Study on annual rainfall forecast of Xishan station in Wenzhou City

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Abstract. Wenzhou city is located in the southeast of Zhejiang Province, it belongs to subtropical climate. The main factors that affect the climate in Wenzhou include strong solar radiation and the regulation of marine water body. The annual variation of rainfall in Wenzhou City is very large. The disastrous weather in Wenzhou mainly includes typhoon, rain and drought. The ways of Typhoon Affecting Wenzhou include direct landing and adjacent area landing. Direct landing is more harmful. Rainfall is the most important factor affecting flood and drought disasters in Wenzhou City, so the analysis of rainfall can provide a reference for flood control and drought relief work in Wenzhou City. In this paper, BP neural network method is used to analyze and forecast the rainfall of Xishan station in the main urban area of Wenzhou City. The results show that the precipitation in Wenzhou City will change greatly in the next ten years. Flood disaster may occur in 2022 and 2028, and drought may occur in 2023.

1. Introduction to Wenzhou

Wenzhou City is located in the southeast of Zhejiang Province, bordering the East China Sea in the East, Fujian in the south, Lishui City in the West and northwest, and Taizhou City in the north and northeast. The whole territory is between 27 degrees 03 minutes to 28 degrees 36 minutes north latitude and 119 degrees 37 minutes to 121 degrees 18 minutes east longitude. Wenzhou is located in the middle section of China's golden coastline and the intersection of the Yangtze River and Pearl River Delta economic zones. It is one of the first 14 coastal open cities in Zhejiang Province, one of the top 10 most dynamic cities in China, the top 10 brand capital in China and the advanced city in the construction of civilized city. The total land area of the city is 11784 square kilometers, of which 78.2% are hills, 17.5% are plains, 2.8% are rivers and wetlands, and 1.5% are islands. The sea area is about 11000 square kilometers. Among them, Wenzhou City (Lucheng, Longwan and Ouhai three districts) covers an area of 1187 square kilometers. In 2020, the total number of permanent residents will be 9.3 million.

2. Hydrometeorological situation of Wenzhou City

Wenzhou has a remarkable alternation of winter and summer monsoon [1], moderate temperature, four distinct seasons and abundant rainfall. The precipitation in Wenzhou City has great interannual variation and uneven distribution within the year, mainly concentrated in April to October, accounting for 78.2% of the annual precipitation. The main causes of rainfall are frontal rain and typhoon wind
and rain. April to July is the Meiyu flood season, with more precipitation days and larger precipitation. July October to October is the Taiwan flood season with sunny and hot weather, often affected by typhoon and rainstorm, which often causes flood disasters. October to April of the following year is the non flood season It's sunny and rainy. The annual average evaporation is 1310 mm.

3. Analysis of annual rainfall in Wenzhou
Rainfall is the most important factor affecting flood and drought disasters. The main factors affecting precipitation are location, circulation, ocean current, topography, vegetation, hydrology, human activities and so on. There are many factors affecting rainfall, so the analysis of rainfall is very complicated. However, the analysis and prediction of rainfall is the basis of flood control planning and water resources planning. Without accurate rainfall analysis and prediction, it is impossible to arrange the future water conservancy project plan. At the same time, the rainfall forecast data is also the basis to reduce the harm of future flood and drought disasters on people's property. The rainfall data of Xishan station in Wenzhou City from 1990 to 2019 were collected. The data are shown in the table below.

| Year | Annual rainfall (mm) |
|------|----------------------|
| 1990 | 2389.5               |
| 1991 | 1599.4               |
| 1992 | 2090.1               |
| 1993 | 1745.8               |
| 1994 | 1859.3               |
| 1995 | 1484.9               |
| 1996 | 1371                 |
| 1997 | 2080                 |
| 1998 | 1681.4               |
| 1999 | 2090.3               |

Figure 1. Annual rainfall data of Xishan station in Wenzhou City from 1990 to 2019.
It can be seen from table 1 and figure 1 that the annual rainfall data of the main urban area of Wenzhou City varies greatly, among which the minimum year is 1208mm in 2008, the largest year is 2703mm in 2010, and the average rainfall from 1990 to 2019 is 1818.2mm. From the above analysis, it is difficult to achieve the expected effect by using the traditional method because of the large range of annual rainfall data in Wenzhou City. Therefore, this paper introduces the artificial neural network model which can analyze the inherent laws of the data to analyze and forecast the annual rainfall of Wenzhou City from 1990 to 2019, in order to get more accurate prediction effect.

4. Forecast of annual rainfall in Wenzhou

Artificial neural network [2] is a nonlinear system composed of a large number of simple computing units (i.e. neurons). It imitates the information processing, storage and retrieval functions of human brain neural system to a certain extent and level, so it has intelligent processing functions such as learning, memory and calculation. At present, the theory and application of artificial neural network has been greatly developed, and has penetrated into almost all engineering application fields [3]. There are many kinds of artificial neural network models and algorithms, among which error back-propagation (BP) algorithm is the most important learning algorithm in artificial neural network theory [4-5]. BP network is composed of input layer, output layer and one or more hidden layers. Each layer contains multiple neurons, which are connected by weights. The calculation steps of BP artificial neural network are as follows:

**step 1:** set the number of iterations \( t = 0 \), and randomly initialize each connection weight, threshold, learning rate and inertia impulse.

**Step 2:** \( t \leftarrow t + 1 \), input the first sample \( P \) into the model, and calculate the activation value and output value of hidden layer and output layer according to the formula.

**Step 3:** calculate the total error \( E(t) \) according to the formula, if \( E(t) \leq \varepsilon \) (allowable error), stop iteration; otherwise, carry out step 4.

**Step 4:** calculate the error of hidden layer and output layer according to the following formula, and calculate the error of each layer according to the following formula

\[
 d_k^q = (y_k^q - y_k^q)(1 - y_k^q) \quad (1)
\]

\[
 d_j^q = \sum_{k=1}^{Q} d_k^q w_{jk}^q h_j^q (1 - h_j^q), \quad k = 1, 2, ..., n; \quad f = 1, 2, ..., l; \quad q = 1, 2, ..., Q \quad (2)
\]

Step 5: dynamically adjust learning rate \( \eta \), inertia factor \( \alpha \), weight \( w \) and threshold \( \theta \).

if \( E(t) \leq E(t - 1) \)

\[
 \begin{cases}
 \eta(t) = \eta(t) \ast (1 + \lambda) \\
 a(t) = a(t) \ast (1 + \lambda)
 \end{cases} \quad (3)
\]

Else

\[
 \begin{cases}
 \eta(t) = \eta(t) \ast (1 - \lambda) \\
 a(t) = a(t) \ast (1 - \lambda)
 \end{cases} \quad (4)
\]

Where, \( \lambda \) is the adjustment rate, \( \lambda \in (0,1) \).

The weights from hidden layer to output layer and input layer to hidden layer are adjusted to

\[
 \begin{cases}
 w_{jk}^2(t) = w_{jk}^2(t - 1) + \eta(t) \sum_{q=1}^{Q} h_j^q d_k^q + a(t)(w_{jk}^2(t - 1) - w_{jk}^2(t - 2)) \\
 w_{ij}^1(t) = w_{ij}^1(t - 1) + \eta(t) \sum_{q=1}^{Q} x_i^q d_j^q + a(t)(w_{ij}^1(t - 1) - w_{ij}^1(t - 2))
 \end{cases} \quad (5)
\]

The threshold from hidden layer to output layer and input layer to hidden layer are adjusted to
\[
\begin{align*}
\phi_k^2(t) &= \phi_k^2(t-1) + \eta(t) \sum_{q=1}^{Q} (-1) d_k^{2,q} + a(t)(\phi_k^2(t-1) - \phi_k^2(t-2)) \\
\phi_j^j(t) &= \phi_j^j(t-1) + \eta(t) \sum_{q=1}^{Q} (-1) d_j^{1,q} + a(t)(\phi_j^j(t-1) - \phi_j^j(t-2))
\end{align*}
\]

(6)

Return to step 2 and continue the iteration. According to the above steps, the annual rainfall in Wenzhou is predicted. Using the rainfall of T year and T + 1 year as the input and the rainfall of T + 2 year as the output, the BP artificial neural network prediction model is established. The prediction results are shown in Figure 2.

The forecast values of annual rainfall in the main urban area of Wenzhou City in the next 10 years are shown in the table below.

| year     | Annual rainfall | year     | Annual rainfall | year     | Annual rainfall |
|----------|-----------------|----------|-----------------|----------|-----------------|
| 2020     | 1479.6          | 2021     | 1756.8          | 2022     | 2343.4          |
| 2023     | 1060.5          | 2024     | 1806.5          |          |                 |
| 2025     | 1981.6          | 2026     | 1546.4          | 2027     | 1759.2          |
| 2028     | 2230.8          | 2029     | 1134.5          |          |                 |

5. Conclusion
This paper analyzes and forecasts the rainfall of Wenzhou City by BP neural network. According to the calculation, the future annual rainfall of Wenzhou is 1756.8mm in 2021, 2343.4mm in 2022, 1060.5mm in 2023, 1806.5mm in 2024, 1981.6mm in 2025, 1546.4mm in 2026, 1759.2mm in 2027, 2230.8mm in 2028 and 1134.5mm in 2029. In 2022 and 2028, Wenzhou may suffer from flood and drought in 2023. The analysis results of this paper can provide a reference for flood control and drought relief in Wenzhou City in the future.

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