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Quantitative Analysis of Extreme Rainfall

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Abstract: This paper takes the year and the average value as important indicators and establish a multiple regression model of the year and each meteorological index. Taking the number of days in Zhengzhou in 2021 as an indicator, a multiple regression model of the number of days is established. Finally, it is concluded that the annual precipitation characteristics of Zhengzhou area are mainly related to the 12 indicators of FRSHTT, GUST, MAX, MIN, MXSPD, PRCP, SLP, SNDP, STP, TEMP, VISIB, and WDSP; FRSHTT, GUST, MAX, MIN Changes in indicators such as MXSPD, PRCP, SLP, SNDP, STP, TEMP, VISIB, and WDSP will directly affect the magnitude of precipitation in Zhengzhou; the five years with more precipitation are 1996, 1997, 2000, 1998 and 1999; In 2021 the more relevant indicators of inundation events in the region in Zhengzhou are PRCP, VISIB, and WDSP.

1. Introduction

According to relevant researchers, in the context of global warming, the amount, intensity, frequency and type of future precipitation in my country will be directly affected[1]. The amount of precipitation is expected to increase by about 10% at the end of this century and the probability of extreme precipitation will increase significantly. Due to the large land area of our country and the combined influence of various types of topography and landforms and other factors, the precipitation characteristics of different cities show different characteristics[2]. Therefore, it is imperative to establish prediction models for cities with different potential extreme precipitation events and quantitative analysis models for their losses.

2. Model establishment

The first step is to make a correlation analysis of the annual change characteristics of the precipitation characteristics in Zhengzhou[3]. Calculate the average value of 3 STATION observation data, and establish the mathematical model as:

$$Avg_{ij} = \frac{\sum_{1}^{n} \text{ value }_{ij}}{n} \tag{1}$$

Among them, Avg_{ij} represents the average value of the th parameter in the year; value represents the parameter value; represents DEWP, FRSHTT, GUST, MAX, MIN, MXSPD, PRCP, SLP, SNDP, STP, TEMP, VISIB, WDSP.

Assuming that (X_1, X_2, X_3, X_4) is a 14-dimensional random variable, and any correlation coefficient $\rho_{ij}(i,j=1,2,3,4,5,6,7,8,9,10,11,12,13,14)$ between X_i and X_j exists, the 14th-order matrix of elements is called the correlation matrix of the random vector of this dimension. The mathematical model is established as:

$$R=\begin{bmatrix}\rho_{11} & \rho_{1j} & \rho_{114}\\ \rho_{i1} & \rho_{ij} & \vdots \\ \rho_{141} & \cdots & \rho_{1414}\end{bmatrix} \tag{2}$$

$$\rho_{ij}=\frac{\operatorname{cov}(X_i,X_j)}{\sqrt{DX_i\sqrt{DX_j}}} \tag{3}$$

Cov is the covariance, and the mathematical model is established as:

$$\operatorname{cov}(X_i,X_j)=E\left(\left(X_i-E(X_i)\right)\cdot\left(X_j-E(X_j)\right)\right) \tag{4}$$

Therefore, through the analysis method of the correlation coefficient, the annual change characteristics of the precipitation characteristics in Zhengzhou area are correlated and the multiple regression model is established:

$$\begin{aligned}Y_{\text{Year}} &= \alpha_0+\alpha_1X_1+\alpha_2X_2+\alpha_3X_3+\alpha_4X_4+\alpha_5X_5+\alpha_6X_6+\alpha_7X_7+\alpha_8X_8\\ &+\alpha_9X_9+\alpha_{10}X_{10}+\alpha_{11}X_{11}+\alpha_{12}X_{12}+\alpha_{13}X_{13}+\alpha_{14}X_{14}+\varepsilon\end{aligned} \tag{5}$$

Among them, Y_{Year} represents time index; X_n represents DEWP, FRSHTT, GUST, MAX, MIN, MXSPD, PRCP, SLP, SNDP, STP, TEMP, VISIB, WDSP index respectively; α_n represents model coefficient; ε represents random error term.

The error analysis of the multiple nonlinear regression model is carried out by the method of R^2 and t tvalue testing.

$$R^2=\frac{\text{SSReg}}{SST}=1-\frac{SSE}{SST} \tag{6}$$

$$t=\frac{\bar{X}-\mu}{\frac{\sigma_X}{\sqrt{n-1}}} \tag{7}$$

Among them, SSReg represents the regression sum of squares; SST represents the total sum of squares; SSE represents the residual sum of squares. $\bar{X}$ represents the sample average, μ represents the sample population average, σ_X represents the sample standard deviation, and n represents the sample size.

The second step is to select a batch of years with more precipitation. The five-year data with the largest summation result is selected as an indicator:

$$\text{result Max} = \text{Max}\{\text{Sum}_i\} \tag{8}$$

The third step is to conduct a specific quantitative analysis of the inundation event in Zhengzhou in 2021.Refer to the multiple regression model, specifically to 2021 every day, with the number of days as the dependent variable, establish the number of days and DEWP, FRSHTT, GUST, MAX, MIN, MXSPD, PRCP, SLP, SNDP, STP, TEMP, VISIB, The expression of multiple regression model of WDSP index:

$$\begin{aligned}Y_{Day} &= \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8\\ &+\beta_9X_9+\beta_{10}X_{10}+\beta_{11}X_{11}+\beta_{12}X_{12}+\beta_{13}X_{13}+\beta_{14}X_{14}+\varepsilon\end{aligned} \tag{9}$$

3. Model solution

According to the solved correlation coefficient matrix, the multiple regression model is solved, and after it is obtained with the help of the Python program, it is confirmed on the SPSS tool. It is found that the SPSS tool solves the multiple regression model to eliminate the overall influence of the DEWP index on the model. For this, the SPSS solution model is used as Standard, the DEWP indicator constant is set to 0, and the expression is:

$$\begin{aligned} Y_{\text{Year}} &= 29309.426523 + 0X_1 - 0.006208X_2 + 0.037215X_3 + 0.261014X_4 \\ &+9.607399X_5 + 8.816734X_6 - 10.362443X_7 + 0.287483X_8 - 27.345271X_9 \\ &+0.016125X_{10} - 12.529408X_{11} - 17.385517X_{12} - 5.157365X_{13} \end{aligned} \tag{10}$$

At this time, the R^2=0.976 of the model. With the help of SPSS tools, the error analysis of the model is carried out, and the indicators are tested, as shown in Table 1.

Table 1: The indicators

Model	Unstandardized coefficient		Standardization factor	t	Significance
	B	Standard error	Beta		
(constant)	29309.427	4324.226		6.778	0.000
FRSHTT	-0.006	0.002	-0.644	-3.948	0.000
GUST	0.037	0.172	0.055	0.217	0.829
MAX	0.261	2.865	0.060	0.091	0.928
MIN	9.607	2.866	3.530	3.352	0.002
MXSPD	8.817	1.218	2.996	7.239	0.000
PRCP	-10.362	6.338	-0.706	-1.635	0.109
SLP	0.287	0.072	1.853	4.009	0.000
SNDP	-27.345	4.449	-1.140	-6.146	0.000
STP	0.016	0.032	0.069	0.509	0.613
TEMP	-12.529	2.240	-2.914	-5.592	0.000
VISIB	-17.386	5.371	-3.729	-3.237	0.002
WDSP	-5.157	0.612	-1.846	-8.423	0.000

It can be seen from Table 1 that the standard error of the model is small; the t value is basically more reasonable; the significance value is small, indicating that the model is more reasonable.

The second step is to solve and screen out a batch of years with more precipitation.With the help of Excel tool, the five years with more precipitation were selected, as shown in Table 2.

Table 2: The five years with more precipitation

Serial number	Years	Precipitation index
1	1996	15177.29
2	1997	15027.49
3	2000	14971.1
4	1998	14936.37
5	1999	14923.12

The third step is to solve a specific quantitative analysis of the inundation event in Zhengzhou in 2021. Solving the multiple regression model, the expression is:

$$Y_{\text{Day}} = -7172.745327 + 0.019483X_1 + 0.000060X_2 + 0.145180X_3 - 1.100794X_4 \\ +7.998449X_5 - 21.642502X_6 + 45.971341X_7 + 7.024771X_8 - 0.018679X_9 \\ +0.207750X_{10} - 3.091379X_{11} + 27.292650X_{12} + 21.582163X_{13} \tag{11}$$

At this point, the R^2=0.915 of the model. With the help of SPSS tools, the error analysis of the model is carried out, and the indicators are tested, as shown in Table 3.

Table 3: The indicators

Model	Unstandardized coefficient		Standardization factor	t	Significance
	B	Standard error	Beta		
(constant)	-7172.75	1424.889		-5.0339	5.8E-07
DEWP	0.019483	0.011815	0.034267	1.648946	0.099507
FRSHTT	6.04E-05	0.000302	0.004331	0.200186	0.84138
GUST	0.14518	0.012569	0.269583	11.55086	7.02E-29
MAX	-1.10079	1.25247	-0.06815	-0.8789	0.37969
MIN	7.998449	1.299985	0.504155	6.152726	1.14E-09
MXSPD	-21.6425	2.397441	-3.79695	-9.02733	1.04E-18
PRCP	45.97134	10.82147	0.094558	4.24816	2.38E-05
SLP	7.024771	7.024771	0.257601	5.189081	2.61E-07
SNDP	-0.01868	0.042815	-0.00924	-0.43626	0.662749
STP	0.20775	0.017714	0.28482	11.72801	1.15E-29
TEMP	-3.09138	2.07681	-0.18541	-1.48852	0.136963
VISIB	27.29265	27.29265	0.491401	20.33296	5.93E-76
WDSP	21.58216	2.391142	3.793247	9.025883	1.06E-18

It can be seen from Table 3 that the standard error of the model is small; the t-test value is basically more reasonable; the significance value is small, indicating that the model is more reasonable.

Therefore, the multiple regression model established according to the daily situation in 2021 found that the PRCP, VISIB, and WDSP model coefficients are relatively large, indicating that the overall impact on the model is relatively large. Therefore, the more relevant indicators for the inundation event in Zhengzhou in 2021 are PRCP, VISIB, and WDSP; and a multiple regression model can be established to substitute specific indicator values to solve the situation on a specific day.

4. Conclusion

(1) The annual precipitation characteristics in Zhengzhou are mainly related to the 12 indicators of FRSHTT, GUST, MAX, MIN, MXSPD, PRCP, SLP, SNDP, STP, TEMP, VISIB, and WDSP.

(2) FRSHTT, GUST, MAX, MIN, MXSPD Changes in the indicators of PRCP, SLP, SNDP, STP, TEMP, VISIB, and WDSP will directly affect the magnitude of precipitation in Zhengzhou.

(3) The five years with more precipitation are 1996, 1997, 2000, 1998 and 1999. In 2021 the more relevant indicators of inundation events in the region are PRCP, VISIB, and WDSP.

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