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INFORMATION PAPER

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Bangkok, Thailand 28 April – 2 May 2025

Agenda Item 3: Collaboration between MET and ATM stakeholders

EN-ROUTE TURBULENCE DETECTION USING ADS-B DATA

(Presented by Hong Kong, China)

SUMMARY

This paper presents an algorithm to detect en-route aviation turbulence using information from ADS-B navigation data. A metric of root-mean-square vertical acceleration (RMSVA) is defined and the temporal spike properties are investigated to formulate the detection algorithm. Real time operational run was implemented since November 2024 and the additional turbulence information could raise user situational awareness on aviation turbulence.

1. INTRODUCTION

1.1 Aviation turbulence is a significant hazard which poses threat to aviation safety. Different forecast techniques are employed for forecasting various types of aviation turbulence (e.g. convectively induced turbulence (CIT), clear air turbulence (CAT)). These forecast techniques rely on accurate turbulence observations, which include special air reports (ARS) and measurement from in-situ airborne equipment. Both kinds of observation are sparse especially in the Asia-Pacific region, this study attempts to derive aviation turbulence observations from readily available Automatic Dependent Surveillance Broadcast (ADS-B) data to supplement turbulence observations in the region.

2. DISCUSSION

2.1 The Hong Kong Observatory (HKO) installed an ADS-B receiver at Tai Mo Shan Weather Radar Station in June 2016 to receive aircraft information within a range of approximately 600 km. This study utilises the following information from ADS-B data, including target identification, latitude, longitude, flight level, airborne ground vector, barometric and geometric vertical rate and emitter category. Utilising the vertical rate information, a metric called the root-mean-square vertical acceleration (RMSVA) was defined following Sharman and Lane (2016)[1], which can represent the response of the aircraft to turbulence. It is noted that RMSVA would fluctuate significantly during aircraft manoeuvres and thus the study only focuses on the cruising phase of the aircraft.

[1] Sharman, R. and Lane, T. (2016) Aviation turbulence. Springer International Publishing, Switzerland, DOI, 10, 978–3.

2.2 The cruising phase of an aircraft is characterised by high flight level, high ground speed and zero vertical rate. But different aircraft may have slightly different characteristics. With reference to Sun et al. (2017)[2], the input features are mapped to appropriate membership functions representing different flight phases using fuzzy logic and a fuzzy score is determined. The fuzzy score for different flight phases is then compared and the RMSVA calculation are only performed when the score is highest representing the "cruising" phase.

2.3 In addition to the peak height of RMSVA previously mentioned in Sharman and Lane (2016), the study proposed to use the RMSVA time series and label the spikes formed in the time series. Spike properties are then extracted, which include peak height, spike duration and spike count. A comparative analysis of the spike properties was performed for the study period (December 2019 to May 2024) for flights that have filed special air reports on turbulence during the cruising phase and the same number of randomly selected flights. A total of 122 flights reported turbulence during cruising phase in the study period. Based on the above analysis, a detection algorithm for turbulence encounter was proposed by setting a threshold for each spike properties derived from the RMSVA time series, representing high peak height, large spike duration and more spike count within the past 5 minutes.

2.4 Out of a total of 122 flights, the algorithm achieves a probability of detection (POD) of 63% and a false alarm rate (FAR) of 23%. Appendix A, Figure 1a shows a successful captured case with large peak height and high spike count which reported moderate turbulence. Appendix A, Figure 1b shows a successfully captured case with high spike count which reported moderate turbulence. One of the limitations is that the ARS observations are sparse in the region and for some false alarm cases, it actually shows high peak height which is difficult to determine whether the aircraft has actually encountered turbulence or not, as reporting special air reports can be subjective and the reporting practice may vary for different airlines and pilots. Another limitation is that the number of reports in the study is small, which may not show the full representation. This reiterates the importance of having special air reports, which involves a coordination of pilots, air traffic controllers and meteorological officers.

2.5 Operational implementation of the detection algorithm started in November 2024. The real-time detected turbulence is being displayed on the HKO intranet page "HKO MET-ATM Integrated Monitoring System" (Appendix A, Figure 2), which allows aviation forecasters to monitor real time aircraft and turbulence information. Work is underway to enhance other airline user platforms with the detected turbulence. Further evaluation with the turbulence reported in January to February 2025 reveals promising results that all the cases reported have been successfully detected by the algorithm. The details of the study are submitted to peer-reviewed journal and the research article is currently under review. Interested readers may approach HKO for sharing the publication once it is published.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) recognize the usefulness of special air reports in both operational and research context.

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[2] Sun, J., Ellerbroek, J. and Hoekstra, J. (2017) Flight extraction and phase identification for large automatic dependent surveillance-broadcast datasets. Journal of aerospace information systems, 14, 566–572.

APPENDIX A

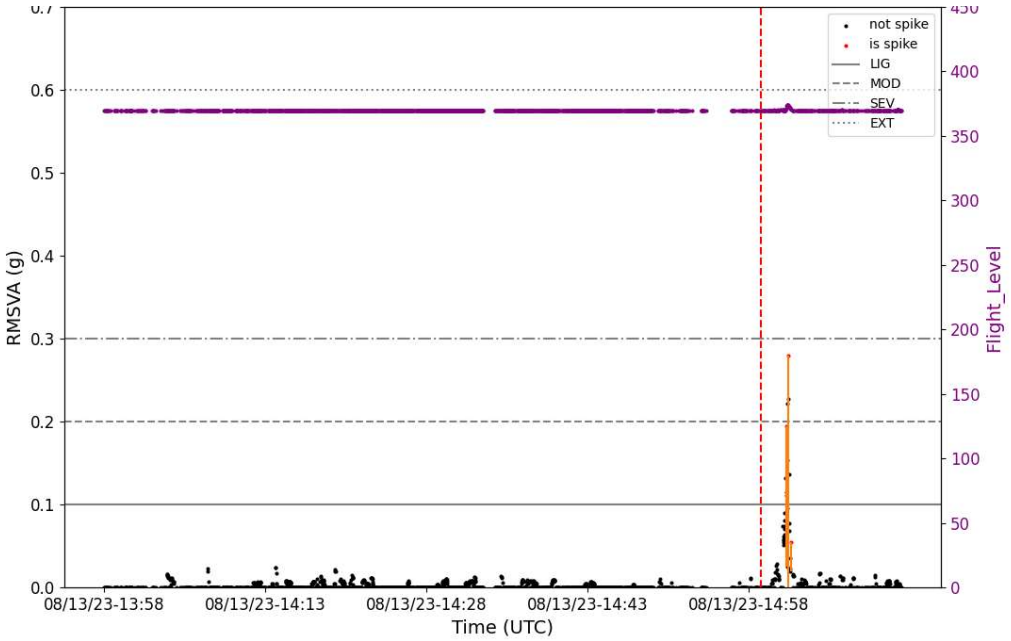

Figure 1a RMSVA timeseries for a flight which reported moderate turbulence on 13 August 2023 with high peak height and large spike count. Red and orange lines in the plot mark the observation time of ARS and RMSVA spike respectively.

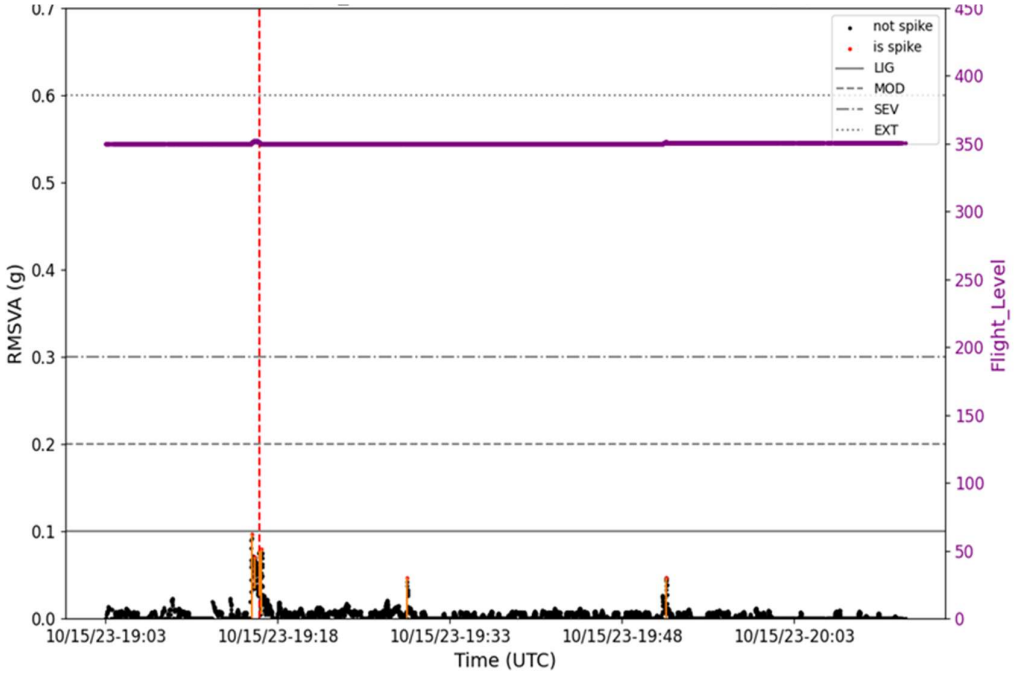

Figure 1b RMSVA timeseries for a flight reported moderate turbulence on 15 August 2023 with large spike count. Red and orange lines in the plot mark the observation time of ARS and RMSVA spike respectively.

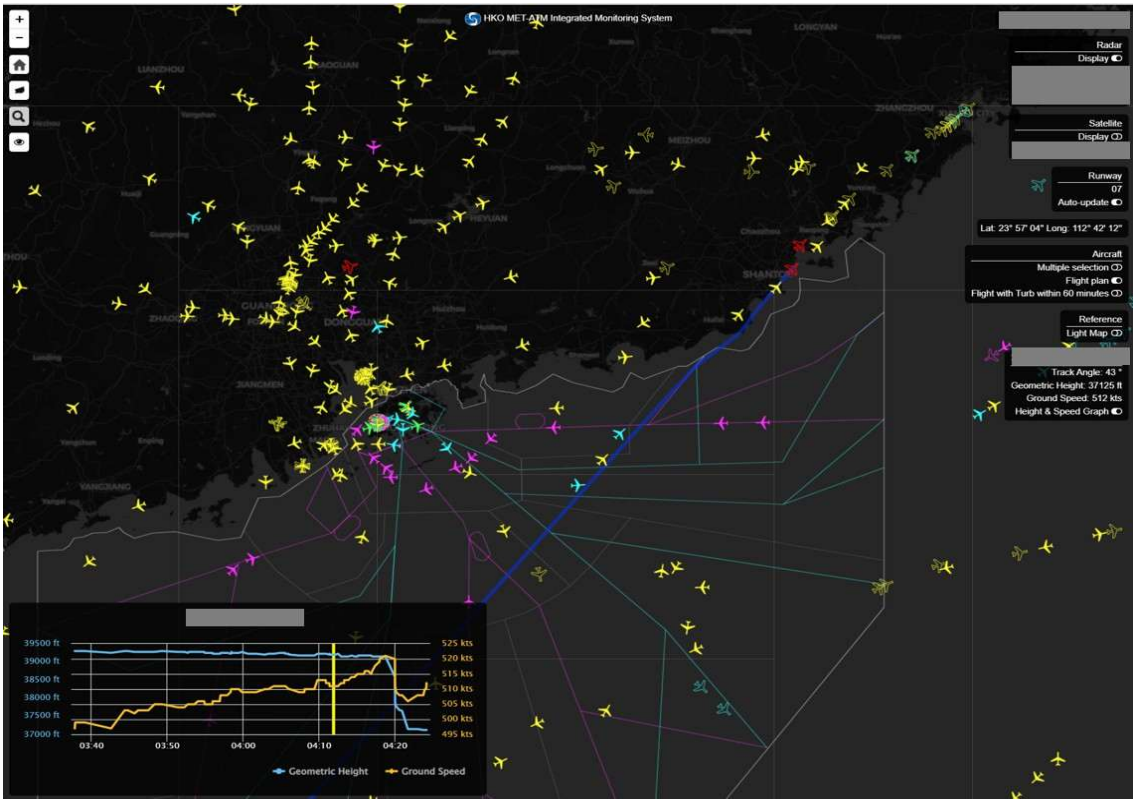

Figure 2 Screenshot of "HKO MET-ATM Integrated Monitoring System" incorporated with turbulence detection algorithm. The flight with detected turbulence will be highlighted in red, expanding the flight profile would highlight the time of encountering turbulence in yellow.