Analysis of Meteorological Service Effect of a Low-cloud and Low-visibility Weather Process at Shanghai’s two Airports

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Abstract. The emergence of low-cloud and low-visibility can affect air activities, and bring huge economic losses to airlines. Based on the aviation meteorological observation, forecast and airport alert of Pudong and Hongqiao airports, this paper analyses the meteorological service effect of a low-cloud and low-visibility weather process in Shanghai from January 27th to 28th, 2016. The results show that: (1) The absolute error between forecast and actual situation of Pudong and Hongqiao airports presents an obvious normal distribution and the forecast accuracy of Pudong is higher than that of Hongqiao. (2) For the airport with cloud ceiling of 30m~60m and prevailing visibility of 600m~800m, the alert of Pudong airport is more accurate and advanced, but for the airport with cloud height of less than 30m and prevailing visibility of 400m~600m, the airport alert is quite different from the actual situation, and lacks lead time. (3) The alert of Hongqiao airport is accurate for the airport with visibility less than 800m from 03:30 to 10:30 on 28th, and the lead time is relatively high. However, it lacks the lead time for the airport with prevailing visibility greater than 1000m at 11:00 on 28th.

Keywords: Meteorological service effect, Low-cloud and low-visibility, airport alert, forecasting verification.

1. Introduction

With the booming development of civil aviation industry and the continuous increase of air traffic demand, in order to improve the use efficiency of airspace and the operation quality of airports, the flow management and multi-airport collaborative decision system (CDM) came into being[1]. The system needs accurate, objective and fine meteorological information services in the next two hours as the support. For low-cloud and low-visibility weather forecast products, the current aviation weather forecast information cannot meet the requirements of CDM system. The analysis of meteorological service effect in low-cloud and low-visibility weather process is of great practical significance for evaluating the current service refinement degree and improving the related forecast ability.

Shanghai is one of the major economic centers in China, and the operation of Hongqiao and Pudong airports is an important part in economic development [2]. Due to its special geographical location, it is greatly affected by the water vapor on the sea. If it happens to have long-time
precipitation weather and appropriate flow field conditions, and the special configuration of the air pressure system makes the warm and humid air flow through Shanghai, it will have a severe low-cloud and low-visibility weather process, which will have a great impact on the flight take-off and landing and the airport operation [3,4].

This paper selects a weather process of low-cloud and low-visibility in Shanghai from January 27th to 28th, 2016, and analyzes the meteorological service effect of airport forecast and airport alert based on the service products in aviation meteorological business.

2. Data and methodology

From January 27th to 28th, 2016, low-cloud and low-visibility occurred successively in Pudong and Hongqiao airports.

This low-cloud and low-visibility weather process was divided into three stages:

1. The first stage (from afternoon to night of January 27): Affected by the easterly air current near surface, the humidification process is obvious in Shanghai;
2. The second stage (from early morning to midnight on January 28): With the convergence of the inverted trough near the surface and in the upper reaches of Shanghai strengthened, the low-cloud weather continued in Shanghai.
3. The third stage (around midnight of January 28): Due to the cold air from the north spreading to the south obviously, the low-cloud weather in Shanghai ended. In addition, the meteorological elements of Hongqiao airport had improved before noon on the 28th, and they did not turn below the standard again in the later period. However, the low-cloud weather of Pudong airport was mainly continuous, but fluctuated from time to time.

In view of the low-cloud and low-visibility weather process, the aviation meteorological observation, forecast and airport alert information of Pudong and Hongqiao airports are collected in this paper.

To facilitate the comparison with hourly data of observation messages, the forecast message is parsed to hourly forecast data. In order to get close to the actual business operation of airlines, the following three principles are followed during the processing of messages:

1. For the period of time overlap in multiple forecast reports, the meteorological elements corresponding to the period of the latest report were used.
2. When TEMPO occurs in the report, for the 9-hour forecast report, one time point value is randomly selected and for the 24-hour forecast report, two time points value are randomly selected.
3. This paper does not analyze the amended forecast.

In the process of analyzing the airport alert, considering that the airport alert is an interval range, and the actual data is a certain value, the actual value is made into a curve changing with time. The alert is represented by a rectangular box along the time axis, and arrows indicate the lead time of the airport alert, the alert is represented by rectangular boxes with different colors. In addition, the earliest one was selected to compare when the alert information have the same content.

This meteorological service in the weather process mainly includes airport forecast and airport alert. Therefore, the accuracy of airport forecast report and airport alert are evaluated.

3. Results and discussion

3.1. Accuracy evaluation of airport forecast report

3.1.1. Absolute error analysis. The data of Pudong airport from 17:00 to 08:00 on 27th to 29th and Hongqiao airport from 03:00 on 28th to 00:00 on 29th are selected, covering two low-cloud intervals. In order to evaluate the accuracy of airport forecast quantitatively and objectively (FC is 9-hour forecast, FT is 24-hour forecast), the deviation value (forecast minus actual) of hourly data of forecast and actual report is divided into three grades: (1) absolute error = 0m, (2) absolute error ≤30m, (3) absolute error ≥ 60m (as shown in Figure 1):
(1) For Pudong airport, in the above three grades, the absolute error of FC are 50%, 30% and 20% respectively, and absolute error of FT are 25%, 40% and 35%. For Hongqiao airport, in the above three grades, the absolute error of FC are 27.27%, 40.91% and 31.82% respectively, and absolute error of FT are 9.09%, 27.27% and 63.64%.

(2) Overall, for this weather process, the accuracy of Pudong FC is the highest, followed by Pudong FT, Hongqiao FC and Hongqiao FT. According to the forecast quasi curvature of TAF, the forecast accuracy of Pudong airport is higher than that of Hongqiao airport.

![Figure 1. Absolute error of forecast in Hongqiao and Pudong airports.](image)

3.1.2. Quantitative analysis. In order to evaluate the accuracy of TAF quantitatively and objectively, this paper makes a statistical analysis of the deviation between the forecast and the actual message.

(1) The average deviation of cloud height of FC in Pudong airport is 3.75 m (as shown in Figure 2), the median is 0 m, and the upper and lower quartiles are 0 m and 30 m respectively. In terms of the definition of small and medium probability events (probability is less than 5%), small probability events occur once, which is -90 m.

(2) The average deviation of cloud height of FT in Pudong airport is 19.5 m (as shown in Figure 2), the median is 0 m, and the upper and lower quartiles are -30 m and 30 m respectively. In terms of the definition of small and medium probability events, small probability events occur twice, which are -60 m and 90 m.

(3) All in all, for FC, 90% of the forecast deviations are between -60 m~60 m, and 50% of the forecast deviations are between 0 m~30 m. In addition, the fitting of forecast deviation is approximately normal distribution and the average value is around 0 m. There is only one extreme event during the whole low-cloud forecast process, and the error is -90 m. For FT, 90% of the forecast deviations are between -60 m~120 m, and 50% of the forecast deviations are between -30 m~30 m. If the extreme value is removed, the forecast deviation fitting is approximately normal distribution and the average value is around 19.5 m. There is only one extreme event during the whole low-cloud forecast process and the error is 240 m.

(4) The average deviation of cloud height of FC in Hongqiao airport is 21.81 m, the median is 30 m (as shown in 50% in FC in Figure 2), and the upper and lower quartiles are 0 m and 60 m, respectively. In terms of the definition of small and medium probability events (probability is less than 5%), small probability events occur twice, which are -60 m and 90 m.

(5) The average deviation of cloud height of FC in Hongqiao airport is 30 m (as shown in 50% of FT in Figure 2), and the upper and lower quartiles are 0 m and 60 m, respectively. In terms of the definition of small and medium probability events, small probability events occur twice, which are -120 m and 210 m.
(3) In a word, for FC, 90% of the forecast deviations are between -30 m~60 m, and 50% of the forecast deviations are between 0 m~60 m. In addition, the forecast deviation fitting is approximately normal distribution and the average value is around 21.82 m. There are two extreme events during the whole low-cloud forecast process, and the errors are -60 m and 90 m, respectively. For FT, 90% of the forecast deviations are between -60 m~90 m, and 50% of the forecast deviations are between 0 m~60 m. If the extreme values are removed, the forecast deviation fitting is approximately normal distribution and the average value is around 30 m. There are two extreme events during the whole low-cloud forecast process, and the errors are -120 m and 210 m respectively.

![Figure 2](image-url)

**Figure 2.** The deviation of cloud height forecast in Pudong airport(left) and Hongqiao airport(right) on 27-28 January (the average deviation is shown in ●, small probability events is shown in ▽ or △).

3.2. Assessment of airport alert accuracy

3.2.1. Assessment of Pudong airport alert. (a) The low-cloud alert in Pudong airport

In Figure 3, the time axis is from 15:00 on January 27, 2016 to 09:00 on January 29, 2016 in Beijing time. In the view of the change of cloud height with time, the cloud height fluctuates between 60m~90m from 16:30 to 19:30 on 27th, 30m~60m from 20:00 to 03:30 on 28th, 30m from 04:00 to 13:00, 30m~60 m from 13:30 to 20:00, 60m~120m from 20:30 to 21:30, and 60m~90m from 22:00 to 05:30 on 29th. After 06:00, the cloud height is stable over 90 m. Compared with the actual situation, it is found that:

(1) In the first half of the 1st-3rd airport alert and the 5th airport alert, the time and cloud height change are consistent with the actual situation. In the 4th airport alert, the cloud height is 30 m~60 m, and the actual cloud height is always equal to 30 m. In the second half of the 5th airport alert, the cloud height is 30 m~60 m, and the actual cloud height is always greater than 60 m. In the 6th airport alert, the cloud height is less than 60 m, and the actual cloud height is always greater than 60 m. There are obvious differences between the three airport alert and the actual situation.

(2) For the 1st-3rd and 5th airport alert with high accuracy, the lead time of the 1st airport alert is 7 hours and 30 minutes, that of the 2nd airport alert is 30 minutes, and that of the 3rd and 5th airport alert has no advance.

(3) On the whole, the accuracy and lead time of the airport alert of cloud height lower than 60 m from the evening of the 27th to the night are the highlights of this support service in Pudong airport. The cloud height maintained 30 m from 03:30 to 13:00 on the 28th, and the airport alert is that the cloud height is higher than 30 m, and the lead time is insufficient.

(b) The low-visibility alert in Pudong airport

In the view of the change of visibility with time, the visibility fluctuates less than 1000 m from 04:00 to 10:00 on 28th, 600 m~800 m from 04:17 to 08:30, more than 1000 m from 10:30 to 17:00, less than 1000 m from 17:30 to 19:00, and fluctuates between 400 m~600 m. After 19:30, the visibility is stable more than 1000 m (as shown in in Figure 3). Compared with the actual situation, it is found that:
The operational effect of civil aviation meteorological service products, especially the visibility of Shanghai on January 27, 2021, is insufficient. The lead time for visibility less than 800 m from 03:30 to 10:30 on 28th is 7 hours and 30 minutes, while the 2nd alert is 50 minutes, the 3rd alert is 45 minutes, and the 4th alert is 7 hours.

In the view of the change of visibility time, the visibility is less than 1000 m from 03:30 to 10:30 on 28th, of which the visibility is less than 600 m from 07:30 to 10:30 (as shown in Figure 4). The visibility is stable above 1000 m after 11:00. Compared with the actual situation, it is found that:

1. The 1st, 2nd and 3rd alert is consistent with the actual situation for the period when visibility turns bad, and the 5th alert is also close to the actual situation for the period when visibility turns good. The 4th alert predicted that visibility would deteriorate again, but it does not appear that visibility will deteriorate.

2. For the 1st, 2nd and 3rd airport alert with high accuracy, the lead time of the 1st airport alert is 9 hours and 30 minutes. The lead time of the 2nd airport alert is 4 hours and 30 minutes. The lead time of the 3rd airport alert is 50 minutes. The 4th airport alert has no lead time, which means that there is no lead time for the forecast when visibility improves.

3. On the whole, the accuracy and advance of visibility deterioration from 03:30 to 10:30 on the 28th are the highlights of this support service in Hongqiao airport. The airport alert of visibility greater than 1000 m at 11:00 on the 28th is insufficient.

### 3.2.2. Assessment of Hongqiao airport alert

In the view of the change of visibility time, the visibility is less than 1000 m from 03:30 to 10:30 on 28th, of which the visibility is less than 600 m from 07:30 to 10:30 (as shown in Figure 4). The visibility is stable above 1000 m after 11:00. Compared with the actual situation, it is found that:

1. The 1st, 2nd and 3rd alert is consistent with the actual situation for the period when visibility turns bad, and the 5th alert is also close to the actual situation for the period when visibility turns good. The 4th alert predicted that visibility would deteriorate again, but it does not appear that visibility will deteriorate.

2. For the 1st, 2nd and 3rd airport alert with high accuracy, the lead time of the 1st airport alert is 9 hours and 30 minutes. The lead time of the 2nd airport alert is 4 hours and 30 minutes. The lead time of the 3rd airport alert is 50 minutes. The 4th airport alert has no lead time, which means that there is no lead time for the forecast when visibility improves.

3. On the whole, the accuracy and advance of visibility deterioration from 03:30 to 10:30 on the 28th are the highlights of this support service in Hongqiao airport. The airport alert of visibility greater than 1000 m at 11:00 on the 28th is insufficient.

### 4. Conclusion

The low-cloud weather process in Shanghai on January 27–28 occurred under the typical circulation controlled by the easterly wind at the top of the surface low pressure inverted trough, which was caused by the coupling effect of the consistent southwest air flow in the middle and upper levels, the low-level shear line in the middle and lower Yangtze River and its easterly air flow.

Based on the evaluation of the operational effect of civil aviation meteorological service products, it is found that for the low-cloud and low-visibility process, Pudong and Hongqiao airports have their own advantages and disadvantages in the service of airport forecast and alert. The details are as follows.

1. In the view of the airport forecast, for this low-cloud process, Pudong airport FC has the highest accuracy, followed by Pudong airport FT, Hongqiao airport FC and Hongqiao airport FT. In addition, the absolute errors of forecast and actual data of Pudong airport and Hongqiao airport show an obvious normal distribution. The average deviation of FC and FT in Pudong airport is 0 m and 19.5 m, and the average deviation of FC and FT in Hongqiao airport is 21.82 m and 30 m, respectively.

2. In Pudong airport, the airport alert was close to the actual situation when the cloud height was 30 m–60 m from the evening of the 27th to the night, and the maximum lead time was 7 hours and 30 minutes. But for the case of cloud height less than 30 m, there is no lead time for airport alert. In addition, for the prevailing visibility of 600 m–800 m, the airport alert is close to the actual situation, the maximum lead time is 7.5 hours. But for the case of visibility of 400 m–600 m, there is no lead time.

3. In Hongqiao airport, the airport alert was close to the actual situation when the visibility was less than 800 m from 03:30 to 10:30 on 28th, and the maximum lead time was 9.5 hours. However, the lead time for airport alert for the visibility more than 1000 meters at 11:00 a.m. on the 28th is insufficient.
Alert 3

Alert 4

Alert 5

Figure 3. Airport alert of cloud height (left) and prevailing visibility (right) in Pudong airport. The left vertical axis is the cloud height, and the right vertical axis is the alert release order. The rectangular boxes with different colours represent the alert content, and ← refers to the lead time.

Figure 4. Airport alert of prevailing visibility in Hongqiao airport.

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