The Study of Flood Forecast Based on Precipitation Ensemble Forecast

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Abstract. Ensemble forecast which makes up for the lack of the single forecast, is a shift from deterministic forecast to probabilistic forecast. Based on the above ideas, this paper takes the Jianghua as study basin, and uses the ECWMF ensemble forecast precipitation data to drive the flood forecasting model for flood forecasting. The result shows that the ensemble forecast flood forecasting can get the range of runoff simulation. And 75% of the process line Q_{75} is used as a deterministic process line which can simulate the flood well. The method not only ensures the accuracy of flood forecast, but also prevents the period of flood. Reliability of the application of ensemble forecast in flood forecast is proved.

1 Introduction

Affected by the frequent occurrence of extreme weather, flood disasters have a new feature: mega-floods occur in new areas that have not been recorded in history; floods are larger than historical floods and occur more frequently [1]. Based on the existing flood control engineering measures, the establishment of a flood forecasting system with high precision and sufficient forecast period will provide an important scientific basis for decision-making of flood control dispatchers.

Precipitation is one of the most important information in flood forecasting. In traditional flood forecasting, hydrological station or rainfall station observation precipitation or radar rainfall data is often directly input into the flood forecasting model, but in this way the hydrological forecasting period of this method is short. From a theoretical point of view, in order to achieve the purpose of prolonging the flood forecasting period, it is one of the most effective ways to use the forecast precipitation during the period as the input of the hydrological model.

In the practice of flood forecasting, the most widely used is deterministic flood forecasting. However, due to the highly nonlinear chaotic characteristics of the atmosphere, there are certain deviations in the deterministic forecast. Therefore, weather forecasting is always only a possible value of the actual atmosphere, and the future state of the atmosphere cannot be calculated completely accurately. Different from deterministic forecast, the idea of ensemble forecasting is a shift from deterministic to probabilistic. Uncertainty in precipitation forecasts is speculated by the possibility of future weather, and ensemble forecast which makes up for the lack of a "single" forecast. The study of flood forecasting based on ensemble prediction can better describe the uncertainty of precipitation forecast, thus

reflecting the uncertainty of flood forecasting, and then provide more risk assessment information for decision-makers of flood control work.

2 TIGGE ensemble forecast

At present, the WMO (World Meteorological Organisation) has established three TIGGE data research centers, including the China Meteorological Administration (CMA), the National Center for Atmospheric Research (NCAR), and the European Medium-Range Weather Forecast Center (ECWMF). The forecast data of the various ensemble forecasting systems (EPS) will be aggregated to form a global interactive platform (Figure 2.1).

TIGGE includes the Australian Meteorological Administration (BOM), China Meteorological Administration (CMA), Canadian Meteorological Center (MSC), Brazilian Meteorological Center (CPTEC), European Medium-Range Weather Forecast Center (ECWMF), Japan Meteorological Administration (JMA), Korea Meteorological Administration (JMA), Meteo-France, the United States Meteorological Administration (NCEP), the British Meteorological Administration (UKMO) and other ensemble forecasting systems.

Figure 1. Three exchange center of TIGGE global data

The classic concept of ensemble forecasting is a method of obtaining a set of forecast values starting with a set of small initial values. Compared with other ensemble prediction systems (CMC, NECP), ECWMF has a good performance [2], and in the 0-10d forecast, ECWMF uses T_{L639L62} mode with the highest resolution. Therefore, this paper uses ECWMF precipitation ensemble forecast data for flood forecasting research.

3 River basin profile

Xiao River is a large tributary of the upper reaches of the Xiangjiang River. The length of main stream is 354km, the drainage area is 12099km², the average annual flow is 345m³/s, and the average annual runoff is 10.88 billion m³. The upstream river is twisted and the water is flowing. Jianghua Station is located in the main stream of Xiao River, with a drainage area of 2158km².

The source of runoff in the Jianghua basin is rainfall. The basin is located in the southern part of China and belongs to the humid climate zone of the mountainous area. After years of research and exploration, the runoff yield under saturated storage is the main mechanism of runoff generation in such areas. Therefore, the flood forecasting model of the basin is Xin'anjiang, the method of the parameters calibration is genetic algorithm. Ten years of hydrological data from 2001 to 2011 were selected for parameter determination. Then parameters of the flood forecasting model of the basin of were obtained, the deterministic coefficient DC=0.943.

4 Test of ECWMF precipitation ensemble forecast

4.1 Test method

The test of precipitation forecast data is the premise and guarantee of ensemble prediction coupled hydrological forecasting. This paper uses the TS score and the Talagrand distribution to score the ECWMF precipitation forecast data. The accuracy and reliability of ensemble precipitation ensemble forecasting are verified by scoring.

4.1.1 TS score

As the most commonly used precipitation evaluation tool in China, TS score is the evaluation standard of deterministic forecast. TS score function:

$$TS = \frac{N_A}{N_A + N_B + N_C} \quad (1)$$

N_A is the number of correct prediction, N_B is number of omissions prediction, N_C is number of false prediction. It can be seen from equation (1) that the closer the value of TS is to 1, the better the effect of the prediction is.

4.1.2 Talagrand distribution

The conditions required to form an ensemble prediction system require that the forecasting capabilities among the members be approximately the same and have a certain degree of dispersion. The Talagrand distribution is one of the methods to test the degree of dispersion of the ensemble forecast. The basic idea is to arrange the forecast data of each member in descending order and calculate the frequency at which the measured precipitation falls in each interval. Talagrand distribution function:

$$X_1 \leq X_2 \leq \dots \leq X_M \quad (2)$$

The measured value is compared with the predicted value. If X falls between X_i and X_{i+1} , i is counted once, and if less than X_1 or greater than X_M , 1 or $M+1$ is recorded once. The probability of each interval will be calculated at last.

4.2 Test result

At present, the meteorological department divides the precipitation intensity into 6 grades based on the cumulative precipitation in 24 hours (Table 1).

This paper selects the data of ensemble forecast and control forecast of ECWMF forecast from 2007 to 2013, and cumulative precipitation data in 24 hours with the forecast period for one day. The forecasting of the area precipitation uses the grid average method, the measured of the area precipitation uses Thiessen polygon. Compared with the measured data, the forecast data is evaluated.

4.2.1 TS score

The TS scores were calculated for each of the control forecast and the average of ensemble forecast according to Equation (1), and the results are shown in Table 2.

It can be seen from Table 2 that the TS scores show a downward trend in the precipitation from mild rain to heavy rain, and the TS scores of the ensemble prediction are slightly better than the control forecast. The result of the control forecast and the ensemble forecast in the heavy rain level are all zero, which is related to the number of precipitations in the heavy rain level in the precipitation. From the statistical point of view, the TS score of the heavy rain level is unrepresentative.

Table1. The grade classification of the cumulative precipitation in 24h

Grade	No rain	Mild rain	Moderate rain	Heavy rain	Rainstorm	Heavy rainstorm
Cumulative precipitation in 24h (mm)	0	0.1-9.9	10-24.9	25-49.9	50-99.9	More than 100

Table2. The result of TS score

Grade	No rain	Mild rain	Moderate rain	Heavy rain	Rainstorm	Heavy rainstorm
Control forecast	0.54	0.76	0.41	0.34	0.13	0
Ensemble forecast	0.39	0.83	0.56	0.41	0.25	0

4.2.2 Talagrand distribution

According to the calculation method, the Talagrand distribution map of ECWMF is obtained (Figure 2).

Figure2. Talagrand distribution of ECWMF

The Talagrand distribution usually has the following four cases [3]: (1) As shown by the dotted line in Figure 2, the distribution is a straight line, it indicates that the forecasting ability of each set member is the same and is an ideal distribution. (2) The distribution is “∩” type, it indicates that the ensemble forecasting members are too divergent. (3) The distribution is “∪” type, it indicates that the ensemble forecast members have insufficient divergence. (4) The distribution is “L” or “L”, it indicates that there is a deviation in the system.

It can be seen from the figure that the Talagrand distribution of ECWMF is “∪” type, it indicates that there will be false and empty forecasts in the ensemble forecast. Therefore, the use of ECWMF precipitation data needs to pay attention to the phenomenon of false reporting of heavy precipitation.

5 Flood forecasting analysis based on ensemble precipitation forecast

The TIGGE data of ECMWF was provided in June 2006 with a resolution of about $0.5^{\circ} \times 0.5^{\circ}$. The forecast areal

precipitation of the basin is the average of the forecast values of the grid points, and the measured precipitation uses the Thiessen polygon. In this paper, the representative floods of 20120512, 20130815 and 20130823 are selected to test the application of ensemble precipitation forecast in hydrological forecasting. Figure 4 shows the precipitation process from ECWMF on the day of the flood start, and the ensemble forecast data drives the flood forecasting model to obtain 50 sets of flood simulation processes, as shown in Figure 5. In the figure, Q_5 , Q_{75} and Q_{95} respectively indicate the corresponding flood process 5, 75 and 95 percentiles.

It can be seen from the flood simulation process lines in Fig. 5(a)-(c) that the results of flood forecasting based on ensemble prediction can include the measured flood process line. That is to say, based on the flood forecasting of the ensemble precipitation forecast, the real flood process is included in the uncertainty of the ensemble forecast.

The measured and the ensemble forecast precipitation that corresponding to the three floods is analyzed. The ensemble forecasting ability is poor for continuous heavy precipitation forecasting, such as the precipitation corresponding to the 20130815 flood. However, for the case which the precipitation corresponding to the flood is single peak or the heavy precipitation is not continuous, the ensemble prediction effect is better, such as: the precipitation corresponding to the 20120512 and 20130822 floods.

Based on the ensemble forecast, the high-flow part, especially the flood peak, has a large uncertainty range. It may be troublesome for the less experienced decision makers. Therefore, it is necessary to refine the flood forecasting results of the ensemble prediction simulation, and give a satisfactory deterministic forecasting result, so as to obtain scientific and reasonable decision-making. From the flood process of the ensemble prediction simulation of the three floods (Fig. 5(a)-(c)), Q_{75} can roughly reflect the actual flow process, and the simulated flood effect characteristics are shown in Table 3.

4(a)

4(b)

4(c)

Figure4. Ensemble precipitation forecasts from ECWMF

5(a)

5(b)

5(c)

Figure5. Flood process based on ensemble precipitation data from ECWMF

Table3. Eigenvalue of forecast result

Date	Peak flow(m³/s)	Q ₇₅		Measured precipitation simulated runoff	
		Peak flow error (%)	Deterministic coefficient	Peak flow error (%)	Deterministic coefficient
20120512	548	-9.87	0.67	+14.6	0.62
20130815	2227	-29.8	0.64	-13.7	0.74
20130822	1079	-5.72	0.72	+14.9	0.95

It can be seen from Table 3 that based on the flood forecasting of the ensemble precipitation forecast, the effect of the ensemble prediction simulation is not ideal in the case of continuous heavy precipitation. However, when the actual precipitation is a single rain peak or a

discontinuous heavy precipitation, the ensemble prediction Q₇₅ is used to simulate the measured flow line. And the flood prediction period can be extended.

Combined with the above research, the flood forecasting based on ensemble prediction can better describe the uncertainty of flood forecasting and provide

rich and useful information for decision makers. It not only provides a strong scientific basis for flood control decisions, but also earns valuable time for flood control dispatchers.

6 Conclusion

The result shows that flood forecast based on the ensemble precipitation forecast can get the range of runoff simulation. Therefore it can provide decision makers with more risk assessment information. And 75% of the process line Q_{75} is used as a deterministic process line which can simulate the flood well. The method not only ensures the accuracy of flood forecast, but also prevents the period of flood forecast. Reliability of the application of ensemble forecast in flood forecast is proved.

References

1. L.Chou, H.M.Wang and J.S.Ma, AWS, **6**(2009).
2. L.N.Zhao, H.Wu, F.Y.Tian and Meteo, **7**(2010).
3. D.Hou, E.Kalnay and K.K.Droegemier, Mon.Wea.Rev, **73**(2001).