}(d_k) = k(k-1)(2k+5)/72$$

In the formula, the cumulative temperature series is defined, UF is the statistic, d is the precipitation statistic.m_i represents the cumulative amount of the ith sample, and is the precipitation statistics from 1960 to 2021.

1. UFk forms a UF curve, and whether it has an obvious change trend can be obtained through reliability test.

2. This method is referred to the inverse sequence and another curve UB is calculated. Then the intersection of the two curves within the confidence interval is determined as the mutation point.

3. Determine the level of significanceα=0.05， The statistics UF and UB that the critical value of is±1.96。UF>0， it represents sequence shows an upward trend. On the contrary, it shows a downward trend, greater than or less than ±1.96, indicating an obvious upward or downward trend.

4.2 Wavalet analysis

Wavelet analysis is a kind of window size fixed but the shapes can be changed, and can be adjustable time-frequency window its time-frequency localization analysis method in time domain and frequency domain at the same time adjustable time-frequency window time-frequency localization analysis method, it is in the time domain and frequency domain at the same time has good localization feature, to localize the time series analysis, Analysis of its internal fine structure, time - frequency multi - resolution function.

Wavelet analysis takes time and frequency as independent variables and expands one-dimensional signals in both time and frequency directions, so as to clearly understand the frequency characteristics of different time domains of time series and time distribution characteristics of different frequencies.

The time-domain form of Morlet sub-wavelet function is as follows:

$$\varphi(t) = e^{-\frac{t^2}{2}} e^{i\omega_0 t}$$

Where: take 6.2, I represents imaginary number.

For the time suquence f(t)∈L2(R),its continuous wavelet change is:

$$W_f(a,b) = |a|^{-\frac{1}{2}} \int_{-\infty}^{+\infty} f(t)\, \bar{\varphi}\left(\frac{t-b}{a}\right) dt$$

In the formula: ω_0 is a scale factor, B time factor, complex common function of P(t) -- (t), W, (ab) wavelet coefficient. In this paper, MATLAB with its own wavelet toolkit wavelet transform.

4.3 ARIMA Model

Differential integrated moving average autoregressive model, also known as integrated moving average autoregressive model (moving can also be called sliding), is one of the predictive analysis methods of time series. P is the number of autoregressive terms. Q is the number of terms of the moving average, and d is the number of differences (order) made to make it a stationary sequence.

p	Order of autoregressive model
d	The differential order
q	Order of moving average model

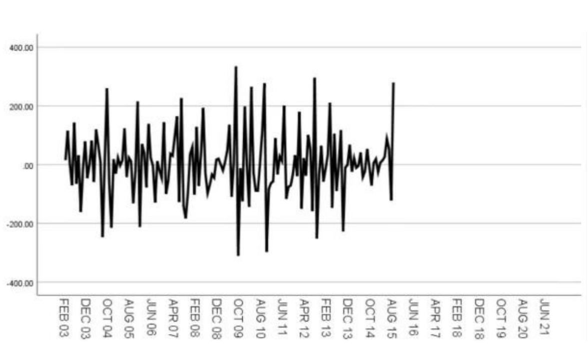
ARIMA(p，d，q) can be expressed as:

$$\left(1-\sum_{i=1}^{p}\phi_i L^i\right)(1-L)^d X_t=\left(1+\sum_{i=1}^{q}\theta_i L^i\right)\varepsilon_t$$

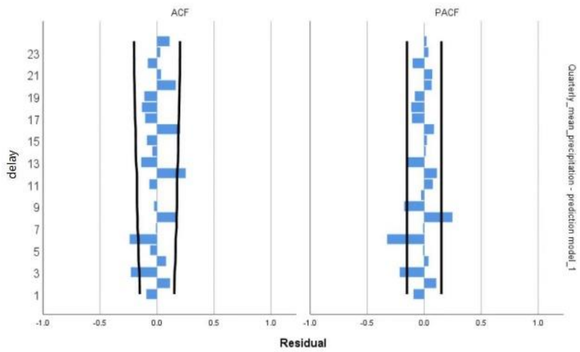
The main steps for predicting data using ARIMA include:

1. Sequence stabilization
2. Determine d
3. Draw acF and PACF diagrams and determine p parameter and Q parameter
4. Use the found parameters to fit the ARIMA model
5. Make predictions on validation sets
6. Evaluate the effectiveness of the forecast

Taking zhengzhou as an example, we used SPSS to predict ARIMA model. After repeated tests, the model was determined as ARIMA(2,1,1), and the results were as follows:



(a)



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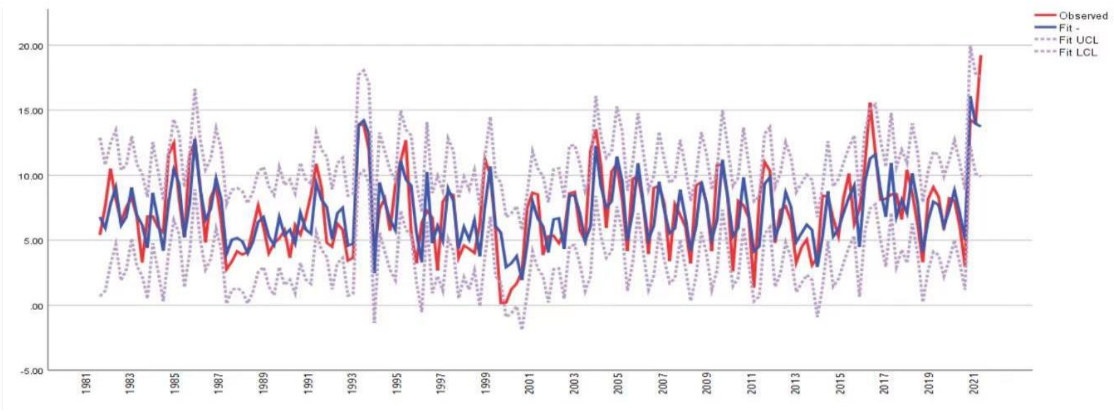


(c)

Fig.1 ARIMA Model Residual line(a. Evenly distributed values on both sides indicate stable data)ACF and PACF(b.) Fitting image(c)

The data are evenly distributed on both sides of the base line, indicating that the data is stable. It can be seen from the figure that both ACF and PACF of the difference sequence are trailing, so ARIMA(P,1, Q) model can be established for the original sequence. After repeated tests, the model was determined as ARIMA(1,1,1).

The residual ACF value and residual PACF were obtained, and the overall performance was stable, but the significance of each outlier was not prominent. Finally, data fitting was carried out. In the case of partial missing data, the correlation coefficient was still large, and the fitting effect was good. So we have the model. The coefficient of AR and MA is 0.947 and 0.664 respectively, and the significance level is less than 0.01, so the coefficients are significantly not 0.

The ARIMA function obtained is:

$$\triangle X_t = 0.947 \triangle X_{t-1} + \varepsilon_t - 0.670 \varepsilon_t$$

4.4 Analysis of Wavelet Neural Network Prediction Model (WNN)

Wavelet Neural Network(WNN) is a kind of artificial Neural Network based on the breakthrough of Wavelet analysis. It is a new layered and multi-resolution artificial neural network model based on wavelet analysis theory and wavelet transform. Combining the advantages of artificial neural network and wavelet analysis, the network has the characteristics of fast convergence speed, avoiding falling into local optimal, and sometimes frequency local analysis.

WNN is to replace S function of hidden node of neural network by wavelet function, and the corresponding weight from input layer to hidden layer and threshold of hidden layer are replaced by scale scaling factor and time translation factor of wavelet function respectively.

Firstly, the determination of the wavelet basis and the whole network structure has a reliable theoretical basis, which can avoid the blindness in the structure design of BP neural network. Secondly, the linear distribution of network weights and the convexity of learning objective function make the network training fundamentally avoid the local optimal nonlinear optimization problem. Thirdly, have strong function learning ability and promotion ability.

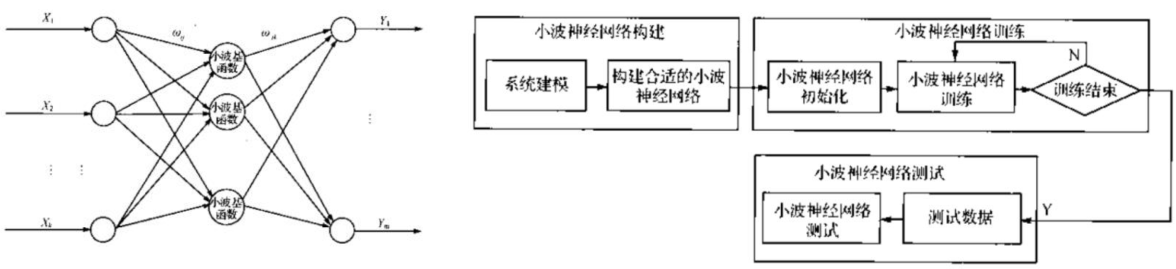


Fig. 2 Topology structure of wavelet neural network

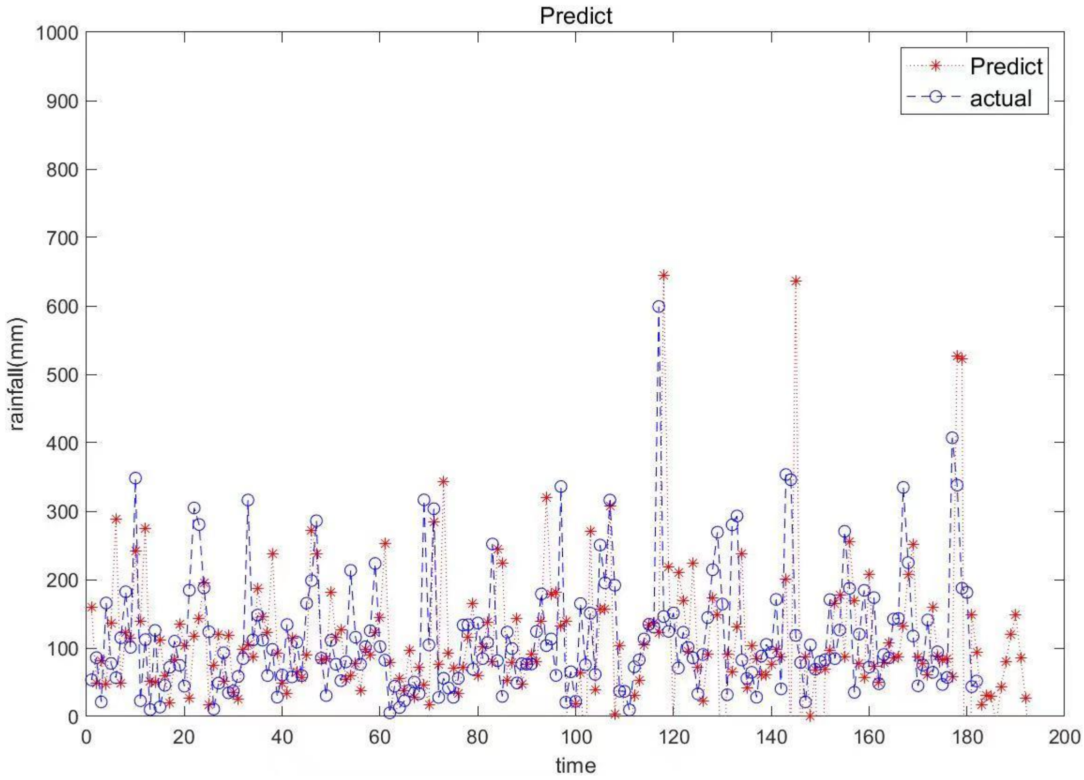


Fig.3 the wavelet neural network prediction mode based on Shanghai

Based on the data of Shanghai, the wavelet neural network prediction model is established to analyze the rainfall data of Zhengzhou. By comparing the predicted value with the actual value, we believe that the model has good fitting effect. Therefore, the wavelet neural network prediction model is used to predict other cities which may have heavy rain.

5.Test the Models

5.1 Correlation of precipitation factors

Firstly, we select the data of zhengzhou Meteorological station in Henan province to analyze the interannual variation characteristics of annual precipitation. After analyzing the data, we remove the special values. Due to data loss, the gust, snow depth and atmospheric pressure of the meteorological station in the first question cannot be measured. Through literature search, it is learned that these three factors have little correlation with rainfall, so the determination of rainfall has nothing to do with these three factors. After the analysis of the remaining data, due to certain errors in daily data and lost data, and the rainfall is related to multi-factor cooperation, the correlation is not obvious, and R2 of most factors is less than 0.2, that is, the correlation is not obvious.

Correlation analysis												
	PRCP	TEMP	TEMP_ ATTRIBUTES	FRSHTT	DEWP	SNDP	DEWP_ ATTRIBUTES	MIN	WDSP_ ATTRIBUTES	SLP	STP_ ATTRIBUTES	STP
PRCP	1.00	0.10	0.14	0.11	0.07	(0.06)	0.08	0.14	0.11	(0.21)	0.04	0.10
TEMP	0.10	1.00	0.04	(0.07)	0.08	0.05	0.02	0.97	0.08	(0.87)	0.07	0.04
TEMP_ATTRIBUTES	0.14	0.04	1.00	(0.01)	0.00	0.01	0.87	0.04	0.75	(0.05)	0.12	(0.14)
FRSHTT	0.11	(0.07)	(0.01)	1.00	0.01	(0.01)	(0.02)	(0.05)	(0.03)	(0.01)	0.03	0.01
DEWP	0.07	0.08	0.00	0.01	1.00	0.00	(0.43)	0.09	0.01	(0.10)	0.04	0.06
SNDP	(0.06)	0.05	0.01	(0.01)	0.00	1.00	0.01	0.04	(0.00)	(0.04)	(0.07)	0.01
DEWP ATTRIBUTES	0.08	0.02	0.87	(0.02)	(0.43)	0.01	1.00	0.02	0.65	(0.01)	0.07	(0.16)
MIN	0.14	0.97	0.04	(0.05)	0.09	0.04	0.02	1.00	0.09	(0.86)	0.06	0.05
WDSP_ATTRIBUTES	0.11	0.08	0.75	(0.03)	0.01	(0.00)	0.65	0.09	1.00	(0.08)	0.10	(0.09)
SLP	(0.21)	(0.87)	(0.05)	(0.01)	(0.10)	(0.04)	(0.01)	(0.86)	(0.08)	1.00	(0.03)	(0.12)
STP_ATTRIBUTES	0.04	0.07	0.12	0.03	0.04	(0.07)	0.07	0.06	0.10	(0.03)	1.00	(0.19)
STP	0.10	0.04	(0.14)	0.01	0.06	0.01	(0.16)	0.05	(0.09)	(0.12)	(0.19)	1.00

Fig． 4 Correlation of precipitation factors

5.2 Analysis of annual precipitation variation

In order to explore the characteristics of monthly precipitation in Zhengzhou, we analyzed the monthly average precipitation in Zhengzhou. In order to explore the correlation between temperature and precipitation, the annual mean monthly rainfall and annual mean temperature in recent 30 years were analyzed.

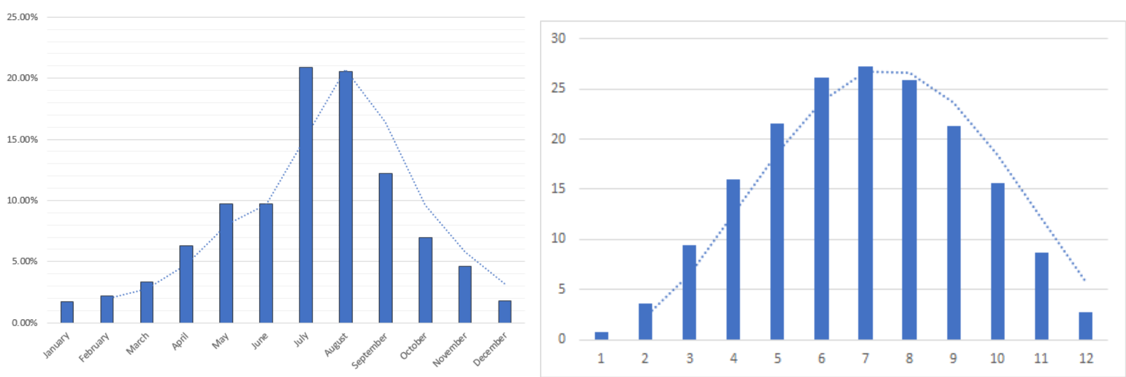


Fig. 5 monthly average rainfall and temperature in Zhengzhou

Figure 5 shows the proportion of multi-year average monthly rainfall to total annual average rainfall in recent 30 years. As can be seen from the figure, the annual rainfall before July increases month by month, and the increase rate increases month by month, reaching the annual maximum of 139.8mm in July, which accounts for 20% of the annual rainfall. After that, the monthly rainfall decreased, and the amplitude slowed down month by month. The total rainfall in July and August was 248.35mm, accounting for 56.86% of the total annual rainfall. The rainfall from May to October in flood season is 386.75mm, accounting for 88.54% of the annual rainfall. There is very little rainfall in spring and winter, and the distribution of rainfall throughout the year is very uneven. And the precipitation in July obviously exceeded the fitting line, and there was a large fluctuation and a large mutation rate.

According to the temperature change in Figure B, the year is gentle and the climate is mild, with a subtropical monsoon climate. By combining the two figures, it is found that the correlation between precipitation and temperature in Zhengzhou is not strong, which cannot be analyzed as a correlation variable. In the following analysis, precipitation is used as the only variable.

5.3Analysis of interannual variation characteristics of precipitation

Since the occurrence of extreme rainfall belongs to climate mutation, we first established mann-Kendal mutation analysis to analyze the years of precipitation mutation, and obtained the years with more rainfall according to the results. After that, in order to explore the periodicity of precipitation, the wavelet analysis method is used to analyze the annual precipitation of Zhengzhou, and the periodicity of precipitation is obtained. After comprehensive analysis of the annual precipitation and time series images as well as the annual precipitation anomaly chart, it is concluded that the precipitation in Zhengzhou has a certain periodicity and mutation.

（1） Mann-kendal mutation analysis: The Mann-Kendal method, also known as no distribution test, is a nonparametric test method.

Mann-kendal mutation was carried out and the following results were obtained:

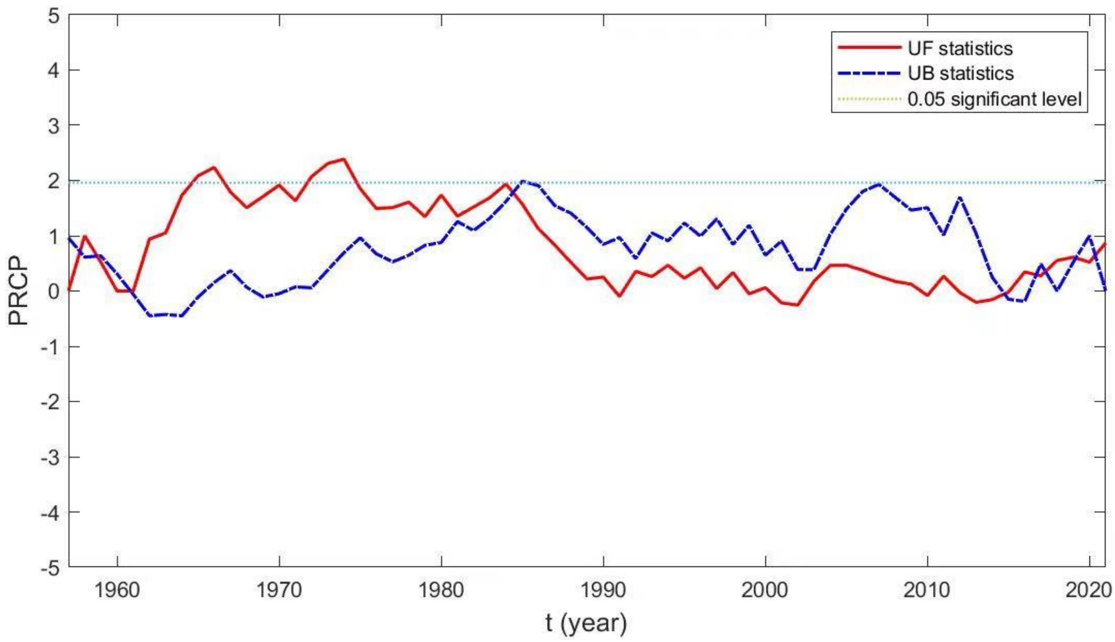
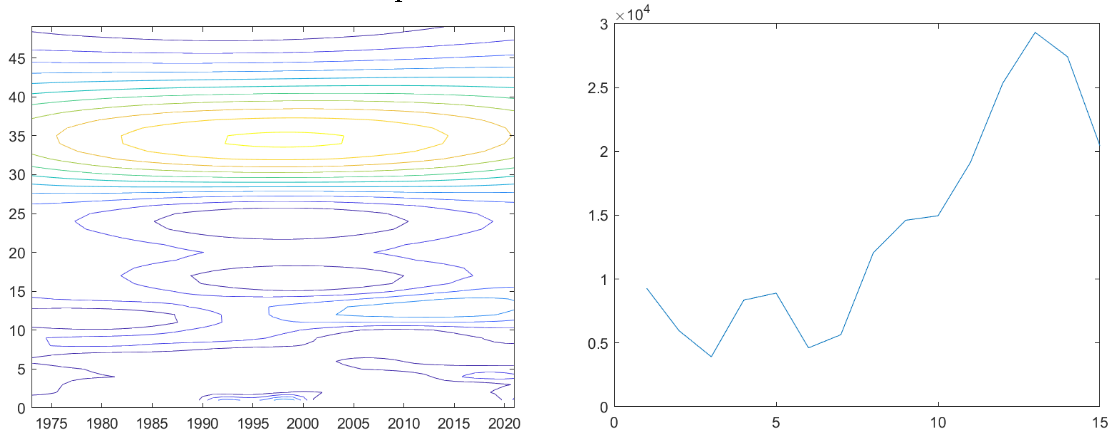


Fig.6 The M-K mutation of annual precipitation in Zhengzhou was carried out

As can be seen from the above figure, the annual precipitation in Zhengzhou in the past 70 years had abrupt changes in 1953, 1958, 1964, 1984, 2014, 2016, 2018 and 2021, respectively. The positive sequence curve (Uf) showed a rapid upward trend after mutation in 1964, and the 1.96 confidence threshold indicated that precipitation had a significant upward trend after 1964. The precipitation series showed a fluctuating trend after mutation (Uf) in 1984, which indicated that precipitation showed a fluctuating change after 1984. After the mutation of precipitation series in 2014, (Uf) showed an upward trend, but it did not pass the critical value of 1.96 confidence, indicating that annual precipitation increased after 2014, but the upward trend was not significant.

(2) Wavelet analysis: In order to obtain the characteristics of interannual periodic variation of annual precipitation, we carry out wavelet analysis. Wavelet analysis takes time and frequency as independent variables and expands one-dimensional signals in both time and frequency directions, so as to clearly understand the difference of time series and frequency characteristics of time domain, as well as the time distribution characteristics of different frequencies. The results are as follows:



(a) (b)

Fig.7 The results of wavelet analysis on the interannual precipitation in Zhengzhou are presented

(3) Annual mean precipitation anomaly: The anomaly refers to the percentage of the observed value of a meteorological indicator in a certain period of time in the mean value of that indicator in the same period of many years. Precipitation anomaly percentage refers to the percentage of precipitation in a certain period of time compared with the same period of precipitation all year round. Precipitation anomaly refers to the interpolation between precipitation in a certain period and precipitation in the same period of the year, and they are generally compared at the same time. The following figure shows the distribution of annual mean precipitation anomaly in Zhengzhou.

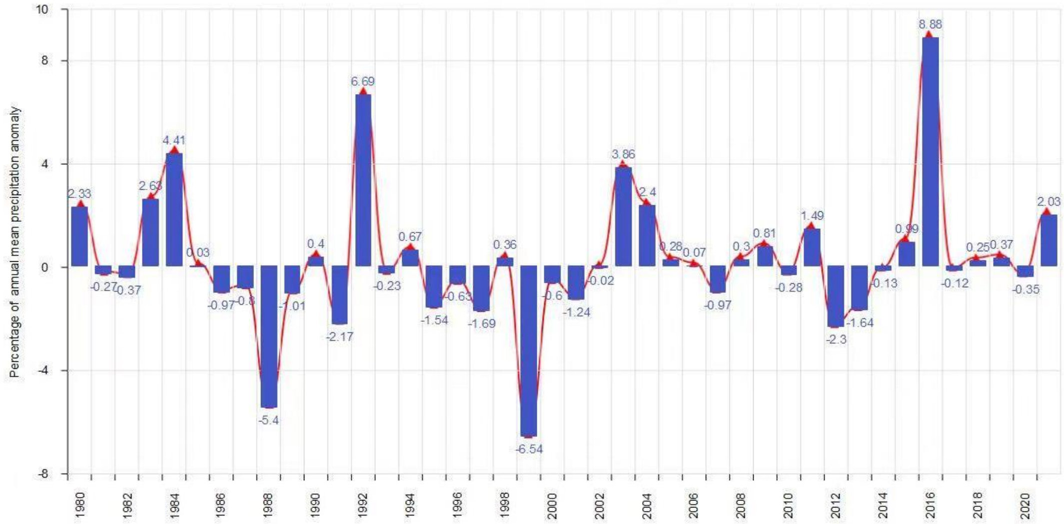


Fig.8 Distribution of departure from the average

As can be seen from the figure above, the annual precipitation in Zhengzhou basically takes a 10-year cycle, showing obvious interannual and temporal fluctuation characteristics. Departure from the average distribution chart and percentage distribution chart are analyzed to obtain the percentage chart of annual precipitation anomaly in Zhengzhou:

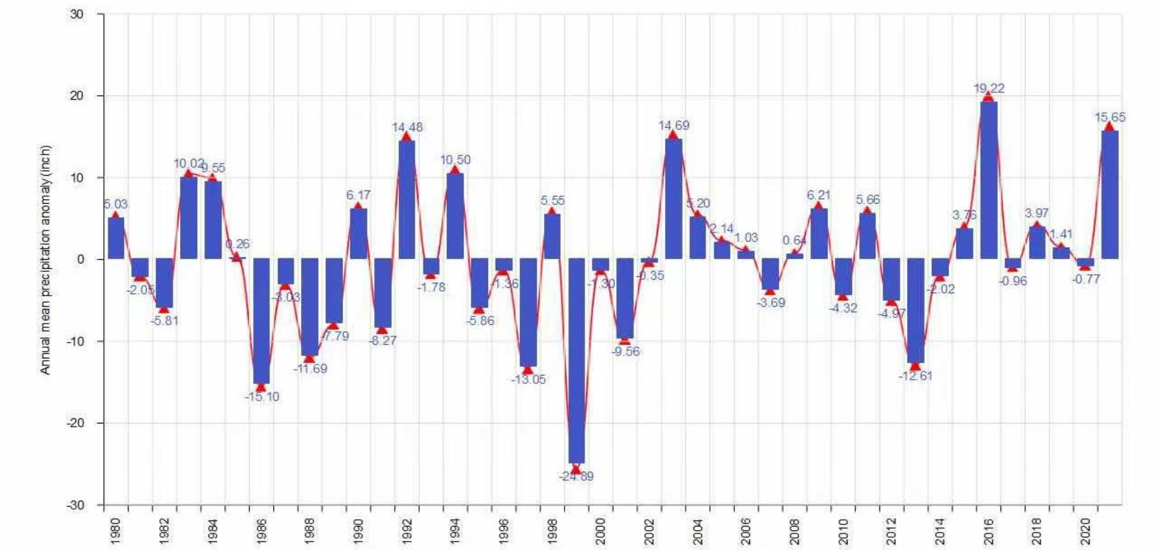


Fig.9 Percentage of departure from the average

The change of annual precipitation since 1980 can be roughly divided into two periods: the first period is the frequent fluctuation period from 1980 to 2014, during which the alternation of abundant and dry precipitation occurs frequently, and the cycle of abundant and dry precipitation takes 10 years as an alternation cycle, in which the annual precipitation in each wet and dry periods is larger than the average, reaching 10 inches. 1999 was more than 20 inches smaller than the serial average; The second phase is the wet season after 20014, with average annual precipitation basically above average, reaching more than 16 inches in both 2016 and 2021.

Annual precipitation and time series images are obtained by summing all dates in the data table:

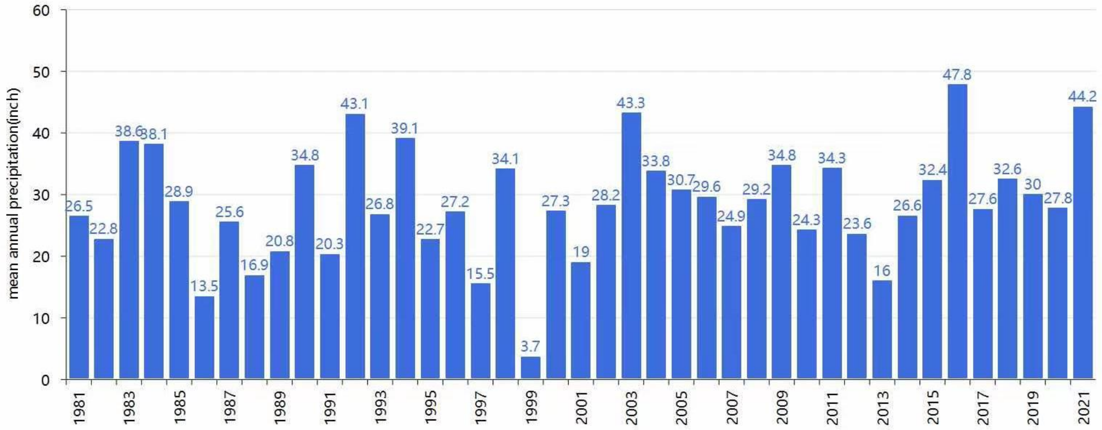


Fig.10 annual precipitation and time series in Zhengzhou

The average annual precipitation of more than 40 inches (i.e. 1000mm) was selected as the basis to judge whether the precipitation was too heavy. Therefore, we can judge 1992, 2003, 2016 and 2021 as the years with too much precipitation from the images.

5.4 Quantitative analysis of rainstorm: :

In July 2021, rare extreme heavy precipitation occurred in Zhengzhou. Through searching the data of several weather stations in Zhengzhou, it was found that the average annual precipitation in Zhengzhou reached 527.4mm. There were more than 100 stations in zhengzhou with accumulative precipitation exceeding 500 mm, and 50 stations exceeded the average annual precipitation in Zhengzhou (641 mm). The maximum accumulative precipitation was 985.2 mm, and the accumulated precipitation of Zhengzhou National Weather Station was 817.3 mm.

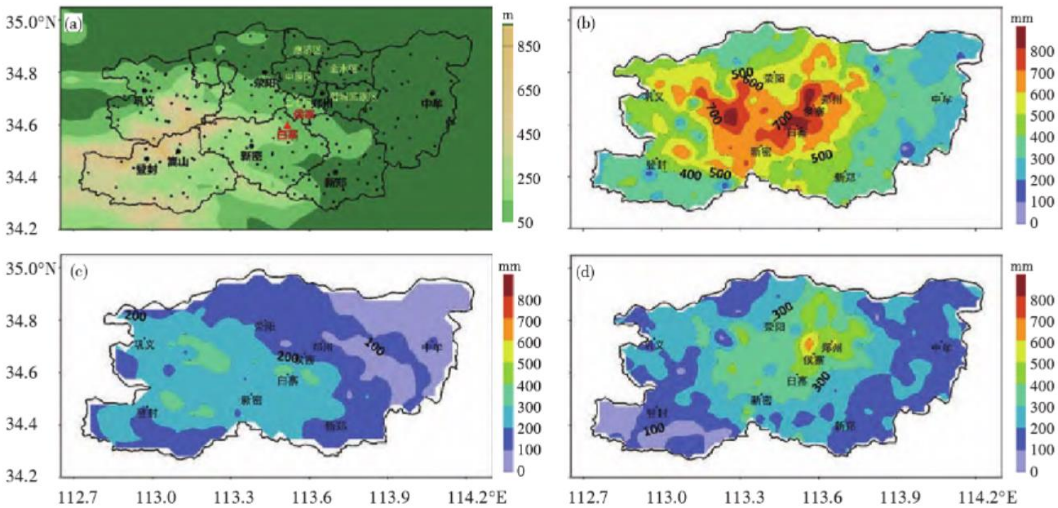


Fig.11 Zhengzhou division and Site distribution map of Zhengzhou (A,▲: where the maximum cumulative precipitation appears) and cumulative precipitation map of

Zhengzhou (Unit: mm) from 08:00 on July 18 to 08:00 on July 22, 2021 (b), 08:00 on July 19 to 08:00 on July 20, 2021 (C), 08:00 on July 20 to 08:00 on July 21, 2021 (D)

In July 2021, rare extreme heavy precipitation occurred in Zhengzhou. Through searching the data of several weather stations in Zhengzhou, it was found that the average annual precipitation in Zhengzhou reached 527.4mm. There were more than 100 stations in zhengzhou with accumulative precipitation exceeding 500 mm, and 50 stations exceeded the average annual precipitation in Zhengzhou (641 mm). The maximum accumulative precipitation was 985.2 mm, and the accumulated precipitation of Zhengzhou National Weather Station was 817.3 mm.

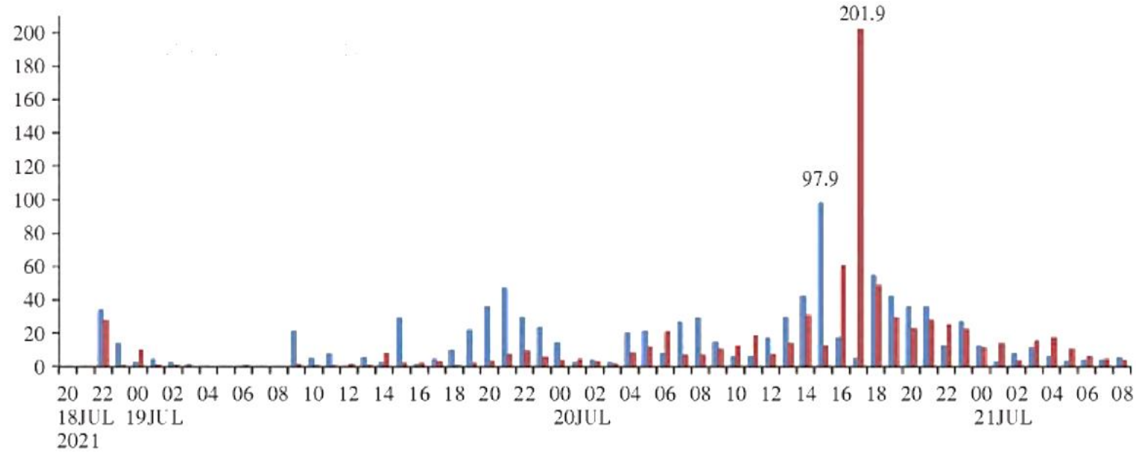
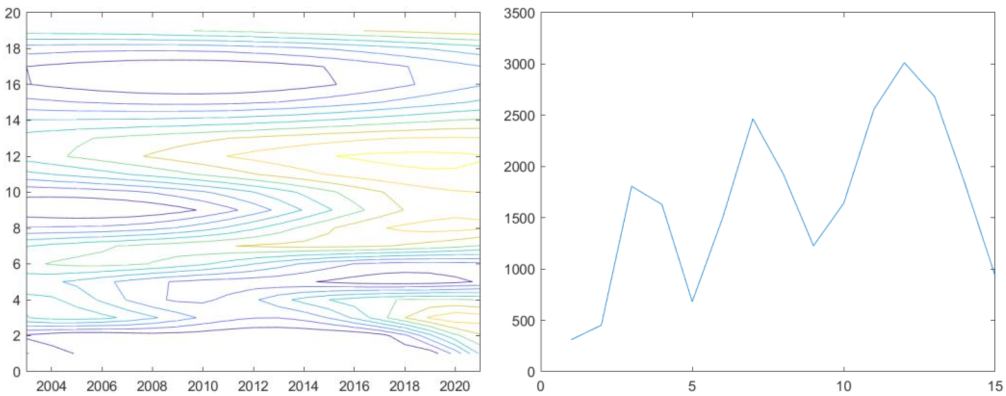


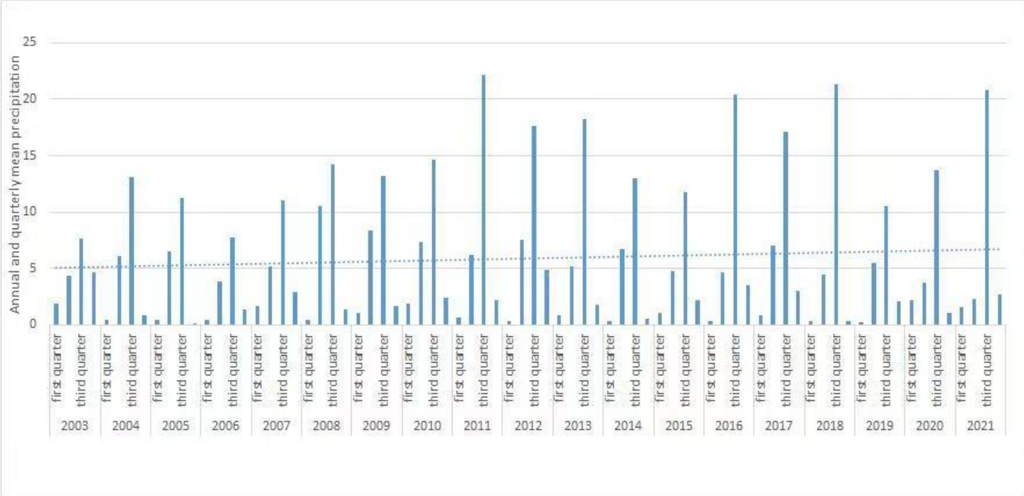
Fig.12 Hourly precipitation sequence diagram of Zhengzhou National Station and Xinmi Baizhai Station from 20:00 on July 18 to 08:00 on July 21, 2021

Further analysis of hourly precipitation distribution at Zhengzhou station and Xinmi Baizhai Station showed that short-term heavy precipitation began to occur at the two stations in the night of the 18th. From 20 o 'clock on the 19th to 12 o 'clock on the 20th, the precipitation intensified, and there was strong hourly heavy precipitation ≥50 mm/h in Zhengzhou. From 16 to 17 o 'clock on the 20th, the precipitation was extremely strong. Reach 201.9 mm/h.

5.5Analysis of precipitation variation trend in different cities



(a) (b)



(C)

Fig.13 Wavelet analysis and Annual and Quarterly Mean Precipitation in Beijing

Beijing is located in the northwest end of north China Plain and in the middle of Haihe River Basin. It has a typical temperate continental climate. The annual variation of precipitation in Beijing is prominent and fluctuates obviously, accompanied by high frequency and large fluctuation, and presents obvious climate change characteristics. The annual quarterly average precipitation chart reflects that there is more precipitation in summer, and precipitation in flood season (the third quarter) is concentrated, which is easy to form flood disaster. And spring, winter and other seasons precipitation is less, often appear drought, drought and flood occur alternately.

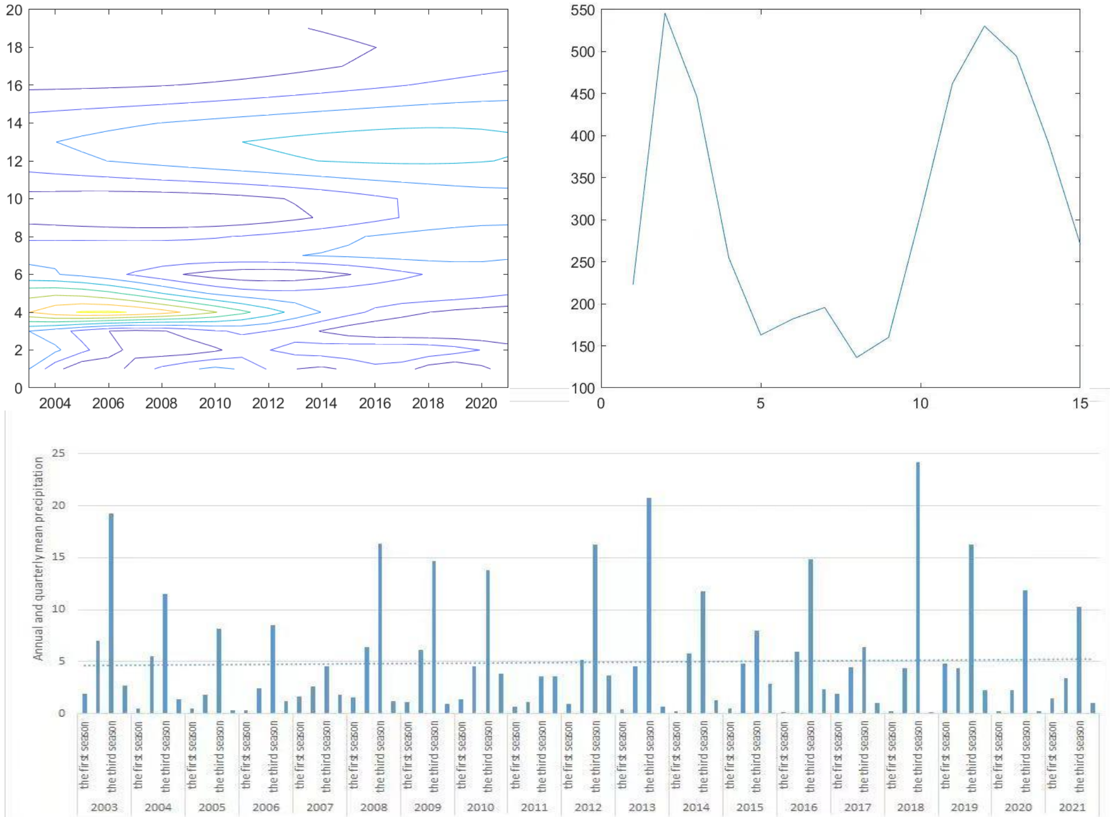
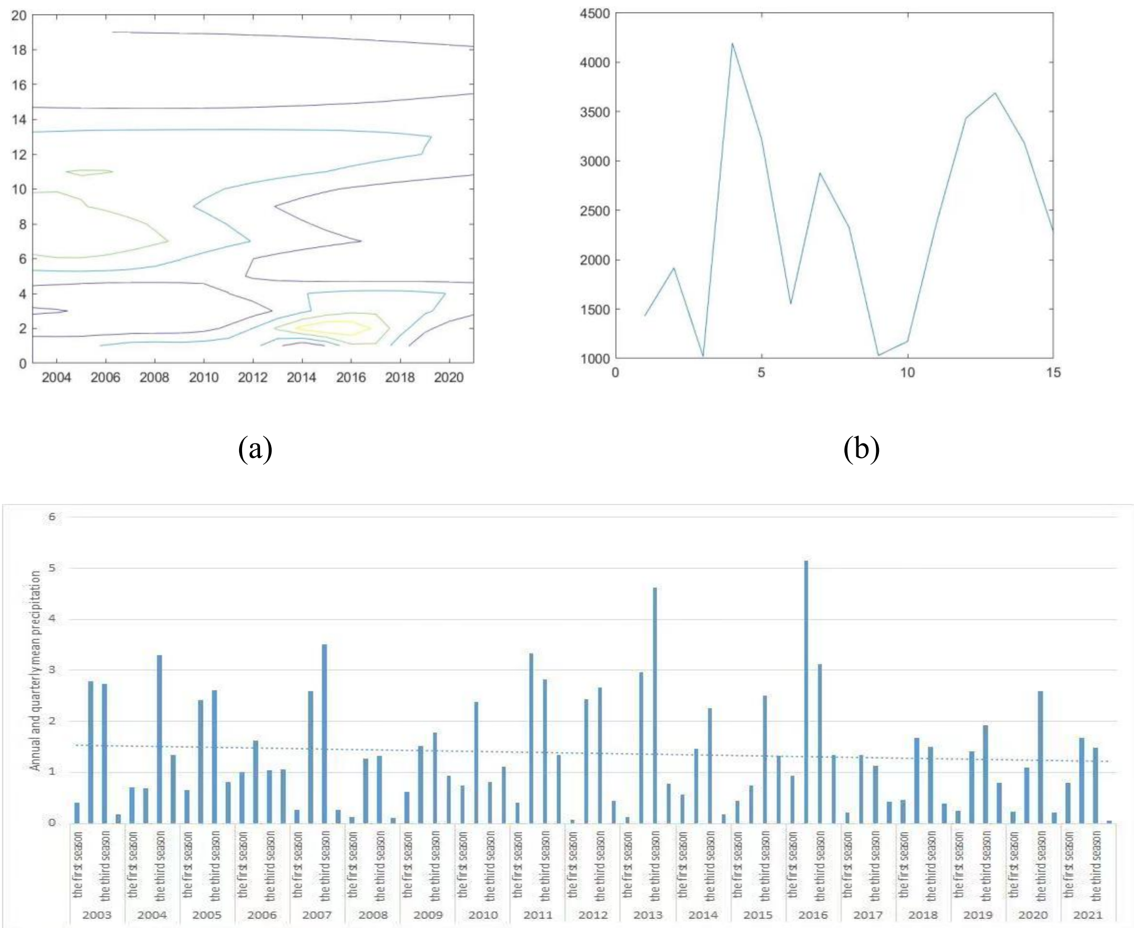


Fig.14 Wavelet analysis and Annual and Quarterly Mean Precipitation in Hohhot

Hohhot is located in the temperate inland region, in the northern part of North China and the central part of Inner Mongolia Autonomous Region. It has a semi-arid continental monsoon climate, with short and warm summers and concentrated precipitation. Dry and windy spring; Autumn is full of sunlight, cool and short, and the annual precipitation has obvious interannual variation characteristics. It takes 2 years as a cycle, the fluctuation range is large but the frequency is small. The precipitation is mainly concentrated in summer, and the precipitation in summer can reach 15 inches, and the overall precipitation shows an upward trend.

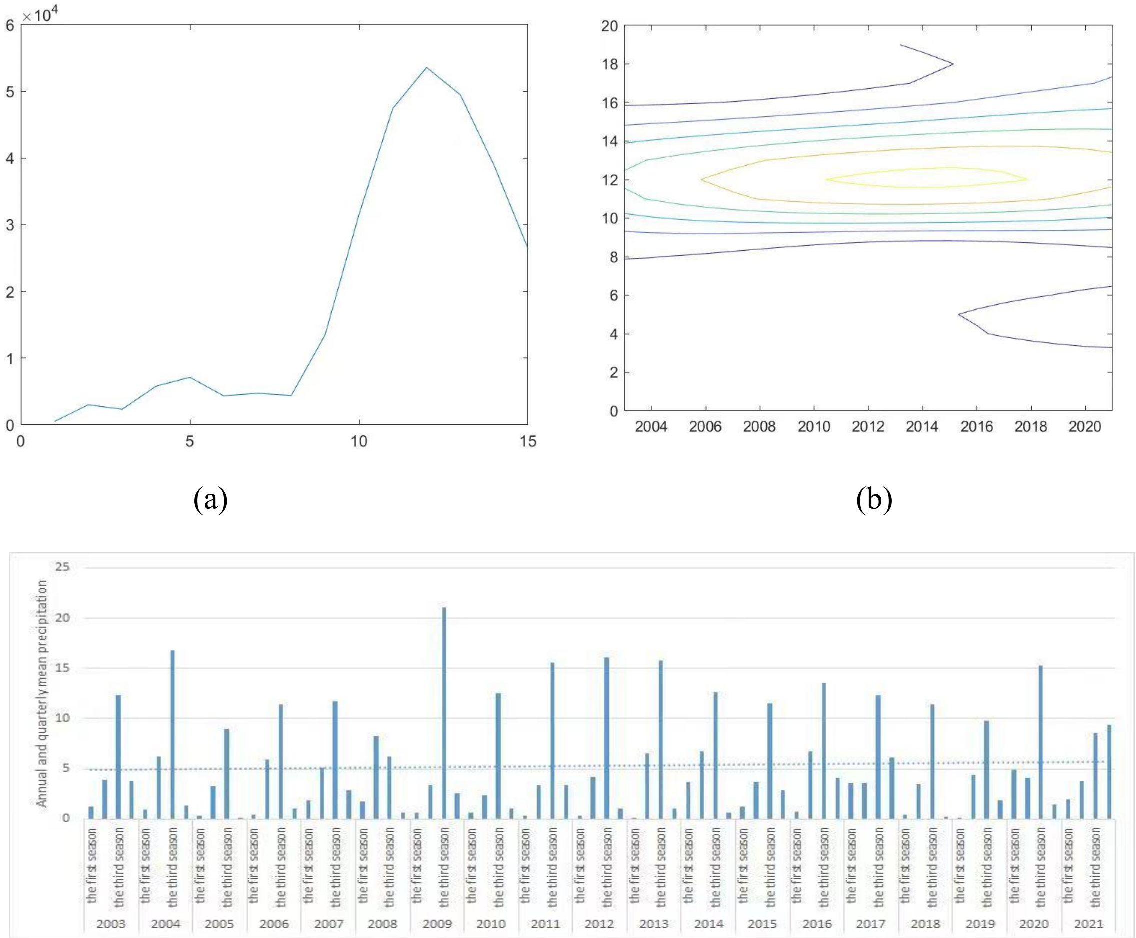


(a) (b)

(c)

Fig.15 Wavelet analysis and Annual and Quarterly Mean Precipitation in Karamay City

Karamay is located in the northwestern margin of junggar basin, and in accordance with the mountain foothill, belongs to the typical continental arid climate, rainfall is obvious interannual characteristics, each 1 year as a cycle, volatility but the frequency of small, precipitation mainly concentrated in summer and autumn, precipitation in 3 inches or more, and less festival in the spring and winter rainfall, belonging to the drought. The overall precipitation in summer and autumn showed an upward trend, but after 2016, the annual precipitation decreased, showing a downward trend.

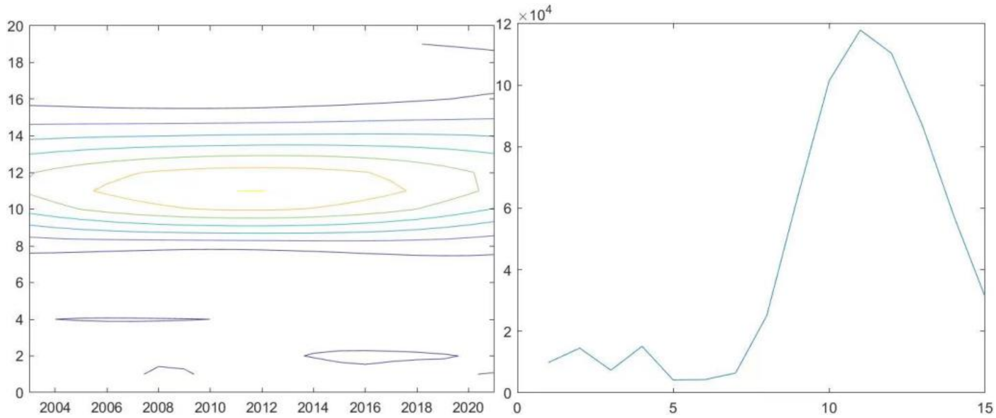


(a) (b)

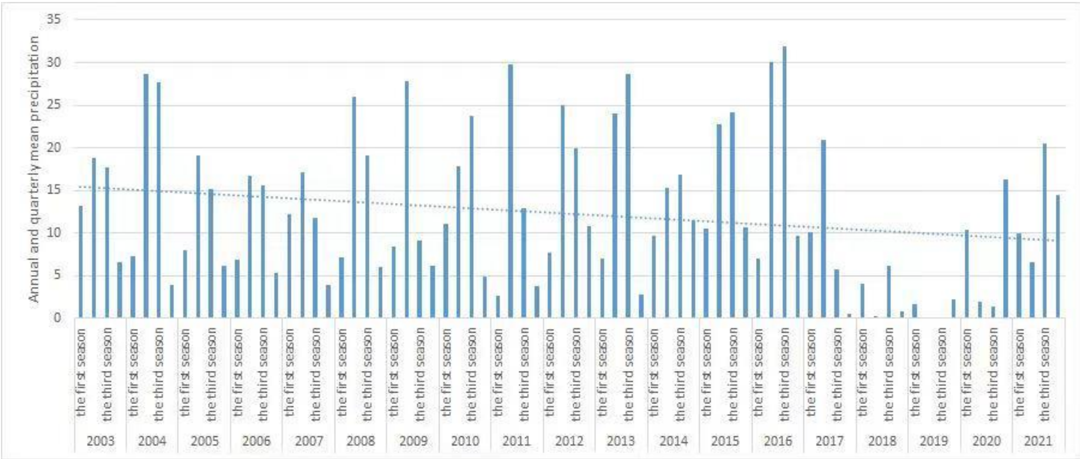
(c)

Fig. 16 Wavelet analysis and Annual and Quarterly Mean Precipitation in Shanghai

Shanghai belongs to the north subtropical monsoon climate. The typical climate characteristics are that the rainy season and summer appear at the same time, and the precipitation is mainly concentrated in the third quarter. There are many rivers and lakes in Shanghai, and the climate is humid and the precipitation is sufficient. The annual precipitation fluctuates greatly and the frequency is low.



(a) (b)



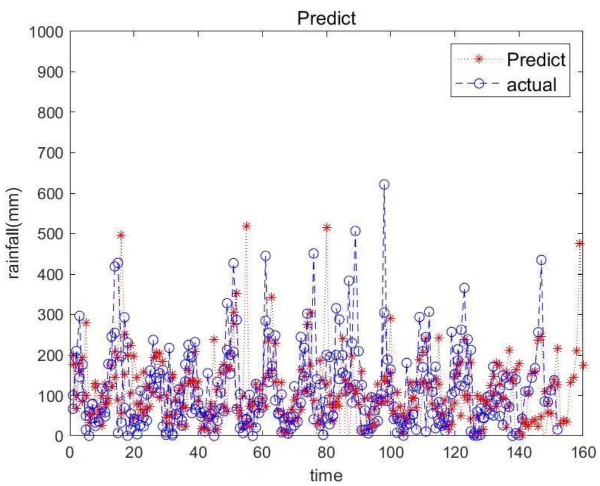
(c)

Fig. 17 Wavelet analysis and Annual and Quarterly Mean Precipitation in Shenzhen

Located in the coastal area of the South China Sea, Shenzhen has a subtropical monsoon climate. The annual rainfall changes show an alternating trend of ups and downs. The 12-year period is a long cycle with large fluctuation range and low frequency. The overall change trend of annual precipitation is decreasing, the overall change trend of annual precipitation is increasing first and then decreasing, and the overall trend change is slightly increasing. The peak of annual precipitation appears in the third quarter.

5.6 Analysis of wavelet neural network prediction model

In question 2, we analyzed the precipitation characteristics of many cities. Among the observation results, Beijing and Wuhan were selected as the analysis of the wavelet neural network prediction model. The data of each city were imported into the function for neural network learning, and the following figure was obtained:



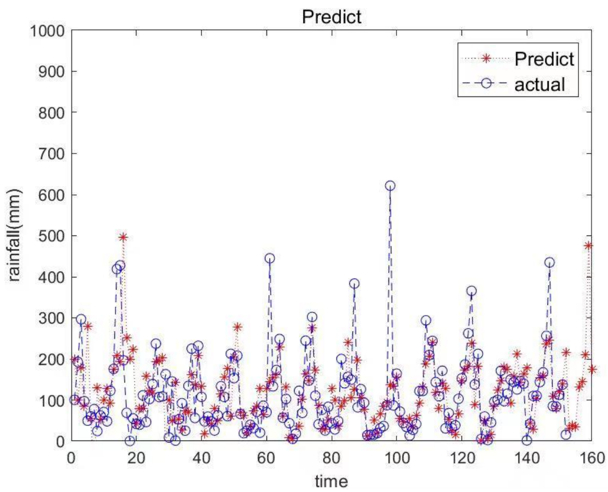


Fig. 18 Beijing (L) and Wuhan (R) wavelet neural network prediction graph

According to our analysis, when the monthly precipitation is significantly higher than that of other months, it is very likely to have heavy rainfall. The prediction result in the figure above shows that precipitation in Beijing and Wuhan is significantly higher than that of other months, so we predict that Beijing and Wuhan are likely to have heavy rainfall in the future

4.3.2ARIMA predict model

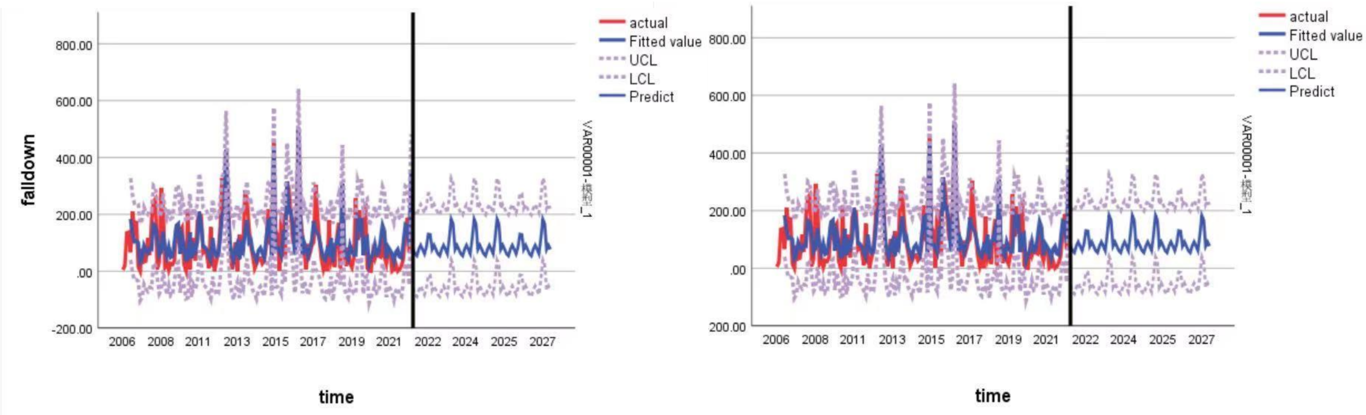


Fig. 19 Shanghai and Wuhan ARIMA model forecast chart

Since the ARIMA model requires timing data to be stationary, or to be stable with differencing, it essentially only captures linear relationships, not nonlinear ones. According to the prediction results of this model, the abrupt change of precipitation cannot be seen, so it is impossible to judge.

5.4.1Analysis of rainstorm characteristics in Zhengzhou and Shanxi in 2021

Through referring to relevant literature and news, we draw the conclusion that the characteristics of the heavy rain in Zhengzhou in July 2021 and the heavy rain in Shanxi in October 2021 are significantly different, which are mainly reflected in the following aspects:

1. There is a great difference between the occurrence time of rainfall and maximum precipitation

Through searching the data of several weather stations in Zhengzhou, it is found that the average annual precipitation in Zhengzhou is 527.4mm. There are more than 100 stations in zhengzhou with accumulative precipitation exceeding 500 mm, and 50 stations exceed the average annual precipitation in Zhengzhou (641 mm), among which the maximum accumulative precipitation is 985.2 mm. The accumulated precipitation of Zhengzhou National Weather Station was 817.3 mm

During the heavy rain in shanxi in October, from 20 o 'clock on October 2 to 8 o 'clock on October 7, the average precipitation in shanxi reached 119.5mm, and the average precipitation in taiyuan was 185.6mm. There were 18 counties (cities and districts) in the province, and 51 counties (cities and districts) had precipitation of more than 200mm. The maximum accumulated precipitation is 285.2mm. The average monthly precipitation of Shanxi Province in October was only 31.1mm, and the average precipitation of Shanxi Province in this precipitation process was 119.5mm, which was more than 3 times of the annual monthly average precipitation in October. The data of several stations broke through the historical extreme value of the same period since the establishment of the station.

2. rain duration and range

Zhengzhou from 8 o 'clock on July 17 to 17 o 'clock on July 20 last three days of rain, heavy rain time from the night, the north, central and western areas of the general rain, heavy rain, local heavy rain. The rainfall process in Shanxi began at 23:00 on October 2nd and lasted for four days until 23:00 on October 6th. The period of the strongest precipitation appeared on October 4th and 5th, covering a wide range of 6 cities and 15 districts and counties.

3.**Important factors affecting rainfall:**

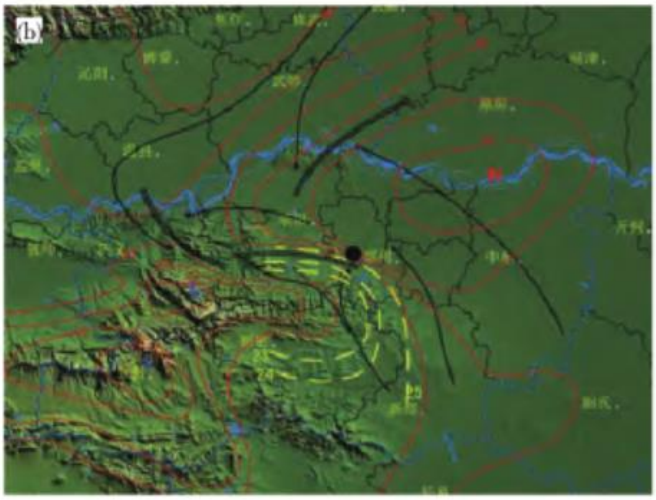


Fig.20 Topographic map of Zhengzhou

According to relevant literature analysis, rainfall in Zhengzhou is greatly affected by topography, and Zhengzhou is located in a pressure field with high northeast and low southwest. Topography has a significant impact on this rainstorm, and convective action is conducive to precipitation enhancement. Zhengzhou in southeast flow, boundary layer wind the songshan terrain blocking effect in the process of the west, topography flattening is beneficial to precipitation strengthening, at the same time, songshan terrain on the north side of the ground temperature, humidity and wind fields have influence, is conducive to the formation of mesoscale convergence line and front area, the mesoscale systems can also play the role of organization convection and the trigger.

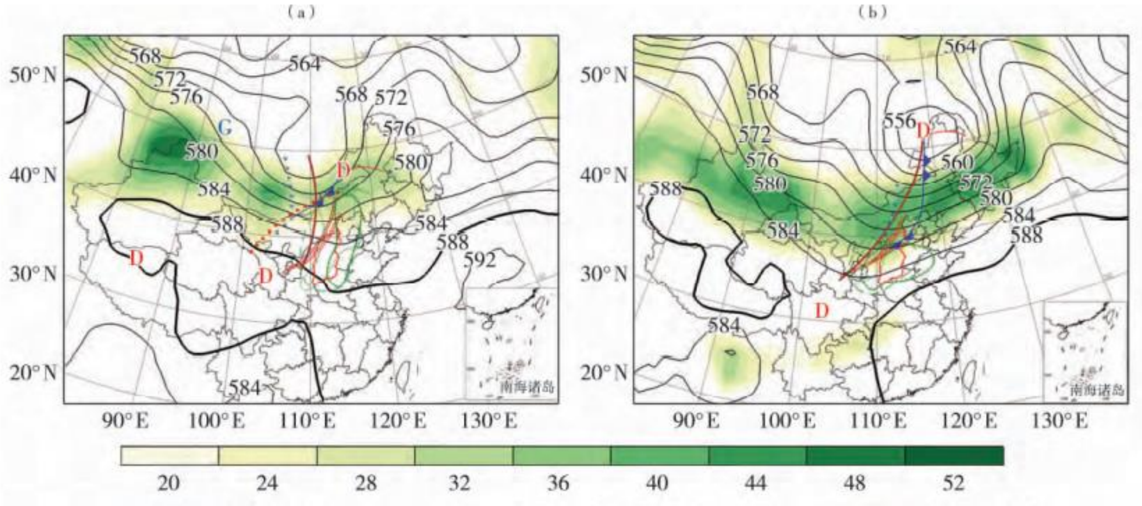


Fig.21 Shanxi altitude, air and ground situation comprehensive configuration map

In October, the precipitation in Shanxi was more influenced by the circulation. In the early stage of heavy rainfall, there was a low vortex in The Asia-Europe Baikal area at 500 hPa. With the low vortex rotation, the cold air behind the trough kept moving southward, and the high-altitude dry and cold advection and strong convergence ascending movement triggered the release of unstable energy in front of the front, resulting in heavy rainfall in central Shanxi.

4.4.2Analysis of losses caused by heavy rain in Zhengzhou and Shanxi

Based on the official release of rainstorm data and relevant official news reports, and based on the assessment of rainstorm disaster risk in Shanxi by Lv Yiqing et al., we get the following results:

Zhengzhou affected by terrain, the storm of public facilities been hardest hit, the mayor of zhengzhou city Hou Hong introduced at the news conference, "July 20" torrential rains caused zhengzhou 143 reservoirs 103 super sin line, area of river water level rose rapidly, multiple regions water or broken network, damaged roads flooded, traffic, underground space, several significant danger. It caused direct economic losses of 53.2 billion yuan.

The heavy rain in Shanxi was greatly affected by the circulation, resulting in the breach of several river dikes, building collapse, cultural relics damage, casualties and other major losses, among which agricultural losses were the most serious. In late October, it was the autumn harvest season, and the heavy rain directly affected the normal harvest and planting of crops. According to data released by relevant departments, crop losses in many areas of Shanxi have been serious, causing direct economic losses of 100 million yuan.

5.5 Long-term urban construction planning under future extreme precipitation conditions

In 2020, the World Health Organization (WHO) announced that the effects of global warming would go far beyond increasing the demand for cooling. It would also exacerbate the chain reaction of extreme weather events such as storms, floods, disruptions to outdoor production, increased diseases and soaring public health costs. Therefore, cities should have long-term plans to deal with extreme precipitation in the future. Under objective conditions, we should adopt "sponge system" and "self-cooling system" according to local conditions, and the multi-faceted disaster resistance system can provide a more comprehensive disaster prevention effect.

First, the adoption of "sponge systems" can improve the resilience of cities against flooding. After the construction of sponge city, in the face of heavy rain, the city can have strong ability of absorbing water, storing water, seeping water and purifying water. The rainwater stored during rain should be released and used to realize the free migration of rainwater in the city. In view of China's cities need to pay attention to the water absorption capacity of the city, it is necessary to appropriately increase the green area, increase the number of parks, green space, permeable roads, rivers, lakes, ponds. And the accessibility of groundwater pipelines must be ensured.

Secondly, "self-cooling system" is an excellent solution to the current urban heat island effect.

"Self cooling system" is divided into "internal cooling system" and "external cooling system".

"Internal cooling system" -- Alleviating the urban heat island effect. First, the transformation of urban underlying surface. The idea is consistent with the "sponge system", adding green space to the city helps cool the city. It is also a good idea to change the external reconstruction of the building and increase the vertical green space. Second, control urban anthropogenic heat emission control. The layout of urban land needs to be optimized. Industrial land must be separated from residential areas as far as possible and set up in the suburbs for emission reduction and heat dissipation. Optimize road layout, advocate green transportation system, pay attention to the distance between residents' residence and work units, and increase the improvement and later maintenance of public transportation modes. Minimize the burning of fossil fuels.

"External cooling System" -- Construction of urban ventilation corridor.

Ventilation corridors have many benefits, the most important three are: one is to effectively alleviate the impact of urban heat island effect, two is conducive to urban air circulation and pollution diffusion, three is to improve human comfort in temperature and urban air quality.

Construction of ventilation corridors: First, pay attention to the layout of multi-type streets. The buildings on both sides of the street should not be too dense, affecting ventilation, and the height of storeys facing the street can be generally reduced, or a sense of level staggered.

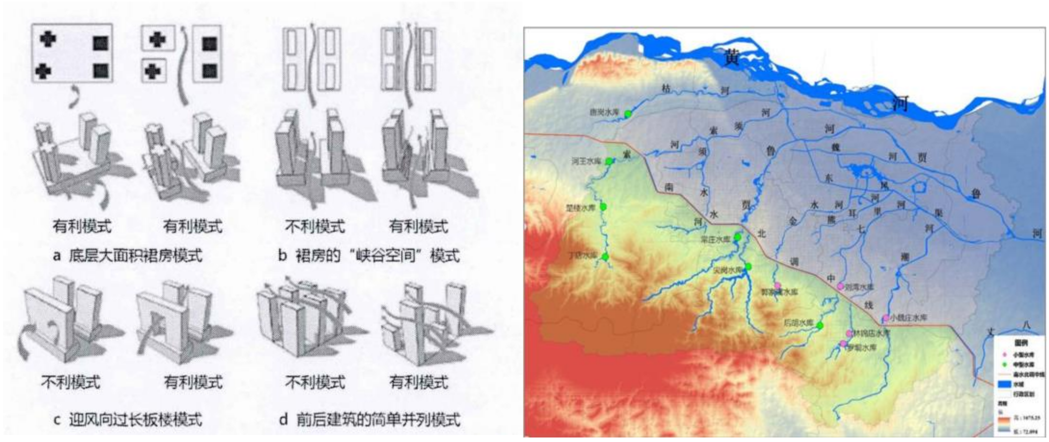


Fig.22 Urban planning and hydrological distribution

Second, the construction of urban ecological green space network. Build parks and protect lakes and rivers according to local conditions. With a network of green Spaces, sponges are like holes to absorb water.

Thirdly, for cities, blocks and single buildings, we sorted out the following table after collecting data:

Planning scale	Planning content	planning application and policy implementation scale	climate scale
City	Urban spatial planning, land classification and distribution, green space, natural vegetation urban form control, not less than 40%	regional development Local planning Local development strategy Blueprint	1~50km overall urban wind environment
Neiborhood	Block urban form control, building height and street width. Construction needs to pay attention to the layout, density, appropriate increase of green space and leisure land, etc.	Urban Design Strategy The streets in the old city were renewed New development area planning Recent Local planning Local development strategy Blueprint	10~1000m Low-level wind environment
Building monomer	Monomer building monomer building form, height, orientation control, surrounding space control, etc	Architectural Design Ordinance Urban Design Strategy Local Development Strategy Blueprint	<300m Wind conditions in microclimates Street canyon effect indoor

Fourth, there are the following design points for urban ventilation corridor planning and control:

(1) the length of the ventilation corridor should be at least 500m, generally more than 1000m is appropriate;

(2) The ideal width of the comprehensive bandwidth of the main urban ventilation corridor is about 400m to 500m, and its minimum width should not be less than 200m. The edge area of the ventilation corridor should be smooth and uniform to reduce the shielding of large buildings and other protrusions.

(3) The channel width of the urban secondary ventilation corridor should be greater than or equal to 30m, generally about 50M is appropriate;

(4) The width of the urban ventilation corridor should be at least 1.5 times the height of the trees or buildings on the edge of the corridor, and the best value is 2~4 times;

(5) The entity width of obstacles (buildings/structures, trees, etc.) perpendicular to the dominant wind direction of the city should be reduced as far as possible (usually not greater than 10% of the total width of the passage). If there are obstacles on both sides, the height of both sides should not exceed 10m. And the ratio of the building height of two adjacent obstacles to the horizontal distance between them should not be greater than 0.1 (buildings/structures) or 0.2 (trees, etc.).

Under subjective conditions, the government should regularly carry out a series of exercises, all departments should do a good job of emergency measures and contingency plans, the government should re-emphasize and standardize the level of early warning, do a good job of organizing the masses when the crisis comes, and need to increase publicity to improve the public's awareness of coping with and preventing natural disasters.

5.5.2 Analysis of typical citie

The heavy rain in Zhengzhou coincided with the maintenance of the municipal government, which did not dredge the drainage pipes in time, causing the city's waterlogging is one of the reasons. Also, because zhengzhou is deep in the inland, the annual rainfall is not high, and it does not have the ability to skillfully deal with flood disaster, lack of overall planning and connection, and the engineering system is not perfect. After the flood disaster, the notification system is single.

Therefore, after the disaster, Zhengzhou needs to comprehensively strengthen infrastructure, dredge pipelines (not just zhengzhou, but all parts of the country), and prevent urban flooding and other problems. Second, conditions should improve and soften the underlying surface to reduce surface runoff. In the later stage, we should pay attention to the layout and design of the green belt, form the green belt network, and make reasonable use of the reservoirs around Zhengzhou, the Yellow River and other rivers. An example is shown below. Third, attention should be paid to controlling carbon emissions, managing factories, restricting private cars from driving, speeding up the development of public transport and so on. Try to reduce the "greenhouse effect", the extreme weather conditions caused by global warming. In addition, it is necessary to prevent natural disasters such as mud-rock flow, mountain landslide and typhoon caused by extreme precipitation, plant windbreak forest belt, comprehensively prevent wind and fix sand, especially focus on possible areas.

6. Strengths and Weakness

Strengths:

1. Nonlinear mapping capability: BP neural network essentially realizes a mapping function from input to output. Mathematical theory proves that three-layer neural network can approach any nonlinear continuous function with arbitrary accuracy. This makes it particularly suitable for solving problems with complex internal mechanisms.

2. Self-learning and self-adaptation: during training, BP neural network can automatically extract "reasonable rules" between output and output data through learning, and adaptively memorize the learning content into the weight of the network.

3. Generalization ability: consider whether the network can correctly classify the required classification objects and whether the network can correctly classify patterns that have not been seen or those with noise pollution after training.

4. Fault tolerance: BP neural network will not have a great impact on the global training results after partial or partial neurons are damaged.

Weakness:

1. Local minimization problem: The neural network is very sensitive to the initial weight of the network. When the network is initialized with different weights, it tends to converge to different local minima.

2, the convergence speed of neural network algorithm is slow: because the neural network algorithm is gradient descent method in essence, the objective function it needs to optimize is very complex.

3, the selection of neural network structure is different: the selection of network structure is too large, the training efficiency is not high, may appear over-fitting phenomenon, resulting in low network performance, fault tolerance decline, if the selection is too small, the network may not convergence. The structure of the network directly affects the approximation ability and generalization property of the network.

4. Contradiction between application instance and network scale: Neural network is difficult to solve the contradiction between application instance scale and network scale, which involves the relationship between the possibility and feasibility of network capacity, namely the learning complexity problem.

5. The contradiction between neural network prediction ability and training ability: The reason is that the network has learned too many sample details, so the learned model can no longer reflect the rules contained in the sample.

6. Neural network sample dependence problem: the approximation and generalization ability of network model is closely related to the typicality of learning samples, and it is

very difficult to select typical samples from the problem to form training set.

7. Conclusion

A predictive analysis model based on wavelet neural network is designed to predict future weather change. Firstly, the precipitation data of multiple cities, as well as the temporal resolution and range of precipitation, are collected and analyzed uniformly. For time series data with data gaps, the method of multivariate interpolation is used to complete the exact missing values. Then, according to the wavelet analysis method and the annual mean anomaly method, the periodic precipitation change in Zhengzhou was analyzed, and the mann-Kendal mutation analysis was carried out for the annual precipitation in 41 years to find the year of extreme precipitation. In order to predict the rainfall data, we use the wavelet neural network time series prediction model to predict the precipitation in the following years.

On the single factor variables, by using wavelet neural network can better both cyclical and respectively, can carry on the comparatively accurate prediction to the subsequent precipitation, but as a result of extreme precipitation formation is relatively complex, the square of R is 0.7, but the wavelet neural network model involved is absolutely better than the established ARIMA model, has a good fitting. The r-square in the model increased by 23% and the prediction error decreased by about 50%. The prediction result of this model is obviously better than that of traditional methods.

From the model and analysis results established for each issue, it can be speculated and discussed:

(1) There is a significant correlation between precipitation and temperature and dew point in Zhengzhou, but a good correlation index cannot be established due to the complexity and variability of meteorological factors. In the process of analyzing the interannual variation characteristics of precipitation in Zhengzhou, we conclude that precipitation in Zhengzhou has continuity, periodicity and mutation. But in the context of global warming, the overall trend is towards heavier rainfall and more frequent extreme rainfall.

(2) Under the background of global warming, extreme weather gradually increases. Precipitation forecast, based on the analysis of many cities because of China's land area is big, many types of climate, so, we selected the different regional climate types of city were analyzed, and found that urban precipitation is cyclical, sustainability, in a city of extreme drought climate region drought increased year by year, the extreme precipitation weather in mild rainy areas gradually frequently.

(3) Under objective conditions, "sponge system" and "self-cooling system" should be adopted according to local conditions, and the multi-faceted disaster resistance system can provide a more comprehensive disaster prevention effect. In fact, environmental protection should be more specific to every citizen, only we make concerted efforts to prevent the further deterioration of global warming, to protect the environment, is to protect ourselves.

References

[1] 刘睿姝,陈末,王冠华,陈寒冰.1991-2020年沈阳市降水趋势变化及突变分析[J].水利科技与经济,2021,27(09):1-8.

[2] 祁顺杰,陈皓锐.Morlet小波在降雨的多时间尺度分析中的应用[J].南水北调与水利科技,2010,8(03):79-82.

[3] 闫慧,赵桂香.山西一次持续暴雨天气过程诊断与集合预报检验[J].干旱气象,2020,38(01):137-147.

[4] 申欣凯,吕义清,张静,赵瑜.基于ArcGIS的山西省暴雨灾害风险评估[J].国土资源科技管理,2020,37(01):61-73.

[5] 隋玉萍. 基于M-K法的牡丹江市气候趋势分析的研究[D].吉林农业大学,2020.

[6] 慕丹丹,褚金镝,高博.基于小波变换的黄河宁夏段水沙变化趋势研究[J].人民黄河,2021,43(11):65-68+75.

[7] 朱新丽,李彦彬,李红星,冯娅.基于小波多孔算法的黑河径流变异规律分析[J/OL].水利水电技术(中英文):1-17[2021-11-14].http://kns.cnki.net/kcms/detail/10.1746.TV.20211101.2017.002.html.

[8] 张卉,程永明,江渊.山西省近49年降水量变化特征及趋势分析[J].中国农学通报,2014,30(08):197-204.

[9] 张卉,李智才,蒋云盛.山西省降水特征变化规律及未来趋势分析[J].农业技术与装备,2009(18):18-20.

[10] 洛桑卓玛,拉巴,巴丹卓玛.西藏那曲地区40多年来降水趋势变化气候分析[J].山地学报,2014,32(03):380-384.

[11] SU Aifang, LÜ Xiaona, CUI Liman, et al. 2021. Prediction and test of optimal integrated precipitation based on similar spatial distribution of precipitation [J]. Torrential Rain and Disasters, 40(5): 445-454

[12] 刘德林.郑州市近60年来降水变化特征及突变分析[J].水土保持研究,2011,18(05):236-238.

[13] 黎彦佐,陆丽秋.南宁市台风暴雨特征分析[J].气象研究与应用,2021,42(03):31-36.

[14] https://www.cnblogs.com/fd-682012/p/11905122.html

Appendix

wavelet neural network prediction model-MATLAB

```
clc
clear
opts = spreadsheetImportOptions("NumVariables", 4);
% specifies the worksheet and scope
opts.Sheet = "Sheet1";
opts.DataRange = "A2:D188";
% specifies the column name and type
opts.VariableNames = ["input1", "input2", "input3", "input4"];
opts.VariableTypes = ["double", "double", "double", "double"];
% Import data
input = readtable("C:\Users\Lenovo\Desktop\text.xlsx", opts, "UseExcel", false);
input = table2array(input);
opts = spreadsheetImportOptions("NumVariables", 1);
% specifies the worksheet and scope
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opts.DataRange = "E2:E188";
% specifies the column name and type
opts.VariableNames = ["output1"];
opts.VariableTypes = ["double"];
% Import data
output = readtable("C:\Users\Lenovo\Desktop\text.xlsx", opts, "UseExcel", false);
output = table2array(output);
opts = spreadsheetImportOptions("NumVariables", 4);
% specifies the worksheet and scope
opts.Sheet = "Sheet1";
opts.DataRange = "F2:I188";
% specifies the column name and type
opts.VariableNames = ["input1t", "input2t", "input3t", "input4t"];
opts.VariableTypes = ["double", "double", "double", "double"];
% Import data
input_test = readtable("C:  \Users\Lenovo\Desktop\text.xlsx", opts, "UseExcel",
false);
input_test = table2array(input_test);
opts = spreadsheetImportOptions("NumVariables",1);
% specifies the worksheet and scope
opts.Sheet = "Sheet1";
opts.DataRange = "J2:J188";
% specifies the column name and type
opts.VariableNames = ["output1t"];
opts.VariableTypes = ["double"];
```

```
% Import data
output_test = readtable("C: \Users\Lenovo\Desktop\text.xlsx", opts, "UseExcel",
false);
output_test = table2array(output_test);
%% Network parameter configuration
M=size(input,2); % Enter the number of nodes
N=size(output,2); % Number of output nodes
n=20; % Number of hidden nodes
Lr1 = 0.1; % learning probability
Lr2 = 0.01; % learning probability
maxgen=1000; % Number of iterations
% weight initialization
Wjk=randn(n,M); Wjk_1=Wjk; Wjk_2=Wjk_1;
Wij=randn(N,n); Wij_1=Wij; Wij_2=Wij_1;
a=randn(1,n); a_1=a; a_2=a_1;
b=randn(1,n); b_1=b; b_2=b_1;
% The node is initialized
y=zeros(1,N);
net=zeros(1,n);
net_ab=zeros(1,n);
% weight learning increment initialization
d_Wjk=zeros(n,M);
d_Wij=zeros(N,n);
d_a=zeros(1,n);
d_b=zeros(1,n);
%% input and output data normalization
[inputn,inputps]=mapminmax(input');
[outputn, outputps] = mapminmax (output ');
inputn=inputn';
outputn=outputn';
error=zeros(1,maxgen);
%% network training
for i=1:maxgen

% error accumulation
Error (I) = 0;

% Cycle training
For kk = 1: size (input, 1)
X = inputn (kk, :);
Yqw = outputn (kk, :);

For j = 1: n
For k = 1: M
```

```
D_Wij = zeros (N, N);
Entries = zeros (1, n);
D_b = zeros (1, n);
Y = zeros (1, N);
Net = zeros (1, n);
Net_ab = zeros (1, n);

Wjk_1 = Wjk; Wjk_2=Wjk_1;
Wij_1 = Wij; Wij_2=Wij_1;
A_1 = a; a_2=a_1;
B_1 = b; b_2=b_1;
The end
end
%% network forecast
% Forecast input normalization
x=mapminmax('apply',input_test',inputps);
x=x';
Yuce = zeros (160, 1);
% Network forecast
for i=1:160
X_test = x (I);
For j = 1: n
For k = 1:1: M
Net (j) = net (j) + Wjk (j, k) * x_test (k);
Net_ab (j) = (net (j) - b (j))/a (j);
The end
Temp = mymorlet (net_ab (j));
For k = 1: N
Y (k) = y (k) + Wij (k, j) * temp;
The end
The end
Yuce (I) = y (k);
Y = zeros (1, N);
Net = zeros (1, n);
Net_ab = zeros (1, n);
end
% forecast output is inversely normalized
ynn=mapminmax('reverse',yuce,outputps);
%% Result analysis
figure(1)
plot(ynn,'r*:')hold on
plot(output_test,'bo--')
title('Predict','fontsize',12)
legend('Predict','actual','fontsize',12)xlabel('time')
ylim([0 1000])ylabel('rainfall(mm)')
```

ARIMA-spss

```
PREDICT THRU END.

* 时间序列建模器.
TSMODEL
   /MODELSUMMARY  PRINT=[MODELFIT RESIDACF RESIDPACF] PLOT=[ SRSQUARE RSQUARE]
   /MODELSTATISTICS  DISPLAY=YES MODELFIT=[ SRSQUARE RSQUARE]
   /SERIESPLOT OBSERVED FORECAST FIT FORECASTCI FITCI
   /OUTPUTFILTER DISPLAY=ALLMODELS
   /SAVE  PREDICTED(预测) LCL(LCL) UCL(UCL) NRESIDUAL(NResidual)
   /AUXILIARY  CILEVEL=95 MAXACFLAGS=24
   /MISSING USERMISSING=EXCLUDE
   /MODEL DEPENDENT=falldown INDEPENDENT=time [E]
      OUTFILE='C:\Users\Lenovo\Desktop\121.xml'
      PREFIX='模型'
   /EXPERTMODELER TYPE=[ARIMA]
   /AUTOOUTLIER  DETECT=ON TYPE=[ ADDITIVE INNOVATIONAL TRANSIENT].
```

Wavalet analysis-matlab

```
clear;clc
s=xlsread('zhengzhou') ;
for i=1:length(s);
for j=1:length(s);
wreal(i,j)=0.0;
wimage(i,j)=0.0;
for k=1:length(s);
t=(k-j)/(1.0+i);
wreal(i,j)=wreal(i,j)+s(k)*exp(-0.5*t^2)*cos(6.5*t);
wimage(i,j)=wimage(i,j)+s(k)*exp(-0.5*t^2)*sin(6.5*t);
end;
wreal(i,j)=wreal(i,j)/((i+1.0)^0.5);
wimage(i,j)=wimage(i,j)/((i+1.0)^0.5);
end;
end;
w=complex(wreal,wimage);
w_abs=(abs(w)).^2;
t=1973:1:2021;
a=1:length(s);
contour(t,a,w_abs)
ylim([0 20]);
figure
contour(t,a,wreal(1:length(s),1:length(s)))
```

```
y=w_abs'
w=sum(y)
plot(w)
xlim([0 15])
```