Analysis of temperature threshold in flight test

Ying Zhang¹,² *, Bin Wang¹,³, Xinyu Liu¹,², Ping Ni¹,², Wenhui Yan¹,²

¹Meteorological Observatory of Field Affairs Department Chinese Flight Test Establishment, Xi’an, China
²Aeronautical Meteorological Research Center of Aviation Industry Corporation, Xi’an, China
³Test Pilot Training and Flight Service Center, Xi’an, China

*Corresponding author: 1449665788@qq.com

Abstract. The annual, seasonal, monthly and daily distribution characteristics, as well as the occurrence and duration of air temperature at Yan Liang Airport were statistical analysis by Matlab software using surface meteorological observation air temperature data from May 2014 to May 2019. It is discussed that the average temperature threshold distribution ranges from 10-25℃ in spring, 25-35℃ in summer, 15-25℃ in autumn and 0-15℃ in winter. It showed a good negative correlation with the temperature and relative humidity and it passed the significance test. The daily difference of temperature is positively correlated with the cloud amount. When the total cloud cover is 8-10 amounts, the daily difference of temperature is about 4℃. When the total cloud cover is less than 7 amounts, the daily difference of temperature is 9-10℃. When the total cloud cover is 0-3 amounts, the daily difference of temperature is 9-10℃. Statistics founds that the lowest temperature of Yan Liang Airport in the past 5 years was -13.2 ℃, and the highest temperature was 41.8 ℃. The minimum temperature occurred in January and the maximum temperature occurred in July. The daily minimum temperature occurred from 05:00 to 07:00 and the daily maximum temperature occurred from 15:00 to 16:00. The corresponding conclusions can provide a scientific basis for the decision of the "window" for a certain subject of flight test. Improve the utilization of meteorological resources and the efficiency that also ensure the progress of the test flight.

Keywords: Flight test; Temperature threshold; Low temperature; High temperature

1. Introduction

Flight test meteorological support has its own unique characteristics. There are specific needs for meteorological elements, such as temperature, humidity, precipitation, wind speed, etc. Currently, the test aircraft has specific support needs for air temperature during the test. For example, aircraft large weight takeoff subjects which are divided into maximum weight and larger weight. Aircraft large weight takeoff subjects are affected by the aircraft thrust, the length of the runway and other factors. When the field temperature rises, the atmospheric air density decreases, the air pressure decreases, resulting in a reduction in engine thrust. To test out the critical threshold of aircraft large weight takeoff, there are certain requirements on the field temperature. Based on the above reasons, this thesis
focuses on the daily, monthly, quarterly and annual temperature changes in Yan Liang Airport with 5°C as a grade, to find out the temperature evolution law, summarize the temperature refinement forecasting method, and guarantee the demand of temperature forecasting for the test aircraft.

At present, domestic research on temperature is mainly discussed from the perspective of inter-annual variation, climate change, high temperature, low temperature, etc. For example, Sui H Q [1] and others studied the annual and seasonal average temperature, maximum and minimum temperature change characteristics of Dalian City from 1951 to 2010. Shi H B [2] studied the climatic characteristics of the number of high temperature days and change patterns in North China. Zhang S J [3] and others studied the characteristics of high temperature disasters in East China in the past 60 years. Ye D X [4] and others studied the spatial and temporal characteristics of high temperature heat waves in China from 1961 to 2010. Sun X [5] analyzed the stage (April-June) low temperature circulation in the central and western regions of Jilin Province.

In summary, domestic experts and scholars mainly study the impact of high temperature and low temperature weather on people's life, production and natural disasters, but no scholars have studied the correlation of temperature from the perspective of flight test. Therefore, this thesis statistics the temperature data of Yan Liang Airport in the past 5 years with 5°C as a grade. According to the horizontal and vertical distribution of time to determine the arrangement of the test season, then gradually refined to a certain time period of a day in the month. In order to find the distribution range of the temperature threshold of Yan Liang Airport, to lay the foundation for scientific arrangement of test subjects and ensure the rational use of meteorological resources.

2. Data analysis

2.1 Monthly variation pattern of overall temperature
The monthly changes of temperature in the past five years (2014.5-2019.5) were calculated and the monthly curves of temperature changes at 08:00, 12:00 and 16:00 were plotted (Fig.2). It is observed that the curves in figure 2 show a single-peak change in temperature at all three times, and the temperature curves are consistent. The average maximum temperature of the year was found to occur in July, and the average minimum temperature was found to occur in January.

2.2 Four-season temperature change pattern
The hour-by-hour variation of temperature in spring (March-May) for the five years (2014.5-2019.5) was counted and plotted in the following graph (Figure 2). It is observed in Figure 2(a) that the temperature in March, April and May increases step by step. The overall temperature in April is 3-5°C higher than that in March, and the May is 3-5°C higher than April. The three temperature curves are all have a single peak change, and the same pattern of daily temperature change, with the highest daily temperature occurring at 15:00-16:00 throughout the day. The daily temperature difference is around 10°C, and the average temperature threshold distribution in spring ranges from 10-25°C.

The analysis of Figure 2(b) shows that the low temperatures in June, July and August are close to each other, and the high temperature in July is obviously higher than that in June and August by about
The daily difference in temperature reaches 15°C, and the daily maximum temperature in summer is basically reached at 16:00. The average temperature threshold distribution in summer ranges from 25-35°C. The analysis of Figure 2(c) shows that the daily difference of temperature in September and October is around 8-10°C. The daily maximum temperature occurs at 15:00, and the average temperature threshold distribution in autumn is in range of 15-25°C.

The analysis of Figure 2(d) revealed that the temperature curves in November, December and January increased step by step, with a large daily temperature variation of 15°C in February. The overall lowest temperature of the year occurred in January, with temperature thresholds between -5-5°C. The smallest daily temperature variation range of the year occurred in November, between 5-10°C. And the average temperature threshold distribution ranges 0-15°C in winter.

Figure 2. Hourly curves of temperature in four seasons, (a) is the hourly curve of spring temperature graph, (b) is the hourly curve of summer temperature graph, (c) is the hourly curve of autumn temperature graph, (d) is the hourly curve of winter temperature graph.

3. Elements of temperature forecasting

3.1 The relationship between temperature and relative humidity
The correlation coefficient is a measure of the degree of linear correlation between variables, which is used to indicate whether there is a correlation between two variables and the degree of closeness of the correlation. There are Pearson correlation coefficient and Spearman correlation coefficient. Generally, a correlation coefficient above 0.7 indicates a very strong relationship, and it indicates a strong relationship between 0.4 ~ 0.7, and an average relationship between 0.2 ~0.4.

The time-by-time information of temperature and relative humidity for the five years (2014.5-2019.5) were counted, and scatter plots were applied to plot the temperature and relative humidity values one by one, and the results are shown in Figure 3. Observing the distribution pattern of scatter values in Figure 3, it was found that the relative humidity showed a good negative correlation with the air temperature. To get further verification, the correlation coefficient between the relative humidity values and the air temperature values for the five years (2014.5-2019.5) from 06:00
to 22:00 times was calculated and the result was tested for significance.

![Figure 3. Correlation curve of temperature and relative humidity.](image)

Significance testing is to make a prior assumption about the parameters of the aggregate or the form of the aggregate distribution, and then use the sample information to determine whether this assumption is reasonable. I.e., to determine whether the true situation of the aggregate is significantly different from the original assumption. The significance test determines whether the difference between the sample and the hypothesis we made about the aggregate is purely chance variation or is caused by an inconsistency between the hypothesis we made and the true state of the aggregate. Significance answers the question of whether there is a relationship between them, and significance indicates whether the results obtained are due to chance (statistically significant). The correlation coefficient answers the question of the strength of the correlation. If the P value (also known as Sig value or significance value) is less than 0.01, that means something happened with at least 99% certainty. And if the P value is less than 0.05 (and greater than 0.01), that means that something happened with at least 95% certainty. When P value is <0.01 or P<0.05, then the level of significance is indicated.

### Table 1. Significance analysis of temperature and relative humidity.

| Project | T/℃  | RH/% |
|---------|------|------|
| Pearson correlation | 1    | -0.99 |
| Significance (bilateral) | -    | 0.00 |
| N       | 17   | 17   |
| RH/%    |      |      |
| Pearson correlation | -0.99 | 1    |
| Significance (bilateral) | 0.00 | -    |
| N       | 17   | 17   |

The correlation and significance of the two sets of data were calculated using SPSS software, and the correlation coefficient was obtained as -0.989 after calculating the weighted average of the 5 years. By performing the significance test on the two sets of data, a P-value of 0.00 was obtained, indicating that the correlation between temperature and relative humidity is high and significant at the 0.01 level (two-sided).

#### 3.2 Relationship between temperature and cloudiness

The daily difference in temperature was 3.96°C for overcast (10 total clouds) days in spring, 9.87°C for 8-10 clouds. There is 2.95°C for overcast days in summer, 10.4°C for 8-10 clouds. In autumn, the daily temperature difference is 3.86°C in the case of 10 total clouds, 8.59°C for 8-10 clouds. In winter, 2.85°C in the case of 10 total clouds, and 6.65°C in the case of 8-10 clouds. The daily difference in temperature is 9.13°C in the case of (4-7 total clouds) throughout the year. The daily difference of temperature in the case of (0-3 total clouds) is 10.36°C throughout the year.
When the total cloud cover is 8-10 amounts, the daily temperature difference is around 4℃ in spring and autumn, and 3℃ in winter and summer; when the total cloud cover is less than 7 amounts, the daily temperature difference is 9-10℃ in spring, summer and autumn, and 6-7℃ in winter when there are 4-7 total cloud covers. In winter, the daily difference of temperature is 6-7℃ when there are 4-7 total clouds, and the daily difference of temperature is 9-10℃ when there are 0-3 total clouds.

![Figure 4. The relationship between daily temperature range and cloud amount.](image)

4. Analysis of extreme temperature

4.1 Maximum temperature
By the statistical of hour-by-hour temperature data for the past 5 years (2014.5-2019.5), it shows that the highest temperature was 41.8℃, which appeared at 16:00 on July 11 and July 24, 2017. Analyzing the upper-level weather situation found that: The 500hPa high altitude map of the middle and high latitudes of Eurasia and north of Baikal Lake is controlled by a large low vortex. The 588hPa line of the mid-latitude subtropical upper-level system is located in Shandong Peninsula - the Central Shaanxi Plain - Central China, and there is a high-pressure center in central Inner Mongolia - Kansu Corridor. Northern Shaanxi is between two high pressures, and the Central Shaanxi Plain area is controlled by the subtropical high pressure. The weather of the Central Shaanxi Plain is sunny, the solar shortwave radiation is intense, and the surface is warming rapidly, resulting in high temperature weather at Yan Liang Airport.

4.2 Minimum temperature
The lowest temperature was -13.2℃, which appeared at 06:00 on January 25, 2016. Analyzing the high-altitude weather situation found that: The 500hPa high altitude map of the middle and high latitudes of Eurasia to establish the East Asian trough, and mid-latitude Shaanxi is under the control of northwest airflow after the East Asian trough. The cold center is located in Bohai Bay, reaching -40℃. The night before January 25, 2016, the sky above Yan Liang field is clear, and the ground long wave radiation makes the ground base temperature is low. Therefore, the field appeared low temperature weather.

5. Application of temperature threshold in subject flight test
From the inter-annual and seasonal changes in temperature, it was found that the subjects with 10-25℃ were suitable to be scheduled in spring and autumn (March, April, May, September, October), where the daily change in temperature in spring was larger than that in autumn, reaching 9-11℃, which was conducive to the arrangement of multiple temperature threshold subjects on the same day. The subjects with 25-40℃ were suitable to be scheduled in summer (June, July, August), where the daily change in temperature in summer was the largest in the whole year, reaching 10-12℃, which was beneficial to the arrangement of multiple temperature threshold subjects on the same day. It
is suitable to increase the early field and night flight. -5-15°C subjects are suitable to be arranged in winter (November, December, January, February).

Through the above statistical analysis found that the temperature threshold range is the widest in January, February, July, August, conducive to the arrangement of subjects with large temperature changes. In November, the temperature threshold range is the narrowest, conducive to the arrangement of 5-10 °C subjects, so that it can fly more days for single-month temperature demand subjects. The subjects which need greater than 30 °C temperature can be arranged in July and August. The temperature distribution of -15-25°C is more abundant, and the related subjects can be arranged in April, May, September and October. The temperature demand subjects of 0-5°C can be arranged in January, February and December. The subjects below 0°C are suitable to be arranged in January and February.

6. Summary
1) The average temperature threshold range in spring is 10-25°C. The average temperature threshold range in summer is 25-35°C. The average temperature threshold range in autumn is 15-25°C. The average temperature threshold range in winter is 0-15°C.

2) The months with the highest frequency of temperature were selected as the recommended test flight months: -5~0°C for January, 0~5°C for December, 5~10°C for February and November, 10~15°C for March, 15~20°C for April, 20~25°C for May, and 25~30°C for June, 25~30°C choose June, 30~35°C choose August, 35~40°C choose July.

3) The relative humidity and air temperature showed a good negative correlation with the correlation coefficient of -0.989. The significance test of the two sets of data obtained a P-value of 0.00, indicating that the air temperature and relative humidity are highly correlated and significantly correlated at the 0.01 level (two-sided).

4) The temperature and cloud amount showed a good positive correlation. When the total cloud cover is 8-10 amounts, the daily difference of temperature is about 4°C in spring and autumn, and 3°C in winter and summer. When the total cloud cover is less than 7 amounts, the daily difference of temperature is 9-10°C in spring, summer and autumn. In winter, the daily difference of temperature is 6-7°C in the case of 4-7 cloud amounts. The daily difference of temperature is 9-10°C in the case of 0-3 cloud amounts.

5) The minimum temperature of the Yan Liang Airport in the past five years (2014.5-2019.5) is -13.2 °C, and the maximum temperature is 41.8 °C. The minimum temperature occurs in January, and the main maximum temperature occurs in July. The daily minimum temperature occurs at 05:00-07:00, and the daily maximum temperature occurs at 14:00-16:00. The low temperature (daily minimum temperature <0 °C) mainly occurs under the weather conditions of when the northwest airflow controlling the Central Shaanxi Plain after the East Asian trough. The high temperature weather (daily minimum temperature >30 °C) mainly occurs in the weather conditions when the sub-high extends westward to the south of the Central Shaanxi Plain, there is a high-pressure center in the northwest of the Loop, Shaanxi is between the two highs, and the shear is located in the north of the Yan Liang Airport.

References
[1] Sui H Q, Zhang C F, Wang X P, etc. Characteristics of temperature changes in Dalian from 1951 to 2010[J]. Journal of Meteorology and Environment, 2011, 27(5): 46-52.
[2] Shi H B. Climatic characteristics and changing laws of high temperature days in North China[J]. Geographical Science, 2012, 32(7): 866-871.
[3] Zhang S J, Yin Z E, Wen J H, et al. Analysis of the characteristics of high temperature disasters in East my country in the past 60 years[J]. Journal of Shanghai Normal University (Natural Science Edition), 2011, 40(1): 95-101.
[4] Ye D X, Yin J F, Chen Z H, etc. Temporal and spatial variation characteristics of summer high temperature and heat waves in my country from 1961 to 2010[J], Progress in Climate Change
[5] Sun Xia. Circulation analysis and medium-term forecasting method research of phased low temperature in the central and western regions of Jilin Province (April to June) [J], Jilin Meteorology, 2003.