

Interpretation of EC Fine Grid Numerical Prediction Products in the Forecast of Frozen Fog in Urumqi Airport

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Abstract

In this paper, Urumqi Airport time-lapse ground man-made observation data from November 2015 to February 2017, European fine grid (0.25 × 0.25) initial field (20 o'clock) and the forecast field within 24 hours were utilized. From November 2015 to February 2016, the relevant materials were used as research samples (a total of 948 times), and from November 2016 to February 2017 as test samples (a total of 922 times), statistical methods were used to establish the scoring standards. And each relevant element was scored. After the score, the score level range was delineated, and the visibility forecast was performed according to the scope. The conclusions are as follows: 1) European fine grid forecast products are with good correspondence with the visibility of this field are 850 hPa and 2 m high temperature inversion, 850 hPa relative humidity and 850 hPa wind field over the field. 2) Through the statistical analysis of scores, it is defined that the score below 400 is level 4, the score above 1000 is level 1, the difference is significant, and the forecast indication is strong. Level 2 and level 3 are more evenly distributed, with no more concentrated fractions. 3) Applying the test sample to test the above indicators. The forecast accuracy of level 1 is 61.2%, and the forecast accuracy of level 4 is 97.2%, so level 1 and level 4 are expected to obtain better forecast results, which is of practical application value.

Keywords

Airport Freezing Fog, Forecast Product Release, Classification Prediction

1. Introduction

With the rapid development of China's aviation industry, large-scale delays in

flights due to weather, air traffic control, airport security and passengers' own reasons are not uncommon. According to the Civil Aviation Administration's 2012 Civil Aviation Industry Development Statistics Bulletin [1], the normal rate of national flights for the year was only 74.8%, of which 21.6% were due to bad weather. For Urumqi Airport, the cancellation of flight delay caused by low-visibility weather is more than the majority of all weather factors, especially the low-visibility weather caused by fog.

The forecasting methods for frozen fog are more diverse with the level of science and technology. In recent years, the level of numerical weather prediction at home and abroad has been continuously improved. In this environment, the number of numerical prediction products is increasing, and the precision of products is also increasing. More and more products have been used by a large number of meteorological business researchers and related departments, especially civil aviation meteorology, mostly concentrated in the research of numerical simulation analysis and parameterization scheme [2] [3] [4]. In this context, there are many numerical products that are constantly being produced, which have achieved good results in the weather forecasting business.

For the study of frozen fog at Urumqi Airport, Zhu Lei [5] analyzed the seasonal and interannual variations of frozen fog. It is proposed that the weather phenomenon causing low visibility of Urumqi Airport is foggy, smoke, and sand, and most of the low visibility is caused by freezing fog. Wang Nan and Yang Hongru [6] [7] analyzed the non-uniformity characteristics and the classification of frozen fog circulation in the fog season of Urumqi Airport, which provided a basis for forecasting the freezing fog weather. The research on airport fog has focused on the statistics of circulation types and the distribution characteristics of fog scales, and has achieved great results, providing reference for airport fog forecasting and on-time safe operation of flights. However, research on the application of numerical forecast product pairs for airport fog is still blank. In addition, with the global climate change, Urumqi airport fog performance in addition to different characteristics, changes in the law of production and elimination make the fog forecast more difficult to grasp. Therefore, the use of low-time-space density numerical forecasting products in the interpretation of heavy fog forecasting is far from meeting the rapid development of weather forecasting services.

At the same time, there is no numerical model at home and abroad that can directly output the forecast products of fog, which shows the complexity of visibility forecasting and the difficulty of improving the accuracy of forecasting. Therefore, it is extremely important to apply numerical prediction products with high spatial and temporal resolution to strengthen the research on the interpretation of fog prediction [8].

This paper attempts to extract the physical factors closely related to the visibility of the field through the interpretation of European fine mesh physical quantity products, find out the forecast indicators of Urumqi visibility, improve

the accuracy of forecasting, and provide reference for the actual forecasting work.

2. Materials and Methods

2.1. Data

In this paper, Urumqi Airport time-lapse ground man-made observation data from November 2015 to February 2017, European fine grid (0.25×0.25) initial field (20 o'clock) and the forecast field within 24 hours were utilized. The relevant data from November 2015 to February 2016 was used as a sample of research (a total of 948 times), and from November 2016 to February 2017 as a test sample (a total of 922 times).

2.2. Methods

The appearance of the frozen fog requires a static and stable structure. The static and stable structure combined with the physical quantity shows the high altitude situation without obvious temperature advection, the ground form with poor air pressure, the inversion temperature, and the humidity near the ground. Therefore, this paper selects 7 physical quantities with close visibility and physical meaning, 500 hpa height field/temperature field, 850 hPa relative humidity, 850 hpa wind field, 850 hpa temperature, T2m temperature, mean sea level pressure. (Note: 2 m relative humidity is highly concentrated in the total time between 70 - 95, there is almost no difference between the visibility of each level, so the physical quantity is not considered in this paper). Urumqi Diwopu International Airport (hereinafter referred to as the airport), the coordinates of the center point of the runway are $43^{\circ}54'23''\text{N}$, $87^{\circ}28'28''\text{E}$. In this paper, (44°N , 87.5°E) is used as the data of the airport to extract and determine the indicators of different visibility weather occurrence.

The generation of freezing fog is a very complicated process, and there is no exact relationship between it and each physical quantity. It is the embodiment of the final effect after the interaction of multiple physical quantities with the law of the airport itself and the upstream and downstream effects. Therefore, this paper divides the visibility of the field into four levels for research and forecasting, and in order to distinguish between level 1 and level 4, the basic scores of the above two are significantly different. See **Table 1** for details.

3. Physical Quantity Field Analysis and Evaluation Score

3.1. Relationship between Visibility and 500 hpa Circulation and Sea Level Pressure Field

For the discrimination of the circulation background, the “Yes” and “No” discriminant, combined with the previous research conclusions, define the westward airflow type, the weak warm ridge type, the Bahu trough type, and the middle Asian high pressure ridge type as the circulation form of the occurrence of heavy fog. As shown in **Figure 1**.

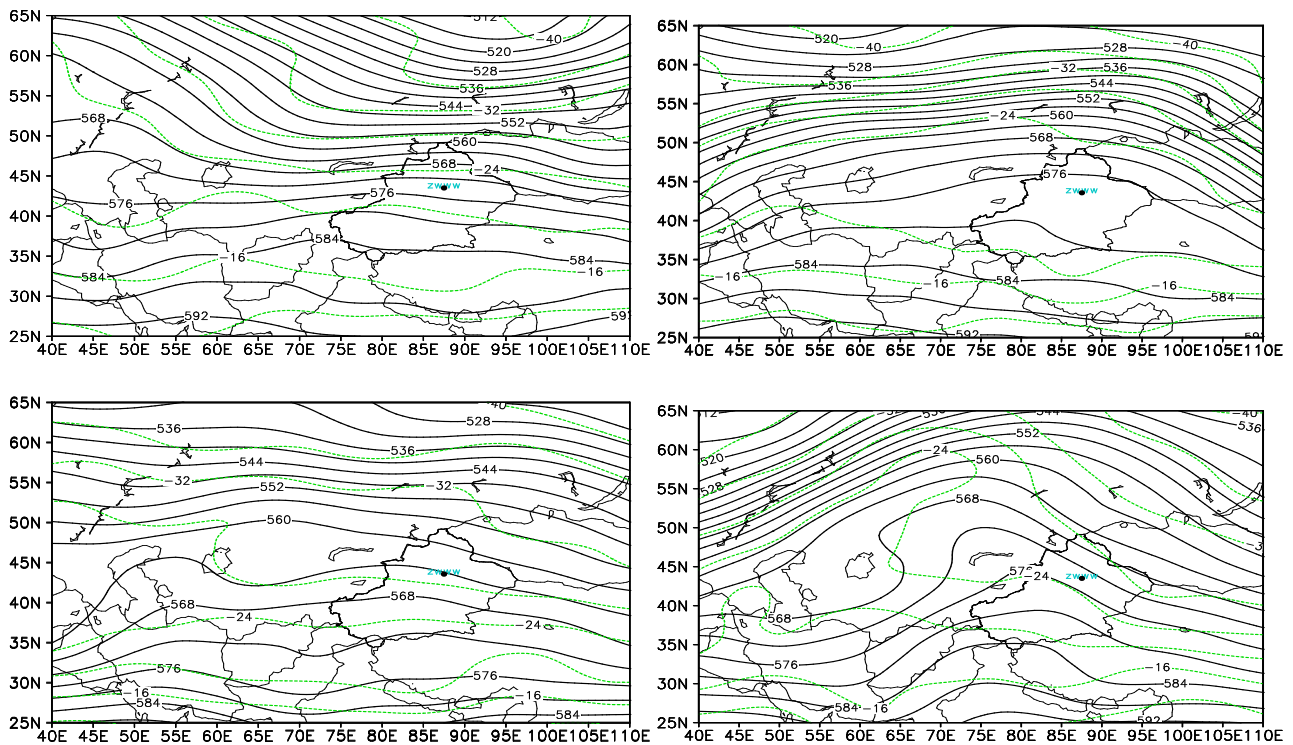


Figure 1. 500 hpa circulation form of frozen fog.

Table 1. Division of visibility levels.

Levels	Visibility Range	Base Score	Influence Level
4	>3000 m	0	Can Flight
3	1000 - 3000 m	40	Monitoring Phase
2	500 - 1000 m	100	Monitoring Phase
1	≤500 m	500	Not Flight

These figures are derived from the European fine grid (0.25 * 0.25) initial field (20 o'clock) and the forecast field within 24 hours. According to experience, the ground form is divided into the bottom of the high-pressure periphery or the bottom of the bottom, the belt-shaped high-pressure type, the transition zone of the north high and the low south, and the east-high west low-type is the form of the pressure field of the fog, as shown in **Figure 2**.

In addition, quantitative indicators can also be used to analyze: According to the relevant conclusions, based on the Lamb-Jenkinson method, it is concluded that there are five types of circulation in the field of heavy fog [9]. They are cyclone type (15.35%), easterly airflow type (13.17%), southeast airflow type (13.0%), westward airflow type (12.24%), and anticyclonic type (11.08%). And the sum of the probability of appealing the five types of circulation types is 64.85%, in order to judge the sea level pressure field of the fog. The above judgment is divided into “Yes” or “No”, and based on the “Yes” discriminant, combined with the following factor scores, the weather conditions of the field are predicted.

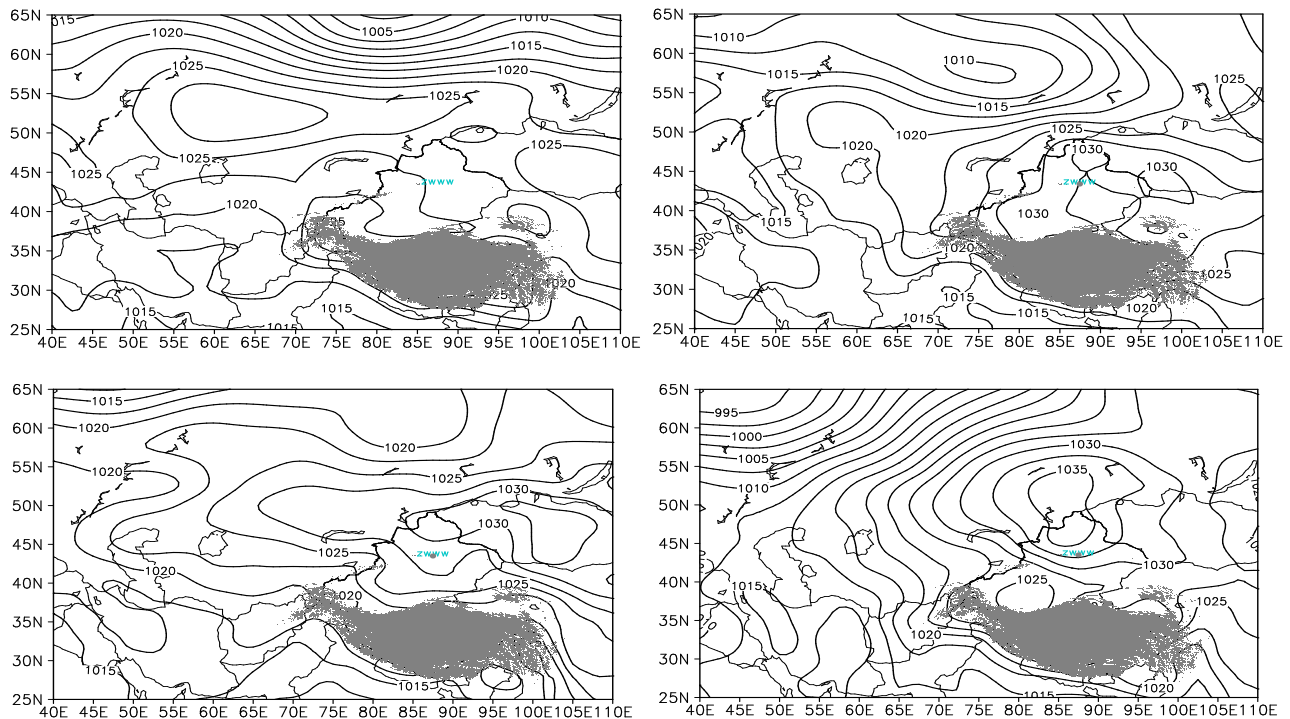


Figure 2. Mean sea level pressure field in the form of freezing fog.

3.2. Relationship between Visibility and Inversion

Combined with the existing conclusions [10], the visibility of the field has a good correspondence with the inversion of the T850 and the ground. Therefore, the T850 hpa-T2m is used to characterize the inversion of the sky over the field. The analysis results are as follows.

It can be seen that the visibility of the 2nd and 1st levels is mainly concentrated above 6 degrees (Figure 3). With the increase of the inversion temperature, the weather of the 4th grade rapidly decreases. The level 3 weather is excessive weather, and the inversion temperature is mainly concentrated at 6 - 12 degrees. The calculation method of the score is given in Table 1. The specific distribution is shown in Table 2.

3.3. Relationship between Visibility and Relative Humidity of 850 hpa

For this field, the maintenance of inversion temperature has a great relationship with the wind field of 850 hpa. Due to the special topographic effects, in the winter, the dry and warm cover caused by the southeast wind is easy to appear, which makes the 850 hpa dry, and the inversion temperature becomes stronger, and the progress can continue to go down. And in the fine grid data, the accuracy of the wind field and relative humidity of 850 hpa is greater than the ground temperature. In addition, the 850 hpa wind field can also well characterize the occurrence and development of disturbances, so it also has a good indication of the dissipation of heavy fog. So next article will study the relative humidity and

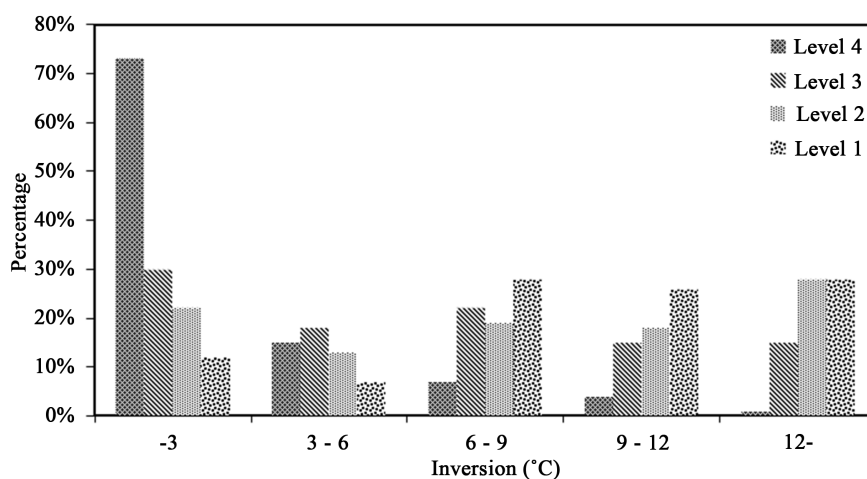


Figure 3. Inverse temperature conditions corresponding to different levels of freezing fog.

Table 2. Distribution of visibility and inversion at different levels.

T850-T2m (°C)	Level 4	Level 3	Level 2	Level 1	Score (Lev4)	Score (Lev 3)	Score (Lev 2)	Score (Lev 1)	Total score
-3	73%	30%	22%	12%	0	12	22	60	94
3-6	15%	18%	13%	7%	0	7	13	34	54
6-9	7%	22%	19%	28%	0	9	19	138	166
9-12	4%	15%	18%	26%	0	6	18	131	154
12-	1%	15%	28%	28%	0	6	28	138	172

wind field of 850 hpa.

It can be seen from **Figure 4** that the low-visibility weather corresponds to the dry layer development of 850 hpa, but the 40% - 50% relative humidity period is the over-visible stage, and visibility weather of all levels may occur (**Table 3**).

3.4. Relationship between Visibility and 850 hpa Wind Field

A synthetic analysis of the continuous freezing fog weather shows that the wind speed of A (44, 87.5) and B (44, 87.25) can better characterize the weather system affecting Urumqi Airport. Advancement of the southeast wind layer to the A-B point has an effect on the sky. The disturbance is sensitive at the B-A point when entering the disturbance, and there is a clear northwesterly flow response. Therefore, the paper takes A (44, 87.5), B (44, 87.25) two points for different levels of visibility, the performance of each wind field is as follows.

It can be seen that the A-point wind field is scattered when it is visible at the 4th level, and the southeast wind (100° - 180°) also occurs (**Figure 5**). However, in general, strong winds (greater than 8 m/s) were concentrated in the northwest wind (270° - 340°), which reflected that cold air entered at that time, and the static structure that formed the frozen fog was broken. As the visibility decreases, the wind direction at point A gradually moves closer to the southeast, and the

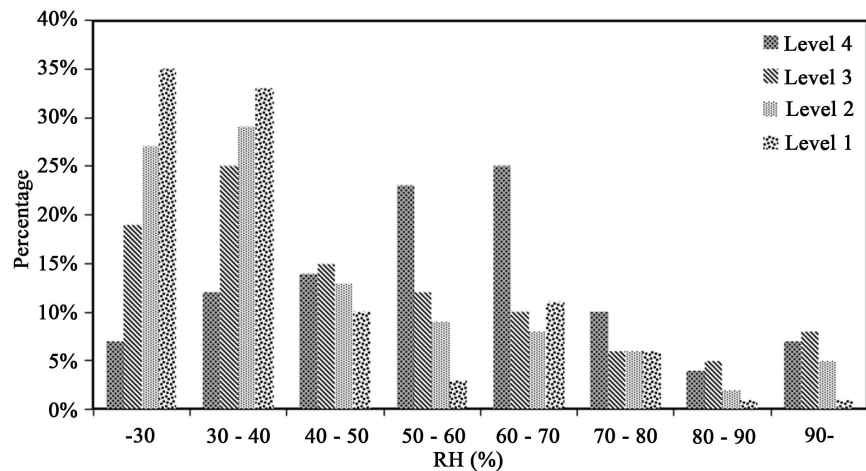


Figure 4. 850 hpa humidity corresponding to different levels of visibility weather.

Table 3. Distribution of visibility and relative humidity at different levels.

RH (850 hpa)	Level 4	Level 3	Level 2	Level 1	Score (Lev4)	Score (Lev 3)	Score (Lev 2)	Score (Lev 1)	Score
-30	7%	19%	27%	35%	0	7	27	174	208
30 - 40	12%	25%	29%	33%	0	10	29	167	206
40 - 50	14%	15%	13%	10%	0	6	13	48	67
50 - 60	23%	12%	9%	3%	0	5	9	15	29
60 - 70	25%	10%	8%	11%	0	4	8	56	68
70 - 80	10%	6%	6%	6%	0	2	6	30	38
80 - 90	4%	5%	2%	1%	0	2	2	7	11
90-	7%	8%	5%	1%	0	3	5	4	12

frequency and wind speed of the southeast wind increase. This feature is also manifested at point B. For point A, the northwesterly wind frequency and wind speed converge faster at point B, and the northwesterly and southeast winds of grades 3, 2 and 1 show greater differences. This is good for the division of visibility.

Combined with the characteristics of AB two-point wind field, this paper only studies the southeast wind (100° - 200°) and the northwest wind (250° - 350°). In addition, the establishment of the southeast wind layer contributes to the establishment and maintenance of the inversion layer and the 850 hPa dry layer, so the establishment of the southeast wind has a physical causal relationship with the above extracted indicators. In the field, the occurrence and maintenance of frozen fog has a large proportion, and the southeast wind has a large wind speed, and the freezing fog is thick and long-lasting. The northwest wind speed and visibility are better. Therefore, in the calculation of the following wind direction

wind speed, the southeast wind speed (5, 10] interval, the score is multiplied by 2, (10, 15] interval, and the score is multiplied by 3 on the original basis. The analogy (20, ∞) interval score is multiplied by 5 on the original basis. The specific demarcation scores are as follows.

Wind Direction of Point A	Wind Speed	Lev 4	Lev3	Lev 2	Lev 1	Score (Lev 4)	Score (Lev 3)	Score (Lev 2)	Score (Lev 1)	Score
100 - 200	00 - 05	18%	34%	30%	37%	0	13.5	30.4	185	228.9
100 - 200	05 - 10	7%	17%	18%	19%	0	6.6	17.9	190	214.5
100 - 200	10 - 15	1%	2%	2%	1%	0	0.9	2.2	15	18.1
100 - 200	15 - 20	0%	0%	0%	0%	0	0	0	0	0
100 - 200	20 -	0%	0%	0%	0%	0	0	0	0	0
250 - 350	00 - 05	21%	18%	21%	13%	0	7.4	20.9	63.4	91.7
250 - 350	05 - 10	22%	11%	7%	4%	0	4.3	6.6	22.4	33.3
250 - 350	10 - 15	2%	1%	0%	0%	0	0.4	0.4	0	0.8
250 - 350	15 - 20	0%	0%	0%	0%	0	0	0.4	0	0.4
250 - 350	20 -	0%	0%	0%	0%	0	0	0	0	0

Wind Direction of Point B	Wind Speed	Lev 4	Lev3	Lev 2	Lev 1	Score (Lev4)	Score (Lev 3)	Score (Lev 2)	Score (Lev 1)	Score
100 - 200	00 - 05	15%	17%	11%	19%	0	6.7	11.4	95	113.1
100 - 200	05 - 10	7%	25%	23%	30%	0	9.9	23.1	300	333
100 - 200	10 - 15	3%	9%	15%	10%	0	3.4	15.0	150	168.4
100 - 200	15 - 20	1%	2%	3%	5%	0	1.0	3.3	100	104.3
100 - 200	20 -	0%	1%	1%	3%	0	0.5	0.7	75	76.2
250 - 350	00 - 05	22%	18%	23%	11%	0	7.3	22.7	56	86
250 - 350	05 - 10	22%	11%	7%	6%	0	4.5	7.0	29.9	41.4
250 - 350	10 - 15	4%	1%	1%	0%	0	0.5	1.1	0	1.6
250 - 350	15 - 20	1%	0%	0%	0%	0	0.0	0.4	0	0.4
250 - 350	20 -	0%	0%	0%	0%	0	0.0	0.0	0	0

The wind fields of other times are replaced by the average value of the point. Finally, the data and the current wind field value are calculated by two points of AB.

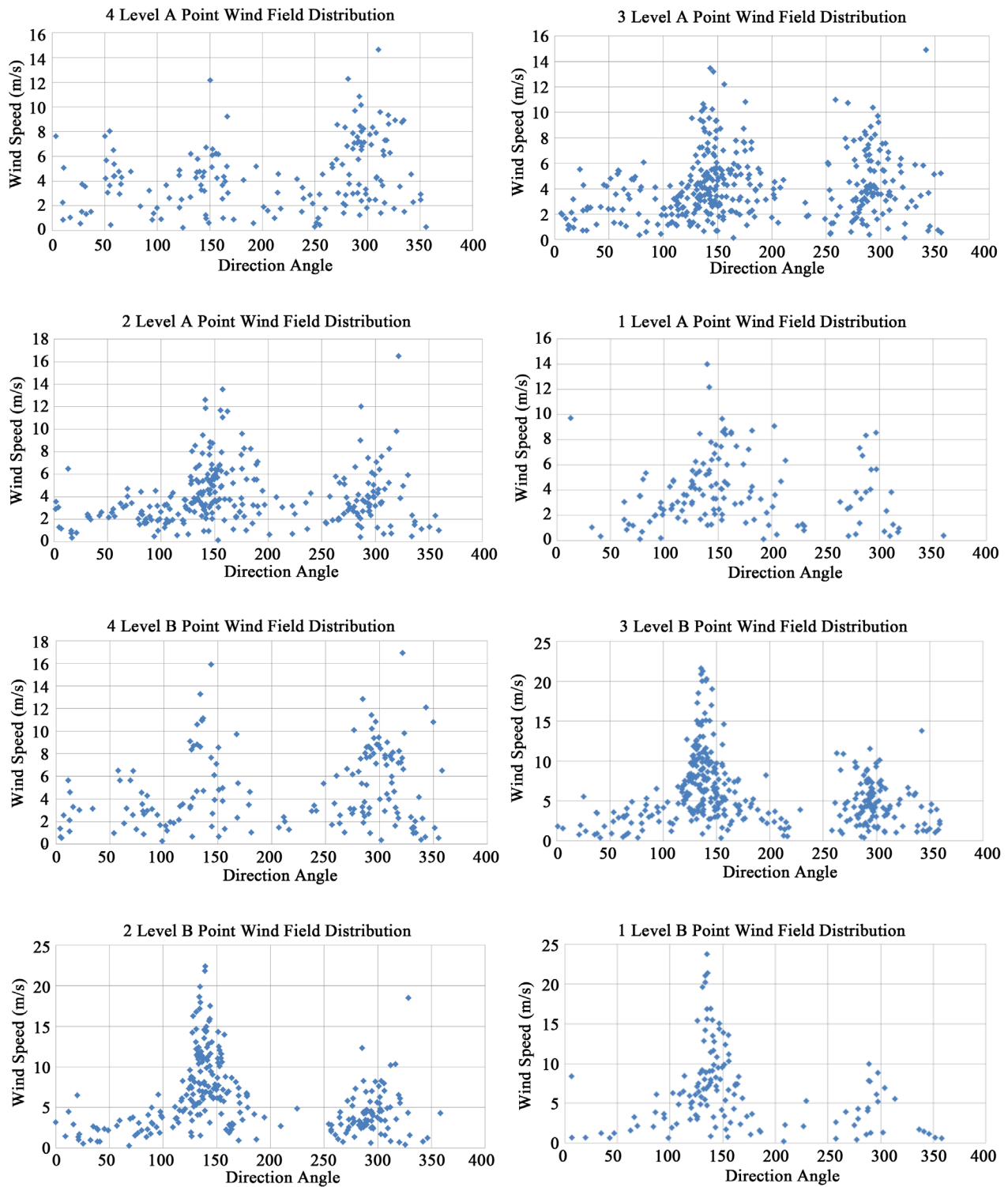


Figure 5. 8AB two points correspond to different levels of wind field distribution.

4. Visibility Level

According to the above analysis of physical quantity standards, this paper compares the time values with the visibility, and the results are as follows:

It can be seen that 84.2% level 4 is concentrated below 400 points, followed by a significant downward trend. Level 1 is the opposite, 63% is concentrated above 1000 points, and each level is less distributed at 600 - 1000 points. According to **Figure 6**, the level 2 level 3 resolution is not good, but level 1 and level 4 have significant differences. This has a good indication of daily work. Level 1 corresponds to a visibility of less than 500 meters, which does not meet the flight operating standards, and in most cases, the corresponding RVR is also below the operating standard. The visibility corresponding to level 4 is greater than 3000 meters. Above the operating standard, the aircraft can operate normally. Therefore, the definition score ≤ 400 is judged as level 4, ≥ 1000 points is judged as level 1, and the remaining scores are level 2 and level 3. The above two levels are not differentiated because they are all above the operational standards and most of the time does not affect the operation, but it is still closely monitored.

5. Inspection Result

Apply the data from December 2016 to February 2017 for the test and calculate according to the above method. Here we only check the forecast accuracy of level 1 and level 4. The accuracy rate of level 1 is 61.2%, and that of level 2 is 68.2%, which has certain indication significance in actual work; and the accuracy rate of level 4 is 97.2%, and the forecast is good.

6. Conclusions

1) It is feasible to use the European fine mesh 500 hpa height field/temperature field, 850 hpa relative humidity, 850 hpa wind field, 850 hpa temperature, T2m temperature, average sea level pressure and other physical quantities to test the visibility of the field, and it has certain warning effect.

2) The forecast of fog needs to be combined with the advancement and the correction. The method of this paper can predict the fog. The prediction of

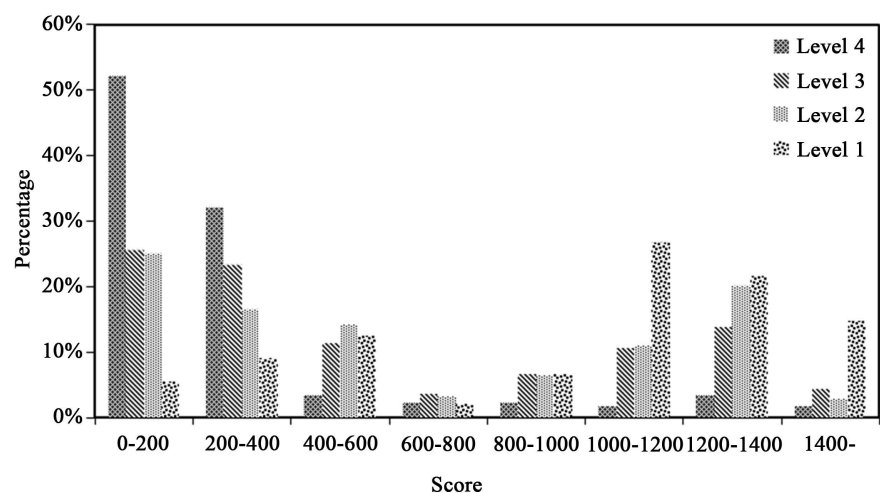


Figure 6. Corresponding situation of different levels of visibility judgment values.

visibility is based on the upstream and downstream effects, the wind profile and the performance of the surface wind field humidity.

3) The accuracy of this method for fog forecasting below 500 meters is 61.2%, and the accuracy of fog forecasting above 3000 meters is 97.2%. The conclusion is good and it has guiding significance for actual forecasting.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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