International Civil Aviation Organization

INFORMATION PAPER

Asia and Pacific (APAC)
Fourteenth Meeting of the Meteorological Requirements Working Group (MET/R WG/14)

Bangkok, Thailand 28 April – 2 May 2025

Agenda Item 3: Collaboration between MET and ATM stakeholders

TEMPORAL AND SPATIAL CHARACTERISTICS OF AIRCRAFT TURBULENCE ON THE SLPOE OF QINGHAI-TIBET PLATEAU AND TURBULENCE FORECASTING SYSTEM BASED ON EDR

(Presented by China)

SUMMARY

This paper introduce the temporal and spatial characteristics of aircraft turbulence on the slope of Qinghai-Tibet Plateau based on aircraft reports, and a turbulence forecasting system based on CMA-MESO (a mesoscale numerical weather prediction system developed by China Meteorological Administration). The system can provide high spatiotemporal resolution grid forecasting products on EDR for 36 hours 4 times a day, of which the spatial and temporal resolution are 3 km and 1 hour respectively.

1. INTRODUCTION

1.1 Under the background of climate change, the aircraft turbulence over China has shown a trend of increasing, particularly in western China where the terrain is complex. Moreover, with its special geographical and climatic characteristics, the Qinghai-Tibet Plateau has became a key region affecting global climate. The turbulence encounters has became more and more in this region, which has a great affect on aviation safety.

1.2 To better understand the characteristics of aircraft turbulence over the slope of Qinghai-Tibet Plateau, we analyzed the aircraft reports of turbulence received from January 2015 to March 2025, tried to find the characteristics and causes of aircraft turbulence. The results are of great help for aviation weather forecasters and ATC to improve the accuracy of turbulence forecasting and the efficiency of air traffic management.

2. DISCUSSION

Temporal and spatial characteristics of aircraft turbulence

2.1 From January 2015 to March 2025, the Lanzhou Controlled Airspace received a total of 1,418 aircraft reports of turbulence. Among them, 882 cases accounting for 62.20% of all aircraft turbulence events occurred above 6,600 meters (including) **(Appendix[A] Fig.1)**. In addition to meteorological factors, this phenomenon is also related to the larger number of flights in the upper controlled airspace.

2.2 The inter-annual variation of aircraft reports showed that the number of aircraft turbulence events was increasing year by year over the Qinghai-Tibet Plateau slope, especially at high altitude. Since 2020, the aircraft turbulence occurred at high altitude had consistently accounted for over 50% of annual turbulence reports, peaking at 74.85% **(Appendix[A] Fig.2)**. The intensity of aircraft turbulence also showed an increasing trend, the frequency of moderate to severe turbulence was increasing. The above two phenomena together showed that, under the background of global climate change, the atmosphere had became more and more unstable. And with the rapid increase of flights, aircraft turbulence would happen more and more frequently.

2.3 On the slope of Qinghai-Tibet Plateau, aircraft turbulence occurred more frequently in spring (March, April and May) and winter (December, January, and February). Over the past decade, the number of aircraft turbulence events in winter and spring was twice than that in summer (June, July and August) and autumn (September, October and November), which accounting for 69.38% of the whole year **(Appendix[A] Fig.3)**.

2.4 Under the combined influence of weather and flight schedules, the aircraft turbulence events were mostly concentrated from 00:00–13:00 (UTC) over the Qinghai-Tibetan Plateau slope, which accounting for 88.95% of the whole day **(Appendix[A] Fig.4)**. 05:00 (UTC) was the daily peak hour. During the day, moderate turbulence predominated over the Qinghai-Tibet Plateau slope. After dusk, especially after 17:00 (UTC), the frequency of severe turbulence increased significantly. It peaked at 20:00 (UTC), with 75% of aircraft reporting severe turbulence. Therefore, enhancing weather monitoring and aviation services for high-altitude turbulence is necessary at nighttime.

2.5 Over the slope of Qinghai-Tibet Plateau, the vertical distribution of aircraft turbulence showed a "double-peak" structure. The low-to-medium altitude turbulence was mainly concentrated during FL180-FL200, the high-altitude turbulence was mainly distributed in FL280-FL360, with FL280-FL300 being the most frequent. Aircraft turbulence occurred in the above flight level accounted for 72.14% of the total **(Appendix[A] Fig.5)**.

2.6 The high-altitude aircraft turbulence was mainly distributed along the slope of Qinghai-Tibet Plateau, especially on the northeast and southeast sides of the slope where the steepest terrain was. The low-to-medium altitude turbulence clustered east and south of Lanzhou Airport and the southeastern of plateau slope **(Appendix[A] Fig.6)**.

2.7 Over the past decade, 65.90% of aircraft turbulence events were attributed to convective clouds, jet streams, and atmospheric turbulence—the three primary causes over the slope of Qinghai-Tibetan Plateau. Notably, the cause of 21.34% of all aircraft turbulence events remained unidentified, particularly in winter. The preliminary conclusion may be related to clear air turbulence **(Appendix[A] Fig.7)**.

<u>Turbulence forecasting system based on EDR</u>

2.8 Based on airborne observation data, especially EDR observation data, we developed a turbulence forecasting system which took CMA-MESO (a mesoscale numerical weather prediction system developed by China Meteorological Administration) as core model.

2.9 The system divides the vertical space into 20 layers, including 1000hPa and 975hPa isobaric surface, and 50hPa intervals from 950hPa to 100hPa isobaric surface. The horizontal space resolution is 3km, temporal resolution is 1 hour. It can provide high spatiotemporal resolution grid forecasting products for 36 hours 4 times a day, including EDR **(Appendix[A] Fig.8)**.

2.10 We conducted a comparative verification of objective assessment results (ROC curves) from February to April 2024 between WAFS and our system **(Appendix[A] Fig.9)**. The results revealed that the performance between WAFS and our system showed minimal differences. In April, the scores of CMA forecasts outperformed WAFS by 0.03.

3. ACTION BY THE MEETING

3.1 The meeting is invited to note the information contained in this paper.

– – – – – – – – – – – – – –

APPENDIX A

1. Temporal and spatial characteristics of aircraft turbulence over the slope of Qinghai-Tibet Plateau

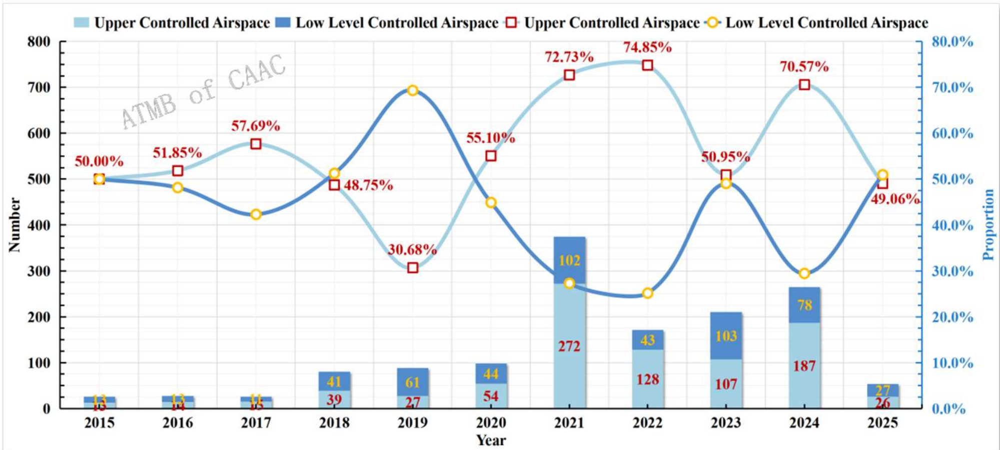

Fig.1 Inter-annual variation of aircraft turbulence events over the slope of Qinghai-Tibet Plateau

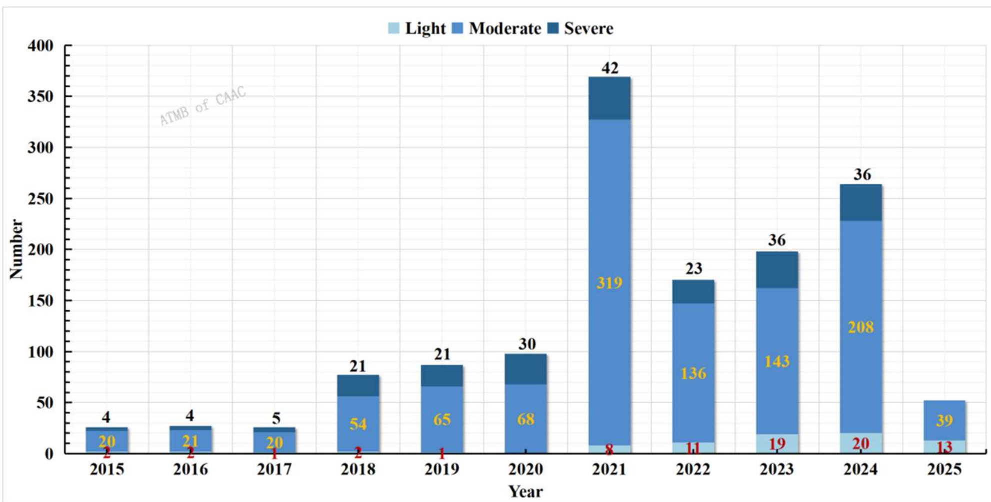

Fig.2 Inter-annual variation of aircraft turbulence intensity over the slope of Qinghai-Tibet Plateau

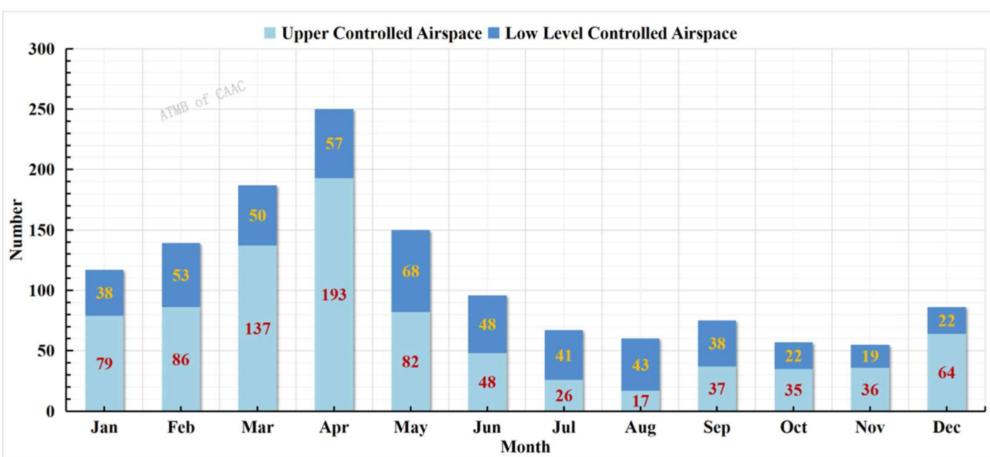

Fig.3 Annual variation of aircraft turbulence events over the slope of Qinghai-Tibet Plateau

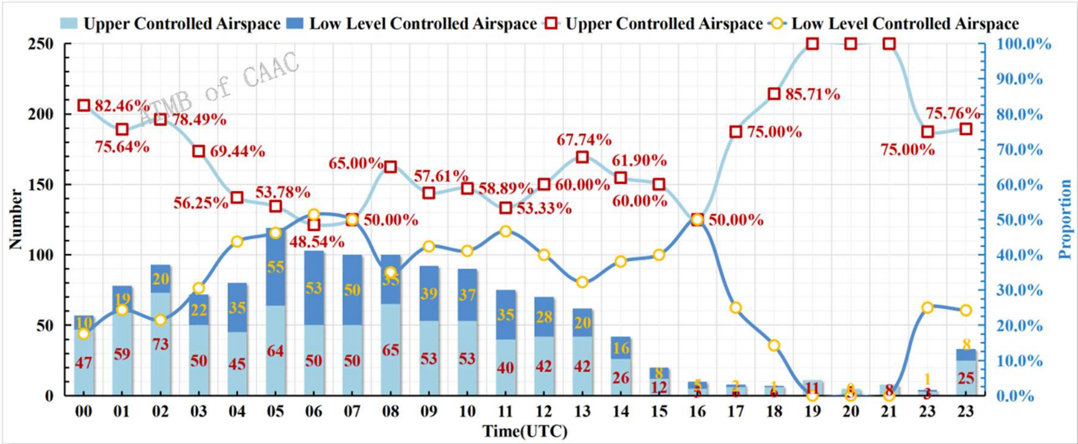

Fig.4 Daily variation of aircraft turbulence events over the slope of Qinghai-Tibet Plateau

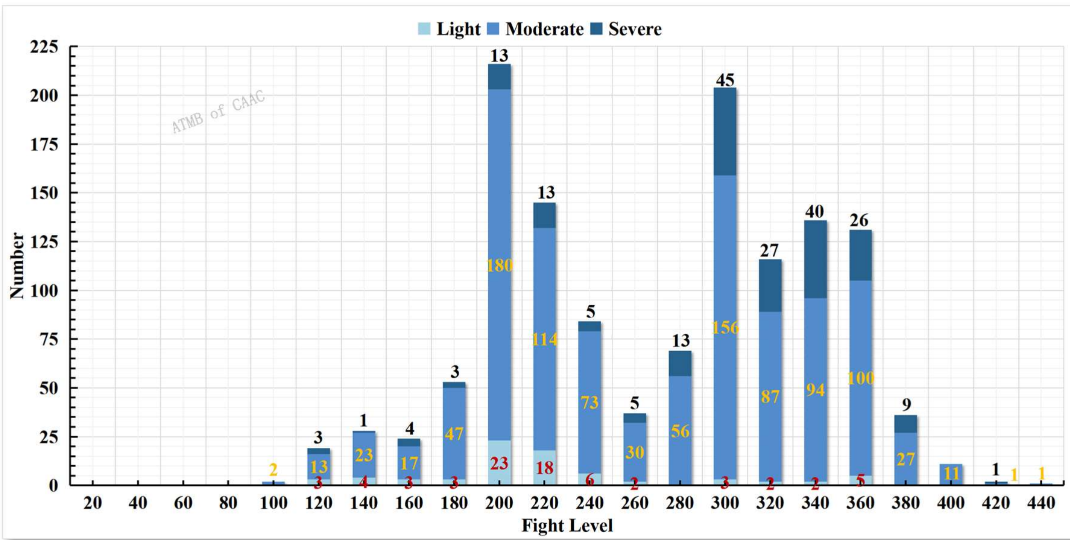

Fig.5 Vertical distribution of aircraft turbulence events over the slope of Qinghai-Tibet Plateau

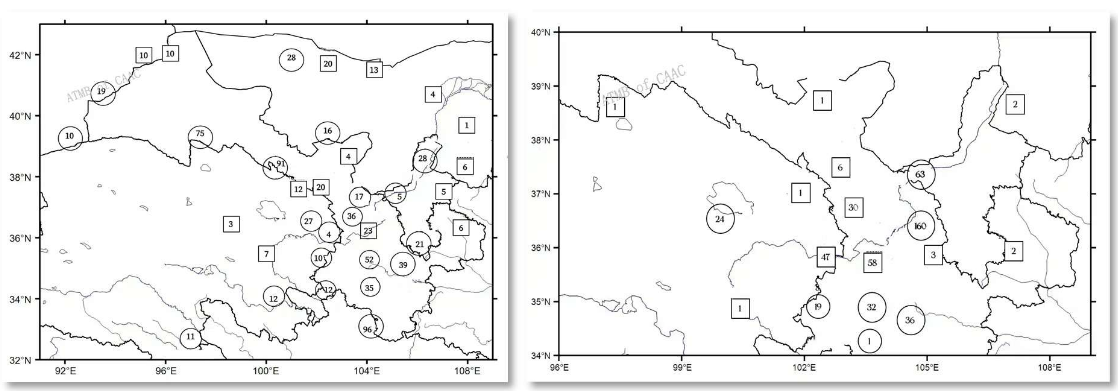

Fig.6 Horizontal distribution of aircraft turbulence events over the slope of Qinghai-Tibet Plateau
(a) high altitude turbulence; (b) low-medium altitude turbulence

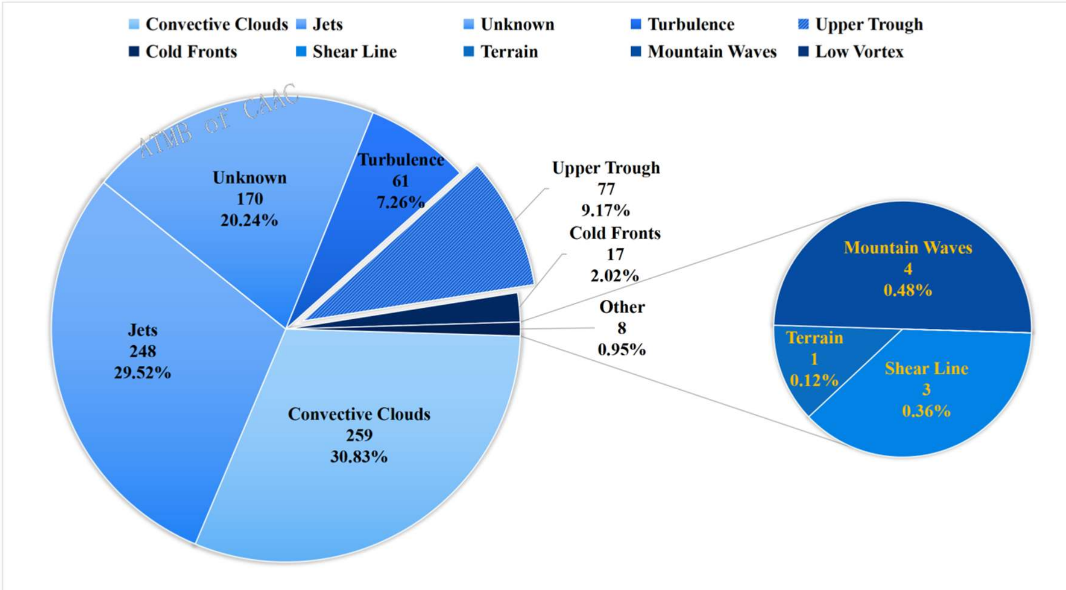

Fig.7 Causes of aircraft turbulence over the slope of Qinghai-Tibet Plateau

2. Turbulence forecasting system based on EDR

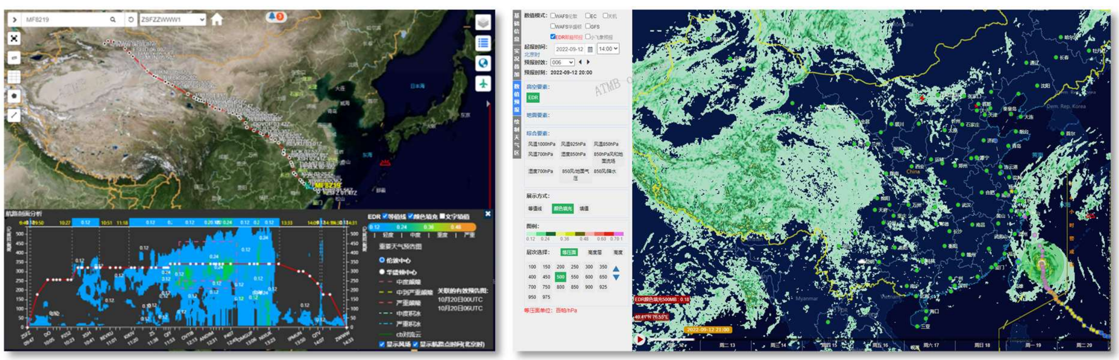

Fig.8 Interface of EDR forecasting system

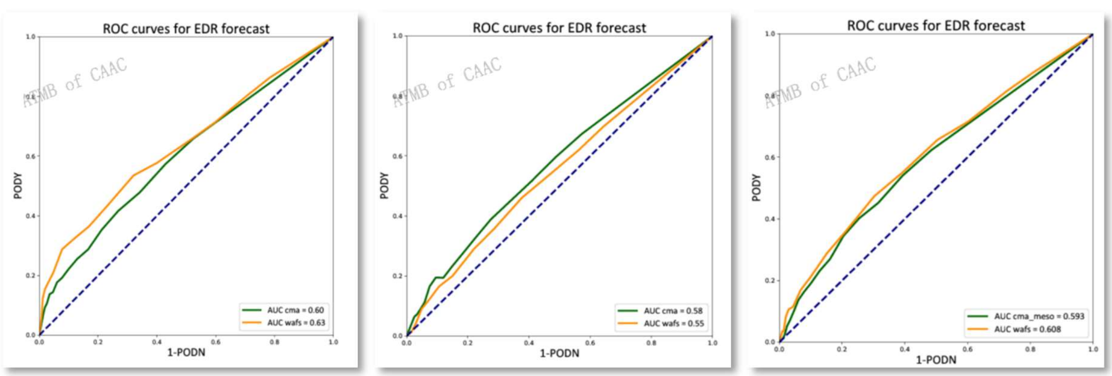

Fig.9 Comparative verification of objective assessment results (ROC curves) from February to April 2024 between WAFS and our system