Analysis on the Causes of a Weather Forecast Mistake in Yan Liang Airport

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Abstract. Using the conventional weather maps and the T639 model numerical forecast products provided by Micaps system, we re-analyzed and diagnosed the precipitation weather process at Yan Liang Airport on May 26, 2018, and analyzed the reasons for the error in the 24-hour weather forecast on May 25. The analysis shows that the upper trough lines are distributed in the north and south, and the plateau low trough on the south side develops into a low vortex. With better water vapor conditions, the Changjiang-Huaihe shear line develops vigorously. When the colder air from the north-west meets the warm and humid airflow of the Changjiang-Huaihe shear line, the low vortex replenishes sufficient water vapor, and the floating dust brings abundant condensation nuclei to facilitate precipitation. During the whole process, the weather system moved slower than expected, but the weather process produced was more intense.

Keywords: Forecast error, numerical forecast product, precipitation, weather process

1. Introduction
With the advancement of science and technology, the accuracy and refinement of weather forecasts are constantly improving, but after all, weather forecasts are numerical forecasts, and it is difficult to achieve 100% accuracy. It can only be said that accurate forecasts are relative and forecasts deviations are absolute. Therefore, we should rationally evaluate the accuracy of weather forecasts and the accusations against forecasters. As a numerical forecast, weather forecasting takes meteorological observation data as the initial conditions, and uses large-scale computers to make numerical calculations, and then use fluid mechanics and thermodynamics equations to solve, finally predict the atmospheric motion state and weather phenomena in a certain period of time in the future. This prediction method requires the observation stations responsible for the initial data to reach an ideal state. At present, the distribution of observation stations in China is extremely uneven. For example, there are few meteorological observation stations on the Qinghai-Tibet Plateau. This compromises the accuracy of the weather forecast. In addition to the data limitations of the observation site, the
instrument observation error cannot be ignored. In addition, the professional quality and technical level of forecasters are also the key to controlling modern forecasting technical capabilities and improving forecasting accuracy and refinement.

Improving the accuracy of weather forecasts is still a worldwide problem. Therefore, at this stage we can only be as accurate as possible. On the one hand, we strive to improve the comprehensive quality of forecasters and form high-quality forecasting teams. Forecasters themselves must strengthen their learning, improve their scientific understanding and grasp of atmospheric laws, improve their ability to control numerical forecasts and to use new data, new methods. The ability to apply new technologies to improve the systematic analysis and grasp of high-impact weather such as catastrophes. On the one hand, forecasters efforts can be made to provide professional meteorological services, to do a good job in major weather processes and meteorological guarantee services for major events. On the other hand, forecasters can strengthen the research on the weather and climate system, so that the theoretical basis on which predictions are based is more perfect.

In summary, this thesis starts from the numerical data and basic data, focuses on the analysis of the reasons for the forecast errors on May 26, finds the rules for the configuration of the weather situation that does not often appear in this field, and provides references for future intelligent forecasting models. The major events will do a good job in the knowledge repository of special cases, find commonalities in different cases, and find differences in the same cases, so as to achieve an effective improvement in the accuracy of the weather forecast.

2. Comparison of 24-hour weather forecast between Yan Liang Airport and Shaanxi Meteorological Observatory

Both Yan Liang Airport Meteorological Observatory and Shaanxi Meteorological Observatory issued a 24-hour weather forecast at 16:00 on May 25, 2018. Both forecasted strong wind and dust in the central Shaanxi plain area at night on the 25th, but the Shaanxi Meteorological Observatory did not consider night showers. During the collective discussion of the weather at the Yan Liang Airport Meteorological Observatory, it is considered that there will be showers on the night of the 25th, which will have obvious dust reduction effects, and will be affected by strong winds. It is expected that the floating dust phenomenon will not have a significant impact on visibility on the 26th. The actual weather at Yan Liang Airport on May 26 was low clouds and overcast days, with light rain in the morning, and 60 to 90% of broken rain clouds. The cloud base height was 300 to 500 m, which had a significant impact on the flight test efficiency and progress on that day. The day, only one helicopter carried out a 95-minute test flight, and the rest of the test flight plans were cancelled.

Comparing the 24-hour weather forecasts of the two meteorological departments with the actual weather conditions at Yan Liang Airport, it is found that there are large discrepancies in cloud element forecasting. The Yan Liang Airport Meteorological Observatory has a preference for early morning visibility forecasts (Shaanxi Meteorological Observatory does not produce visibility forecasts). The forecast of wind direction by the Yan Liang Airport Meteorological Observatory is consistent with the actual situation, and the forecast of wind speed is slightly lower. The guidance forecast of wind direction and wind speed issued by the Shaanxi Meteorological Observatory is basically consistent with the actual weather situation at Yan Liang Airport. In terms of weather forecasting, the Yan Liang Airport Meteorological Observatory forecasted showers, but the actual situation was light rain; Shaanxi Meteorological Observatory did not consider precipitation, and both meteorological departments forecasted sand and dust phenomena.

3. Weather situation analysis

3.1 Analysis of weather chart at 08:00 on the 25th

On the 500hPa high altitude map at 08:00 on May 25, 2018 (Figure omitted), the middle and high latitudes of Eurasia are two troughs and two ridges, one low trough each over the Urals and the Sea of Japan, the big trough of the Urals is north of 65°N with a cold center, the cold air splitting in front of
the big trough of the Urals reaches Hami, Xinjiang, and forms a cold vortex trough in Hami, with a 3-hour temperature change of -3 to -6 ℃. More short-wave troughs are active in the mid-latitudes, there is a short-wave trough from Shandong over the central Shaanxi plain to the western part of Shaanxi-Tsinglingense, Yan Liang airport is in the influence of the trough area. On the 700hPa high altitude map, the cold center near the westerly trough is located at 92°E, 53°N, splitting the cold air southward to form a dense area of temperature gradient in eastern Xinjiang and the Kansu Corridor [1-2], with a 3-hour temperature change of -7 to -13 ℃. The mid-latitude airflow is more volatile, and the low trough at the bottom of the North China low vortex crosses Taiyuan to Xi'an, and Yan Liang Airport is affected by the northeast airflow after the trough. The 850hPa temperature gradient dense area is located in the middle of the Kansu Corridor, the 3-hour temperature change reaches -12 ~ -17 ℃. It can be seen that the cold air brought by the high altitude trough along with strong sinking airflow has affected the boundary layer.

At 08:00 on the 25th on the ground weather map, the cold front is located in the Helan Mountains - Lanzhou - Kangting, the cold front behind the Badain Jaran Desert and the Tengger Desert 40°N north of the region has a small range of sand, floating dust phenomenon (a total of two stations recorded).

In the early morning of the 25th, Yan Liang Airport showers, the weather turned clear in the afternoon, small daily changes in the field, the wind speed in the morning was 0 ~ 2 m / s, the wind direction is uncertain, after 11:00 stable for the system after the southwest wind 4 ~ 6 m / s.

3.2 Analysis of the weather chart at 20 o'clock on the 25th

At 20:00 on May 25, 2018, the 500hPa high altitude map (figure omitted) on the cold center is located at 97°E, 55°N; 70 hPa cold center is located at 97°E, 53°N, $\Delta T3 = -10 ~ -13 ℃$, 850hPa cold center pressed south to the west of Liupan Mountain, $\Delta T3 = -9 ~ -15 ℃$, there is a strong warm center around Hohhot in the northeast of the Hetao area. The warm center temperature is 24 ℃. The cold and warm centers are located in the east and west of the Hetao area, resulting in the dense temperature gradient line, close to the northwest-southeast distribution. On the ground map, the cold front is located in Yinchuan – Chengdu. The high altitude - ground overall system at 20:00 is eastward 5 degrees longitude than 08:00, which are moving faster than T639 model numerical forecast products forecast.

On the night of May 25, the field weather cloudy to overcast, the temperature is lower than the highest temperature during the day 8 ℃, wind speed at about 3:00 a.m. began to increase, continued for the southwest wind 4 ~ 6 m / s mainly. Sand lifting was observed at 5:30 a.m. at this site, and visibility dropped to 3 km, indicating that cold air had moved south to this site and the weather system moved faster than expected.

3.3 Analysis of the weather chart at 08:00 on May 26, 2018

On the 500hPa high altitude map at 08:00 on the 26th (Figure 1a), the middle and high latitudes of Eurasia are two troughs and one ridge, the high pressure in the Bay Lake area is strengthened, the cold air split by the large the Urals trough moves eastward to 107°E, 50°N, accompanied by a -20 ℃ cold center, the Tibet plateau trough extends from Lanzhou to the east side of the Tibet plateau. Yan Liang field is controlled by the southwest airflow in front of the Tibet plateau trough, the Ningxia-the central Shaanxi plain isotherm is dense, $\Delta T3 = -7$ to -11 ℃. 700hPa (Figure 1b) is the same as 500hPa, with a high-pressure center in the mid-latitude plateau and the Changjiang-Huaihe shear line in Nanjing-Anhui on the south side, the field is the intersection of plateau high pressure and Changjiang-Huaihe shear line, controlled by northeast airflow. 850hPa (Figure 1c) is the front of the Tibet plateau of northerly airflow, the field west of $\Delta T3 = -7$ ~ -11 ℃ cold advection. North China has a warm center which temperature is 20 ℃. Shaanxi eastern is the east - west strong cold and warm air convergence area.

05:00 on the ground weather map (Figure 1d), the cold front is located in Taiyuan - Xi'an - Chengdu, Yan Liang field is in the front after the western Helan Mountains $\Delta P24 = +14hPa$. 08:00
on the ground map near the Helan Mountains $\Delta P24 = +15\text{hPa}$. The Hetao area pressure gradient is dense, the cold front eastward to Taihang Mountains - eastern the central Shaanxi plain. The cold front north of the eastward faster, the southern section of the stable less mobile, affecting the central Shaanxi plain and southern Shaanxi produce Light rain.

May 26 Yan Liang field weather is sand, dust, with light rain. The visibility influenced by sand and dust that impact of the short turn poor. Then after a light rain wash, the visibility quickly turns good. The gale is 6 to 8 m / s, gusts of 8 to 10 m / s. The precipitation process affects the system for 500hPa shallow trough at high altitude, water vapor conditions are the north of the Changjiang-Huaihe shear line at 700hPa where are easterly airflow water vapor transport. The trigger mechanism is the warm center of North China and the western Hetao area strong cold air in the central Shaanxi plain meet. Badain Jaran Desert and the Tengger Desert source from the sand with high altitude gale south to affect the central Shaanxi plain, resulting the sand, dust, light rain weather in the central Shaanxi plain.

Figure 1. Weather chart analysis of 500 hPa altitude chart at 08:00 on May 26 (a), 700 hPa altitude chart weather chart analysis (b), 850 hPa high-altitude weather map analysis (c), ground weather map analysis (d), the red five-pointed star in the picture is the field.

4. Physical field analysis

4.1 Relative humidity field analysis
On the 500hPa relative humidity field (Figure 2a) at 08:00 on May 26, the relative humidity in eastern the central Shaanxi plain reached 80%-90%, and the T639 numerical forecast model product [3-4] predicted that the development trend was that the high humidity area in the west would gradually move eastward and affect the central Shaanxi plain area during the day. At 700hPa (Figure 2b), the T639 numerical forecast model products forecast 70% to 80% relative humidity in the central Shaanxi plain throughout the day. At 850hPa (Figure 2c), the relative humidity is 40% to 50% at 08:00, and T639 numerical forecast model products forecast 50% to 60% relative humidity in eastern the central Shaanxi plain throughout the day, with the high humidity area in the Yangtze River basin. Overall, the humidity field does not cooperate well to meet the precipitation conditions for this light rain.
4.2 Water vapor flux field analysis
The meaning of water vapor flux is the mass of water vapor flowing through a unit cross-sectional area orthogonal to the velocity per unit time. It indicates the direction and intensity of water vapor transport.

Analysis of the water vapor flux at 20:00 on May 25 (Figure omitted) and the water vapor flux field at 08:00 on May 26 reveals that at 500 hPa 20:00 on the 25th, there is a water vapor flux 0~40 g/(cm-hPa-s) on the east side of the Hexi Corridor-Plateau, and at 08:00 on the 26th the water vapor on the east side of the Plateau moves eastward to Shaanxi-Sichuan with a water vapor flux of 40 g/(cm-hPa-s), which is consistent with the eastward path of the plateau trough. At 08:00 on the 26th the water vapor flux at 700 hPa was 40 g/(cm-hPa-s) less than that at 20:00 on the 25th. 850 hPa water vapor flux strong center location with 500 hPa, 26th 08:00 the central Shaanxi plain area water vapor intensity than the 25th 20:00 more 40 g/(cm-hPa-s), indicating that the 26th field 850 hPa from the north side of the Changjiang-Huaihe shear line convergence of water vapor, 700 hPa water vapor flux is lower than the previous day. In a comprehensive view, there is moisture gathering in the high and low layers, the water vapor conditions in the middle layer are slightly worse, not entirely favorable to the precipitation situation.

4.3 Analysis of divergence field
At 08:00 on May 26 2018 (Figure 3), a strong negative center in eastern the central Shaanxi plain at 500 hPa (Figure 3a), indicating where is a convergence area. And there is a positive center in eastern the central Shaanxi plain at 700 hPa (Figure 3b), indicating where is a divergence area. The divergence in eastern the central Shaanxi plain at 850 hPa (Figure 3c) is a negative center, indicating where is a convergence area. Through the above analysis that the low level of eastern the central Shaanxi plain is convergence and the middle level is divergence. In order to compensate for the dispersion of the middle layer, the middle and low layers must have an up-flow, which is conducive to the intersection of cold and warm advection [5-6] and triggers the instability mechanism.
4.4 Infrared Satellite cloud image analysis

From the infrared satellite image at 22:30 on the 25th (Figure 4a), we can see that there is a band-like cloud system from Helan Mountain-Lanzhou-North of Lhasa, which is consistent with the position of the upper-level trough. There is a vortex cloud system on the south side of Lanzhou, the temperature of the cloud top is low, the cloud mass is developing vigorously which is moving to the northeast. In addition, there is a lateral cloud band in Changjiang-Huaihe area which matches the position of the Changjiang-Huaihe shear line, where is an unstable cloud mass with extremely strong development in cloud band. At 04:30 on the 26th (Figure 4b) the band cloud system moved east to Hohhot-Hetao-Chengdu, the vortex cloud system south of Lanzhou moved east and weakened, forming a small band cloud system in Shaanxi-Yinchuan-Lanzhou. At 09:30 on the 26th (Figure 4c) the band cloud system at Hohhot weakened slightly, Shaanxi Yan Liang is in the tail cloud band of the band cloud system, the small band cloud system in the Hetao area moved northeastward to North China which formed a cloud mass. At 13:30 on May 26 (Figure omitted), the band cloud system at Hohhot moved eastward to the northeast, and the tail of the band cloud system moved eastward to the south of Shanxi. Shaanxi Yan Liang Airport is affected by low and medium clouds where the precipitation already stopped.

Figure 4. Infrared satellite cloud image at 22:30 on May 25 (a), infrared satellite cloud image at 04:30 on May 26 (b), infrared satellite cloud image at 09:30, the red five-pointed star in the picture is the field.

5. Conclusion

Summary, the current weather process that upper-level trough line runs north-south, the plateau trough develops into a northwest vortex, bringing better water vapor conditions. The Changjiang-Huaihe shear line develops vigorously. The two weather systems from north and south converge in the east side of Shaanxi, the plateau trough with the strong cold air from the northwest south meets the warm and humid airflow from the Changjiang-Huaihe shear line where produce precipitation weather. The weather systems of the whole process are stronger than the forecast, so the weather phenomena produced are also more intense.

5.1 Analysis of the cause of forecast errors

5.1.1 Overview of forecast ideas. The weather process is mainly influenced by the eastward movement of the 500hPa plateau trough, controlled by the northeasterly airflow at the top of the 700hPa Changjiang-Huaihe shear line. Meanwhile, the small trough split by the large Ural Mountain trough with the strong cold center moving southward, which meets with the warm and humid airflow from the Changjiang-Huaihe shear line where produce precipitation weather. The weather systems of the whole process are stronger than the forecast, so the weather phenomena produced are also more intense.
upper-level char the Yan Liang Airport is the northward airflow in front of high-pressure center on the plateau. The cold trough at the Kansu corridor is expected to affect the central Shaanxi plain in the evening of 25th where will have windy and cooling weather at night. The sandy weather appears at two stations near Alashan League on the surface map where the scope is small and the intensity is weak. It is expected not to cause too strong floating dust weather in the central Shaanxi plain, and the windy and cooling showers at night make the floating dust purified that expected not to be affected by floating dust during the day. According to the above analysis, so the forecast of the Yan Liang Airport is cloudy to overcast weather during the day on 26th, and the visibility is good with windy and cooling.

5.1.2 Analysis of the causes of forecast errors. A) There are few floating dust stations upstream which make us consider this process as light floating dust and much less than the intensity of the impact of the actual situation. But the interaction between weather phenomena should be fully considered, and think of the floating dust brings abundant condensation nuclei to facilitate the occurrence of precipitation.

b) The T639 numerical forecast did not report the development of a low vortex to the south of Lanzhou, which seriously affected the precipitation forecast of this process, and the low vortex brought sufficient water vapor conditions for this precipitation.

c) The impact speed of the whole process is considered slightly faster than the actual situation, mainly considering that the 26th day is controlled by the anticyclone front after the system, but the actual situation is influenced by the development of the low vortex makes precipitation delayed and more intense.

5.2 Summary of forecast support experience.

(1) As long as there is a weather system, weather elements should be reflected. Although the weather system configuration is not a typical precipitation situation, but still to carefully consider the probability of precipitation. When missed or weak elements of the test flight have an impact on progress, efficiency, quality, safety that is much greater than the empty report.

(2) When multiple weather systems affect together, we need to analyze the degree of impact of each weather system, and more comprehensively analyze the superimposed effect of multiple weather systems. Generally, the forecast of the Yan Liang Airport mainly focuses on the weather systems from the northwest southward and southwest northward, but seldom considers the weather systems on the southeast side which is easy to ignore the impact of the system on the Yan Liang Airport. Therefore, the future forecast should take into account the direction, intensity, and water vapor of the system in order to prepare for the weather that may occur or will occur in the Yan Liang Airport.

(3) The knowledge base of special cases should be prepared, not only to summarize the successful cases, but also to enhance the summary and refinement of the failed cases. So as to accumulate the experience of failed forecasts and learn the lessons, and to lay the foundation for the improvement of the quality of weather protection.

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