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Analysis of a Typical Case of Meteorological Service in Tangpu Reservoir

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Abstract The continuous rainy precipitation process from February to March in 2019 was selected to analyze the effect of meteorological service in Tangpu Reservoir basin, so as to sum up service experience and then lay a better foundation for subsequent services. In response to the rainy weather from December 2018 to early 2019, three rounds of flood discharge were carried out in Tangpu Reservoir. During February - March in 2019, the hit rate of short-term area rainfall forecast for Tangpu Reservoir was 80.0%. Compared with the median of forecast interval, the average absolute error was 7.6 mm, and the relative error was 32.7%. The large deviation in the forecast from March 27 to 28 was deeply analyzed, and it is found that the main reasons were excessive reliance on and trust in a single model, insufficient correction of the actual situation, and insufficient judgment of the nature of precipitation. For the future reservoir meteorological service, three aspects of thinking were put forward, such as further strengthening the sharing of hydrological and meteorological information, improving the forecasting ability, and deepening the research of runoff forecast models.

Key words Tangpu Reservoir; Meteorological service; Continuous rain; Analysis of a typical case

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The benefits of a reservoir come from water, and the process of precipitation, water storage, water use and water disposal is a close combination of reservoir operation with meteorology and hydrology, as well as a scientific decision-making process for dispatching personnel to correctly use hydrological and meteorological forecast information to seek benefits and avoid hazards for flood control. Since Zhejiang Province began to carry out reservoir meteorological service in the 1990s, service products have grown from scratch, and service means have become diverse. Meanwhile, the accuracy of service has been gradually improved. Especially in the past two years, with the development and utilization of multi-model numerical forecast and the construction of hydrological and meteorological service platform, the meteorological service effect of reservoirs has been greatly improved.

Since the end of 2018, meteorological services have been provided for Tangpu Reservoir, and the service effect has been paid particular attention to adjust the forecast strategy timely. From December 2018 to March 2019, continuous rainy weather occurred in Zhejiang Province, which caused a lot of pressure on reservoir dispatching personnel, so the reservoir meteorological support service plays a role. In this paper, the precipitation process and the effect of reservoir meteorological service during February - March in 2019 were analyzed, and service experience was summarized, thus laying foundation for subsequent services.

1 General situation of the weather process

From February to March in 2019, continuous rainy weather occurred in Tangpu Reservoir (Fig. 1). The cumulative number of rainy days reaching 48 d (59 d in total), and cumulative rainfall was up to 384.6 mm. Among them, under the effect of cold air, there was obvious rainfall from February 6 to 10, and local sleet appeared on February 9. From February 14 to 22, sustained heavy rainfall happened due to the influence of warm and humid air flow. Since March, the continuous rainy weather had been improved slightly, and there was mainly process rainy weather, but the interval was not long, and there was basically no more than 3 days of continuous sunny weather. The main process was concentrated during March 1 -2, 14, 21 -22, and 27 -28.

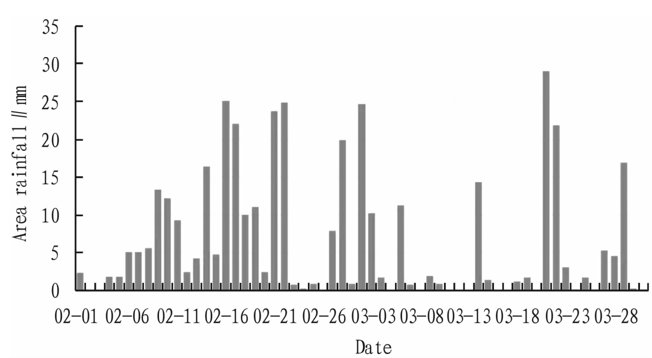

Fig. 1 Daily area rainfall of Tangpu Reservoir basin from February to March in 2019

2 Discharge situation of the reservoir

At the beginning of 2019, there was continuous rainfall in the Tangpu Reservoir basin, and the water level continued to rise. In order to further implement the requirements of the provincial and municipal flood control departments in the *Notice on Effectively Strengthening the Safety Management of Reservoirs and Pools*, Tangpu Reservoir Company ensures the safety of the reservoir on the

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premise of early prediction, early dispatching and early pre-discharge. According to the rainfall forecast, water level and runoff of the reservoir, Tangpu Reservoir carried out three times of flood discharge in February and March, and achieved the expected effect. The basic situation of the three times of flood discharge will be introduced as follows.

2.1 The first flood discharge Since February, the rain continued to appear in Tangpu Reservoir. As of February 18, the cumulative rainfall was 128.8 mm, and the maximum inflow reached 130 m^3/s. The water level of the reservoir rose from 30.14 m on February 8 to 32.36 m on 08:00 on February 18, increasing by about 2.2 m, and it was predicted that it would continue to rain in the later period.

Tangpu Reservoir held a flood control meeting at 09:00 on February 18 to form a dispatch opinion, and the floodgates were opened at 14:00 after the approval of Hangzhou Flood Control and Drought Relief Headquarters. When the floodgates were opened, the water level was 32.44 m, and the corresponding storage capacity was 190.55 million m^3. The initial discharge flow was 95.7 m^3/s, and the maximum discharge flow was 274.8 m^3/s. By 17:00 on February 22, the floodgates were closed, and the first flood discharge work in 2019 was successfully completed. The water level dropped to 31.20 m, leaving enough storage space for later rainfall.

According to statistics, the accumulated water inflow was about 65 million m^3, and the actual water inflow was about 58 million m^3 (as of 17:00 on February 22). The discharged water was about 37.9 million m^3, and the discharge time was about 98.85 h. In the discharge period, the absolute safety of reservoir facilities and equipment, hydraulic buildings and downstream rivers must be ensured.

2.2 The second flood discharge After a short interval of rain, from February 26 to March 2, Tangpu Reservoir basin once again ushered in a large rainfall process, and the cumulative rainfall in the basin was up to 58.2 mm, and the water level of the reservoir increased by nearly 1.2 m.

At 09:00 on March 4, Tangpu Reservoir held a flood control meeting to form a dispatch plan, and after the approval of Hangzhou Flood Control and Drought Relief Headquarters, the floodgates were opened at 11:45. As the floodgates were opened, the water level was 32.80 m, and the corresponding storage capacity was 195.55 million m^3, while the initial discharge flow was 97.5 m^3/s. By 12:35 on March 6, the floodgates were closed, and the water level declined to 31.79 m. The discharged water was about 16.27 million m^3. To March 10, the water level rose to 31.91 m, and then decreased day by day with the water supply. It can be said to maximize the flood control and storage within the flood control level.

2.3 The third flood discharge Under the influence of strong cold air, heavy rain happened in the Tangpu Reservoir basin since 20:00 on March 20. According to statistics, as of 11:00 on March 27, the cumulative rainfall in the basin was 57.7 mm, and the water level rose from 31.66 m at 21:00 on March 20 to 32.34 m at 11:00 on March 27, with an increase of 0.68 m. It was 0.29 m higher than the flood control level. The total water inflow was nearly 15 million m^3, and the upstream inflow was still 6.24 m^3/s. According to the weather forecast of the basin, there would still be rain in the next two days.

At 10:00 on March 27, Tangpu Reservoir held a flood control meeting to form a dispatch opinion. After the approval of Hangzhou Flood Control and Drought Relief Headquarters, the floodgates were opened at 14:00. The initial discharge flow was 97.5 m^3/s. By 11:10 on March 28, the floodgates were closed, and the water level dropped to 31.80 m. To April 2, the water level increased to 32.04 m, only 1 mm lower than the flood control level, and accurate dispatch was achieved.

3 Forecast service

From February to March in 2019, a total of 11 short-term area rainfall forecast materials were provided for Tangpu Reservoir, mainly about the weather and area rainfall range in the next 48 h, and the interval span was generally 10 – 20 mm. There were also 8 medium-term area rainfall forecast materials, mainly involving the analysis of the main impact system, the summary of the weather process, the daily weather element forecast and rainfall prediction in the next 14 days, and finally the forecast value of area rainfall in the next 10 days was formed.

According to the comparison between the forecast and the actual situation (Table 1), if the area rainfall obtained by the short-term forecast fell within the interval, or the area rainfall obtained by the medium-term forecast floated by ±30%, the forecast had a hit. 11 times of short-term forecast had 8 hits, with a hit rate of 80.0%. Compared with the median of the forecast interval, the average absolute error was 7.6 mm, and the relative error was 32.7%. Medium-term forecast had 5 hits, with a hit rate of 62.5%. The average absolute error compared with the the forecast value was 15.1 mm, and the relative error was 25.7%.

In addition, for the three flood discharge processes, an encrypted rainfall telephone service was made for Tangpu Reservoir. Especially for the third flood discharge, due to the divergence and large error in the forecast of rainfall during March 27 – 28 by the model, the rainfall was timely lowered by the manual telephone service. The reservoir was originally expected to discharge flood for 3 days, and according to the adjustment of rainfall, the flood discharge was ended in advance, providing a scientific basis for its dispatch and recovering the loss.

4 Analysis of meteorological service

Seen from the rainfall forecast, the hit rate of forecast was still relatively high. This is largely due to the establishment of the hydrological and meteorological service platform, the multi-model data was analyzed to provide a reliable basis for the artificial rainfall forecast. Meanwhile, the experience of the forecaster is also extremely critical, especially for the medium rainfall forecast. Because of the large time span, the uncertainty of the later model forecast is greatly increased, and then the manual adjustment is particularly important.

The reasons for the forecast error during the third flood discharge (March 27 – 28) will be analyzed as follows. There were obvious errors in the rainfall forecast this time, and especially in the first two periods (from 08:00 to 20:00 on March 27 and from 20:00 on March 27 to 08:00 on March 28), the forecast value was obviously large. Although timely tracking and correction were carried out, the effect was still not satisfactory. The reasons are mainly as follows.

Table 1 Comparison between forecast and actual area rainfall of Tangpu Reservoir during February – March 2019

Time interval	Forecast value//mm	Actual value//mm	Absolute error//mm	Relative error//%
021608 – 021808	10 – 25	32.1	14.6	83.43
021808 – 022008	10 – 20	13.3	1.7	11.33
021808 – 022308	40 – 60	62.6	12.6	25.20
022008 – 022208	35 – 50	48.5	6.0	14.12
022708 – 030108	20 – 30	20.6	4.4	17.60
030108 – 030308	20 – 40	34.9	4.9	16.33
032008 – 032208	30 – 50	50.7	10.7	26.75
032708 – 032720	10 – 20	2.3	12.7	84.67
032808 – 032820	15 – 25	15.2	4.8	24.00
040208 – 040408	10 – 20	18.5	3.5	23.33
021720 – 022720	96.0	96.5	0.5	0.52
022108 – 030708	80.3	103.3	23.0	28.64
022208 – 030408	59.7	66.6	6.9	11.56
022608 – 030608	74.2	71.2	3.0	4.04
030208 – 031008	67.0	26.4	40.6	60.60
031308 – 032308	45.6	72.2	26.6	58.33
032008 – 032908	76.0	82.1	6.1	8.03
032608 – 040208	40.9	26.9	14.0	34.23

Note: The shadow stands for forecast hit. "021608" means 08:00 on February 16.

(1) There were large differences in numerical models. The models represented by EC and JMA has a large forecast magnitude, while GFS has a small forecast magnitude. According to the stability and consistent performance of the model in the earlier stage, EC forecasts were more adopted in the service, but GFS forecast was paid less attention.

(2) In the case of obvious empty report, although the EC and JMA rainfall was slightly reduced, it was still significantly larger than that of GFS. After consulting with the provincial forecasters, the magnitude was lowered to a certain extent in the follow-up tracking service, but the reduction was not obvious, so that an empty report appeared once again in the second stage (from 20:00 on March 27 to 08:00 on March 28).

(3) The precipitation pattern of the whole process was mainly divided into three stages. In the first stage (the day of March 27), the main rain belt was in northern Zhejiang, and the rainfall area was concentrated, with a clear boundary. Moreover, the rainfall gradient was large. The rainfall in northern Shaoxing was more than 20 mm, while it was only 0 – 5 mm in central and southern Shaoxing. The actual rain band was further north than the forecast value. In the OCF model (Fig. 2, ▲ means the location of Tangpu Reservoir), the Tangpu Reservoir in central Shaoxing was also on the southern edge of this rain band, so the magnitude of 10 mm + was also forecast. In the second stage (the night of March 27), the main rain belt was in central Zhejiang, and the rainfall area was more concentrated. The rainfall in the north of Jinhua and the north of Taizhou was more than 20 mm, while that in the south of Shaoxing was only 0 – 5 mm. The actual rain band was further south than the forecast value. In the OCF model (Fig. 3, ▲ stands for the location of Tangpu Reservoir), the central part of Shaoxing was on the northern edge of the rain band, so the magnitude of 10 mm + was also forecast. In the third stage (the day of March 28), the rain band was mainly in the central and southern Zhejiang. In the OCF model, the rainfall area was reasonable, and the magnitude was too large, so the magnitude of 20 mm + was predicted.

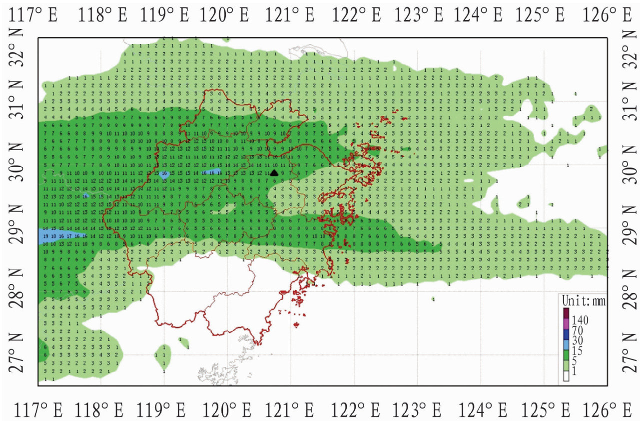

Fig. 2 12-h cumulative rainfall during 08:00 – 20:00 on March 27 predicted based on the OCF model released by Zhejiang Meteorological Observatory at 20:00 on March 26

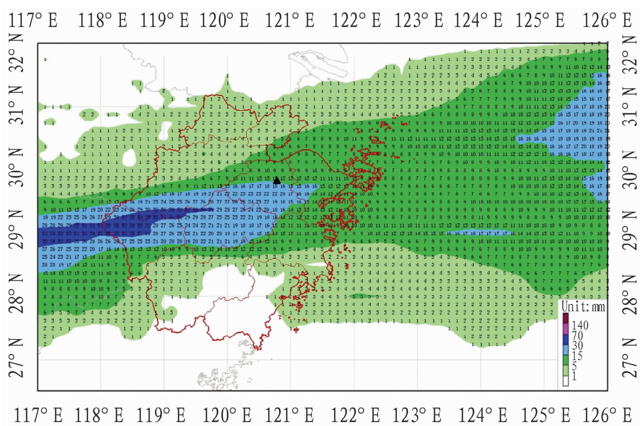

Fig. 3 12-h cumulative rainfall from 20:00 on March 27 to 08:00 on March 28 predicted based on the OCF model released by Zhejiang Meteorological Observatory at 20:00 on March 26

6 Service experience summary and reflection

From February to March in 2019, continuous rainy weather appeared in the province. After sustained several times of service, the dispatching personnel of Tangpu Reservoir had gradually established trust in the forecast. In their words, with the rainfall forecast as scientific support, their dispatch gradually became passive and fine. However, the weather forecast is never fully accurate, and only by absolutely serving with heart can we increase the benefit and reduce the loss of reservoir operation as much as possible in the course of weather.

6.1 Experience summary In view of the previous forecast services, the following experience can be summed up for the improvement and upgrading of hydrological services in the future.

(1) It is not possible to place too much trust in a single model, and especially when there is a large gap between the models, it is necessary to further analyze the reasons and make further judgments according to the situation field and rainfall type.

(2) When there is a large gap between the real situation and the previous forecast, it is necessary to strengthen the research and judgment in time, make tracking and revised forecasts for the reservoir, further analyze the changing trend and stability of the model, and adopt the model that is closer to the real situation.

(3) Convective rainfall tends to have more concentrated rain bands and large boundary rainfall gradients. When the forecast area is located at the edge of the rain band, the location of the rain band has a great influence on rainfall. Therefore, more attention should be paid to the location of the actual rain band. If there is a deviation from the model, the corrected forecast and tracking service should be made in time, and two sets of forecasting services for extreme cases can be provided for the reservoir, such as the maximum rainfall when convective precipitation occurs in the reservoir basin and the minimum rainfall when no convective precipitation occurs.

6.2 Service thinking Although the hydrological and meteorological service of Zhejiang Province started relatively early and developed rapidly in recent years, there are still shortcomings such as insufficient products, large dependence on models and unstable forecasting effect. Hence, in the future service, the development of the following directions can be tried to constantly improve the service capacity, and seek advantages and avoid disadvantages for reservoir regulation.

(1) The sharing of hydrological and meteorological information and data should be further strengthened. After quality control, the data of meteorological observation stations, hydrological observation stations, reservoir water level, etc. are collected into the same platform for real-time display and query, so as to grasp more comprehensive real information in time, which is of great help to timely tracking and correction of services.

(2) The forecasting capability should be further improved. At present, the hydrological and service platform in the province has integrated the results of a number of numerical forecasts, and they can be comparatively analyzed to facilitate forecast services, but there are still problems such as incomplete data, deviation of long-term forecast effect of individual models, and instability of models in the process of use. In the next step, more model data can be introduced, and methods such as machine learning can be used to automatically track the models that have performed well in the recent past. Meanwhile, the application of short-time products such as radar can be strengthened within 0 – 12 h to provide a more convenient and accurate reference for forecasting services.

(3) The research of runoff forecast models should be further deepened. Seen from the contact with reservoir users, they have a very large demand for runoff forecast, and this aspect of the product is very lacked. Relevant research on model application has been carried out for Shanxi Reservoir in the early stage, and good results have been achieved. Moreover, users are also very satisfied. In the next step, it is needed to expand the scope, conduct in-depth research, compare the effects of various models, and establish a multi-model collection platform for the runoff forecast of large and medium-sized reservoirs in the province as far as possible, so as to provide more abundant products for reservoir users.

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