Availability analysis of precipitation forecast results in reservoir flood control operation in Anqiu

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Abstract. Anqiu is located in the Weihe River basin. The precipitation is mainly concentrated in the flood season. There are more than 100 large, medium and small reservoirs such as Shangzhuang reservoir and Moushan reservoir. It is of great significance for reservoir operation and flood control decision-making to study the accuracy of precipitation forecast in flood season in Anqiu and to analyse the availability of the forecast results.

1. Introduction

Anqiu County, located in the middle of Shandong Peninsula, is an important water source in Shandong Province. More than 50 rivers in Anqiu City originate in the non-polluted Yimeng Mountains with over 100 large, medium and small reservoirs. More than 50 large and small rivers, mostly in the east, north and south, belong to the Weihe River basin. There are 5 large rivers, Weihe, Wenhe, Quhe, Honggou and Shijiao River, with a controlled watershed area of 1884 km², accounting for 93.7% of the total area of the county. Wenhe has 6 tributaries in the county, including Dasheng River, Cyprinus Dragon River, Hot Spring River, Ling River, Xiaowen River and Moxi River, with a watershed area of 1076 km².

Anqiu is the important water-producing area of reservoirs in this county, with warm temperate continental monsoon climate, hot and rainy summer, annual average precipitation is 646.3mm and the maximum precipitation is 1027.0mm in 1974.

In the actual application of reservoir, flood forecasting can already be applied to actual operation, but the forecast period is very limited if only considering the measured rainfall information. In order to prolong the forecasting period and provide conditions for optimizing reservoir operation, 24-hour rainfall forecast from the Central Meteorological Station is usually used as a rainfall factor to be correlated to the flood forecasting model in daily flood forecasting. Therefore, the qualified rate of flood forecasting largely depends on the accuracy of the associated rainfall forecasting data.

Rainfalls will be classified according to the habits of meteorological department in this paper. Using Anqiu next 24h rainfall forecasting information issued by the Central Meteorological Station and the observed rainfall values during June-September in 2016-2019, we will analyse the characteristic index values of rainfall forecasting information, such as accurate rate, missing rate and...
vacancy rate, and the actual availability and importance of rainfall forecasting information from angle of the reservoir flood control safety.

2. Rainfall classification, inspection and evaluation Method

2.1. Rainfall classification

According to the habits of meteorological departments, the rainfall is classified to 6 grades (Table 1).

| grade      | rainless | light rain | moderate rain | heavy rain | torrential rain | downpour |
|------------|----------|------------|---------------|------------|----------------|----------|
| Range of value(mm) | 0        | 0.1-10     | 10.1-25       | 25.1-50    | 50.1-100       | 100.1-250 |

2.2. Rainfall inspection and evaluation Method

When there is precipitation forecast or actual precipitation ≥ 0.1 mm, it should be tested. The evaluation results are divided into three types, namely "accurate", "missing report" and "vacancy report". When the actual precipitation magnitude is consistent with the forecast level, the magnitude is evaluated as "accurate". When the actual precipitation magnitude is inconsistent with the forecast level, the larger grade is selected as the test level, and only this level is evaluated. For example, if torrential rain occurs during heavy rain forecast, it will be assessed as rainstorm missing report and will not be evaluated as heavy rain air report; if moderate rain occurs during heavy rain forecast, it will be rated as heavy rain vacancy report, and not moderate rain missing report.

In the precipitation forecast, generally only one precipitation magnitude is predicted and tested. If two different grades of magnitude are predicted, only the larger ones will be tested; if "light rain to heavy rain" is predicted, only "heavy rain" forecast will be tested, but not "light rain" forecast.

2.3. Calculation formula

Comparing the forecasting and observed magnitude of precipitations, we tested the times of missing report, accurate report and vacancy report day by day, and calculated the accuracy rate, vacancy report rate and missing report rate.

The calculation formula of rainfall forecast accuracy rate for different grades is as follows:

$$\eta = \frac{n}{m} \times 100\%$$  \hspace{1cm} (1)

Where: m is the number of forecast times; n is the number of times the observed precipitation value falls within the forecast level area.

The calculation formula of rainfall forecast missing rate for different grades is as follows:

$$\beta = \frac{u}{m} \times 100\%$$  \hspace{1cm} (2)

Where: u is the number of times missing report times (the observed precipitation value is greater than the upper limit of forecast level threshold) in the release forecast.

The calculation formula of rainfall forecast vacancy rate for different grades is as follows:

$$k = \frac{v}{m} \times 100\%$$  \hspace{1cm} (3)

Where: v is the number of times vacancy report times (the observed precipitation value is less than the lower limit of forecast level threshold) in the release forecast.

$$\eta + \beta + k = 1$$  \hspace{1cm} (4)

3. Accuracy analysis of rainfall forecast

In this paper, taking the next 24h rainfall forecast data of Anqiu released by the Central Meteorological Bureau during June to September in 2016-2019 (488 days in total) as the sample, the accuracy rate, missing rate, and vacancy rate of short-term rainfall forecast in basin were calculated using above statistical methods. The results are shown in table 2.
Table 2. The rainfall forecast information analysis of rainless, light rain and moderate rain

| forecast grades | rainless | light rain | thunder shower | moderate rain | heavy rain | torrential rain |
|----------------|---------|------------|----------------|--------------|------------|----------------|
| forecast times | 331     | 17         | 103            | 26           | 4          | 7              |
| accuracy rate (%) | 87.6   | 64.7       | -              | 34.6         | 25.0       | 28.6           |
| vacancy rate (%)  | 0       | 17.6       | 38.8           | 57.7         | 50.0       | 57.1           |
| missing rate (%)  | 12.4    | 17.6       | -              | 7.7          | 25.0       | 14.3           |
| rate of actual rainfall grades when missing forecasts occur (%) | light rain | 11.8 | 64.7 | 40.8 | 38.5 | 25.0 | 14.3 |
|                 | moderate rain | 0.6 | 5.9 | 13.6 | 34.6 | 0 | 0 |
|                 | heavy rain   | 0 | 5.9 | 3.9 | 3.8 | 50.0 | 0 |
|                 | torrential rain | 0 | 5.9 | 2.9 | 3.8 | 25.0 | 28.6 |
|                 | downpour     | 0 | 0 | 0 | 0 | 0 | 14.3 |

It can be seen from the table:

(1) Except for the thunderstorm forecast, the empirical frequency distribution of the actual precipitation corresponding to the other five rainfall forecast grades is shown skewed. In the rainfall forecast of any grades, the vacancy report rate is greater than or equal to the missing report rate, that is, the other precipitation forecast grades tend to be larger than their actual observed values except for rainless forecast.

(2) In 331 rainless forecasts, the accuracy rate is 87.6%, and the missing rate is 12.4%. When missing forecasts occur, the probability of light rain is 11.8%, the number of times is 39, the probability of moderate rain is 0.6%, and the probability of occurrence of heavy rain is 0.

(3) In the 17 times of light rain forecasts, the forecast accuracy rate is 64.7%, the vacancy rate is 17.6%, and the missing rate is 17.6%. When missing forecasts occur, the probability of occurrence of moderate rain, heavy rain and torrential rain are all 5.9%, and the occurrence times are all once. The torrential rain occurred once on June 26, 2018, and the weather forecast was light rain on that day, but the actual accumulated rainfall reached 98.25 mm, and the rainfall period was 0:00-8:00. This is because this precipitation was predicted on June 25, 2018 and the actual accumulated 24-hour rainfall was 125.25 mm. Therefore, the rainfall on June 26th is the continuation of the 25th rainstorm process, considering its little impact on the actual reservoir flood control work, this torrential rain can be identified as not been missed.

(4) In the flood season, due to the influence of weather situation, thunderstorms often occur in the afternoon or evening. It is difficult to determine the range, area and time of Thunderstorm in summer, so the rainfall magnitude in the forecast is also difficult to determine. In the 103 thunderstorm forecasts, the probability of no rain is 38.8%, the probability of light rain is 40.8%, the probability of moderate rain is 13.6%, the probability of heavy rain is 3.9%, and the probability of torrential rain is 2.9%.

(5) In the 4 times heavy rain forecasts, the accuracy rate was 25.0%, the vacancy rate was 50.0%, the missing rate was 25.0% and one timetorrential rain was missed.

(6) Among the 7 times torrential rain forecasts, the accuracy rate was 28.6%, the vacancy rate was 57.1%, the missing rate was 17.3% and one heavy rain was missed.
4. Application of rainfall forecast in reservoir flood control operation

According to the above analysis, when the 24h rainfall forecast of the Central Meteorological Bureau is adopted for reservoir flood control operation:

1. If there is no rain or light rain forecast, the probability of heavy rain is very low, and the forecast reliability is high, so it can be used completely;

2. If there is moderate rain forecast, due to the low accuracy rate and high vacancy rate, it can be lowered by one level when there are no extreme weather conditions;

3. If there is thunderstorm forecast, the probability of moderate rain and below is 93.2%, and the probability of heavy rain and torrential rain is 7.8%. The reservoir management and operation department should make preparations comprehensively considering the previous rainfall and whether there is an extreme weather conditions;

4. If there is heavy rain or above forecast, the missing rate is low, so we should prepare for the large flood in advance.

It should be noted that although the rainfall forecast information of no rain and light rain has reached the available level, the probability of heavy rain and above rainfall is very small, but the forecast accuracy rate is not 100%, and it still has the possibility of missing forecast. Therefore, when there is precipitation missing forecast, whether it will increase the risk of the reservoir itself and the upstream and downstream flood control objects is the most concerned problem of reservoir management and operation decision-makers. It is necessary to consider whether the reservoir dam’s flood resistance standard reservoir dam has changed from the most unfavourable point of view of reservoir operation, and focus on the risk analysis of real-time dynamic control of flood limit water level under extremely adverse conditions.

Acknowledgments

Found project: Shandong Jiaotong University Doctoral Research Fund (NO:BS201901059), Key projects of Art Science in Shandong Province (NO:QN202008265), Provincial water conservancy research projects in Shandong Province(NO: SDSLKY201804).

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