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Agenda Item 2: Improving the safety and efficiency of international air navigation through enhanced meteorological service provision

2.2: Enhanced integrated meteorological information to support strategic, pre-tactical and tactical operational decision-making from 2018 (including ASBU Module B1-AMET)

OBJECTIVE QUANTIFICATION OF WEATHER IMPACT ON AIRCRAFT OPERATIONS DUE TO SIGNIFICANT CONVECTION

(Presented by China)

SUMMARY

This paper presents the effort in Hong Kong, China to develop an objective methodology to identify common weather avoidance actions based on flight position data; and the preliminary results on a study to quantitatively assess the impact of significant convection on aircraft operations using weather radar parameters.

1. INTRODUCTION

1.1 Significant convection has direct impact on air traffic. Inflight aircraft have to adjust the flight routes, perform holding, or even divert to alternates when the airspace is affected by significant convection. Whether such action is initiated by ATC or the pilot, it will reduce airspace capacity, especially when the convection is extensive and prolonged. As the demand of air space and airport capacity at the Hong Kong International Airport (HKIA) has been increasing throughout the years, weather related impact to air traffic also increased. In the accompanying paper on Nowcasting Services to support air traffic flow management (ATFM) and airport operations at HKIA (MET/14-IP/11|CAeM-15/INF.11), nowcasting systems developed by the Hong Kong Observatory (HKO) were described.

1.2 In line with the concept for ATM-MET integration[1] of Aviation System Block Upgrade (ASBU) (MET/14-WP/9|CAeM-15/Doc.9), a key feature of these nowcasting systems which are tailored for aviation purpose is the impact to air traffic are translated into three levels of colour code, viz. green, amber and red. To establish the relationship between the intensity of convection and the consequential impact to air traffic, Lincoln Lab of MIT, e.g., has developed the Convective Weather Avoidance Model (CWAM) to identify convective areas where pilots could choose to avoid based on the radar parameters provided. Similar to CWAM, HKO developed an objective methodology to automatically identify common weather avoidance actions based on flight position data. The impact of significant convection to aircraft operations is assessed by analyzing the statistics of weather radar intensity, including 3km

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[1] There are four elements in ATM-MET integration, namely (i) MET information, (ii) MET information translation to meteorological constraints and airspace or aerodrome threshold events, (iii) ATM impact conversion and (iv) integration with decision support.

(7 pages)

Constant Altitude Plane Position Indicator (CAPPI) reflectivity and Vertically Integrated Liquid (VIL), when avoidance actions were taken. The result of this weather avoidance study was used as a reference when defining the impact levels of different forecast products. This paper presents an overview of the methodology used in the impact study.

2. DATA SET AND METHODOLOGY USED IN THE STUDY

2.1 Planned flight routes and actual flight position data covering weather disruption cases from April to July 2011 arriving at HKIA were used in this study. The corresponding weather radar data at 6 minutes scanning interval were collected for searching any significant convective activity in the vicinity of the airport as well as ahead of the aircraft.

Dataset

2.2 The actual aircraft position data recorded every 5 seconds, were provided by ATC. These are represented by pink line(s) in the Figures 1-5. The planned flight routes, which refer to the paths aircraft will normally follow when flying to HKIA during fine weather and normal traffic condition, are represented in blue line(s). Two common routes identified were considered in this study: “arriving from the east” and “arriving from the northeast”. Visually, a number of flight avoidance actions, including “holding”, “slow-down”, “missed approach”, “path-finding” and “deviation” were identified based on their deviation pattern from the planned flight path. Automatic identification algorithms were then developed. Among these, the most well defined types are: “holding”, “slow-down” and “missed approach”. The “path-finding” and “deviation” are more complicated and not included in this paper.

2.3 To quantify the severity of convection, the data from Tai Mo Shan Doppler weather radar[2] operated by HKO were used in this study. Reflectivity factor at 3 km CAPPI height within 256 km range and the respective VIL were extracted at 6 minutes interval (the update cycle of the radar volume scan). For illustrative purpose, the colour thresholds for red, yellow, green in drawing the reflectivity are chosen to be 41 dBZ, 33 dBZ and 20 dBZ respectively. The weather radar data around the time of initiation of avoidance action was analysed to identify the radar thresholds causing the avoidance action. The relationship between weather radar parameters and weather avoidance was then established statistically.

Identification of weather avoidance action

2.4 Objective algorithms were devised to trace an aircraft’s actual flight positions from the point it first enters the 256 km radar range till it lands at HKIA. “Holding” is a common type of avoidance action. It is initiated usually by ATC because the airport is too busy at the time to receive the in-coming aircraft. Aircraft generally fly in a “race course” or similar pattern at fixed and separated heights in holding areas. Figure 1 shows an example of “holding”. The key to identify “holding” in the flight route data is to detect if there is any looping pattern (i.e. overlapping of aircraft positions). The identification algorithm checks each subsequent position of an aircraft to see if it overlaps with any of its past positions. A “holding” is further confirmed by double-checking if the aircraft has ever flown “away” from HKIA which is also necessary when making a loop. Though simple, the above algorithm is found to be rather effective and efficient.

2.5 “Slow-down” is another avoidance action which is achieved by flying in a zig-zag pattern in order to increase the flying distance and time. Figure 2 shows an example of “slow-down”. The

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[2] The Tai Mo Shan Doppler weather radar is a S-band radar (2.82 GHz) for long range weather surveillance. It completes a volume scan every 6 minutes.

key to identify “slow-down” is to detect if there is any large and frequent variation in the aircraft’s heading. The algorithm keeps track of the aircraft’s bearing relative to HKIA for the entire route in order to identify any “slow-down” action.

2.6 “Missed approach” always occurs in the close proximity of the aerodrome. The key to identify “missed approach” is to detect if an aircraft enters the aerodrome and then fly away immediately without touching down. Figure 3 shows an example of “missed approach”. For identification of “missed approach”, aircraft positions are checked if the aircraft enters an area covering the aerodrome and the short finals and then fly away from the area. It should be noted that more than one avoidance action, for example “holding” followed by “missed-approach”, may coexist for the same aircraft in a single flight.

2.7 “Non-impact” type refers to aircraft not affected by nearby significant convection. In order to achieve a more representative statistics, the number of flights which took no action when encountering significant convection, i.e. flying according to the planned flight route without significant deviation, was included in the statistics. “Non-impact” flights are identified when the largest distance between the actual flight position and the planned flight position was less than 10 km. Figure 4 shows an example of a “non-impact” flight.

Radar parameter analysis and statistical results

2.8 The radar 3km CAPPI reflectivity and VIL in an area of around 54 km x 54 km immediately ahead of the aircraft were extracted to compute the 90th percentile quantities so as to remove any noise. Similar representative convection intensities at and near the aerodrome were also computed. Since avoidance action may be initiated by ATC due to significant convection over the aerodrome instead of immediately around the aircraft (illustrated in Figure 5), the most intensive one among all these areas was used for compiling statistics on distribution of weather radar intensity. In the study period, 212 flights were identified as “holding”, 30 as “slow-down”, 14 as “missed approach” and 286 flights were identified as “non-impact”. The distributions of convection intensity for impact and non-impact flights can be visualized on a frequency plot with reflectivity as the Y-axis and VIL as the X-axis. Quantitative assessment of the impact of significant convection on aircraft operations was made and probability of impact was derived.

2.9 Figure 6 to 9 show preliminary results in terms of frequency plot, respectively for non-impact, impact, total (including non-impact and impact) and the probability of impact. In Figure 6, it can be seen that the reflectivity values for most (orange and warmer colour) non-impact flights were lower than 24 dBZ, with VIL lower than 2 mm. Figure 7 plots the number of impact flights including “holding” and “slow-down” actions. Most of the avoidance actions were taken when reflectivity values were around 42 dBZ or higher and VIL around 3-4 mm or higher. Flights identified as “missed approach” have not been included due to too few cases. Figure 8 shows the number of all flights (non-impact and impact). Figure 9 shows the derived probability of avoidance, or probability of impact, which were calculated by dividing the number of impact by the total number of flights. Avoidance actions were unlikely when reflectivity and VIL was below 36 dBZ and 2 mm respectively. On the contrary, the probability of avoidance actions taken was more than 50% when reflectivity and VIL was above 39 dBZ and 4 mm respectively. Note that these thresholds of convection intensity were all referring to the highest of the 90th percentile figures in the 54 km x 54 km boxes.

2.10 Coincidentally, the probability thresholds obtained by the study agreed reasonably well with the significant convection forecasting products developed by HKO, in collaboration with the civil aviation authority, to support air traffic management operation. These products use three levels of colour code to indicate the impact to air traffic, viz GREEN for mild or no impact, AMBER for medium impact and RED for significant impact. The thresholds for different colour levels were determined independently from past cases of air traffic disruption and feedback from traffic control unit. The thresholds for RED roughly correspond to 50% probability of taking avoidance action, and thresholds for AMBER roughly correspond to 25% probability. Feedbacks from ATM also confirmed that the threshold identified agreed reasonably well with their subjective experience.

3. CONCLUSION

3.1 The results in this study, though preliminary, provided an objective ground for defining the impact of significant convection on air space capacity, and can be used to fine tune the thresholds. The results can also serve as a key component for the future development of probabilistic forecast of capacity of aerodrome/airspace associated with significant convection.

3.2 Based on the positive results of this study, further collaborative study on the impact of weather to air traffic is being explored between HKO and the ATM in Hong Kong, China. While there are many considerations in runway and airspace capacity forecast and weather is only one of them, our experience highlights the need for meteorological services to be fully involved in the ATM impact study.

4. ACTION BY THE MEETING

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

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APPENDIX

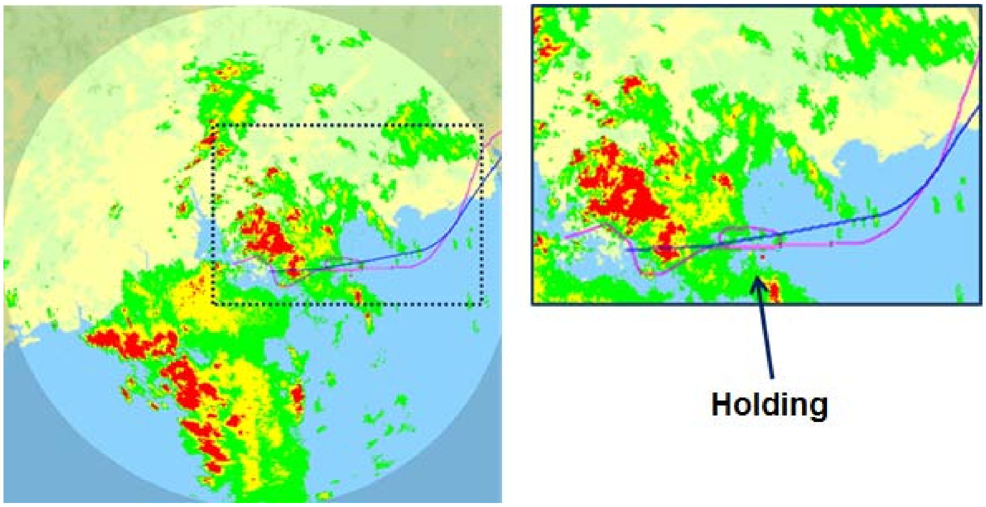

Figure 1. Example of a “holding” path.

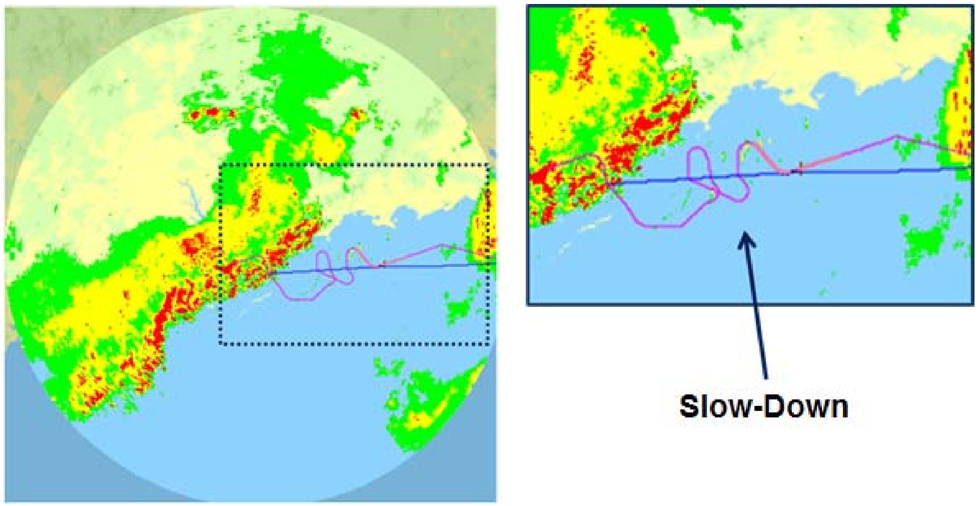

Figure 2. Example of a “slow-down” path.

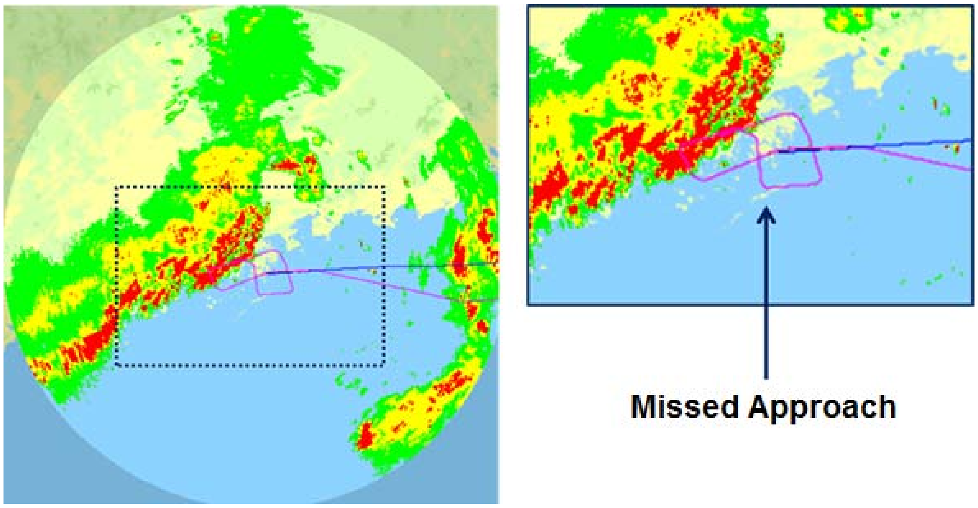

Figure 3. Example of a “missed approach” path.

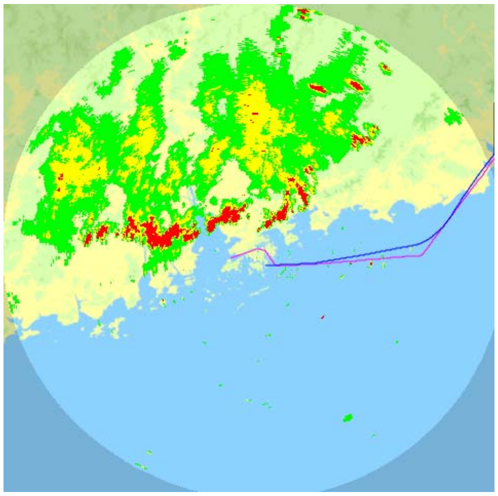

Figure 4. Example of non-impact.

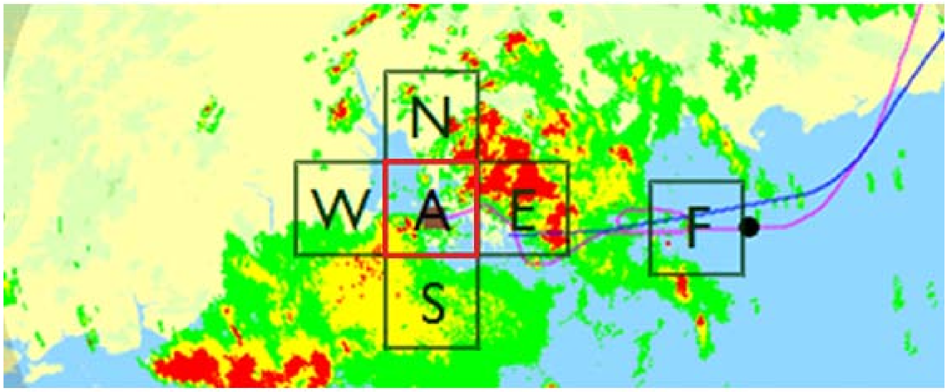

Figure 5. Areas checked for radar parameters. Red box (Box A) marks the aerodrome area. Box F covers the “future” flight path of the aircraft. Each area represents a square of around 54 km x 54 km.

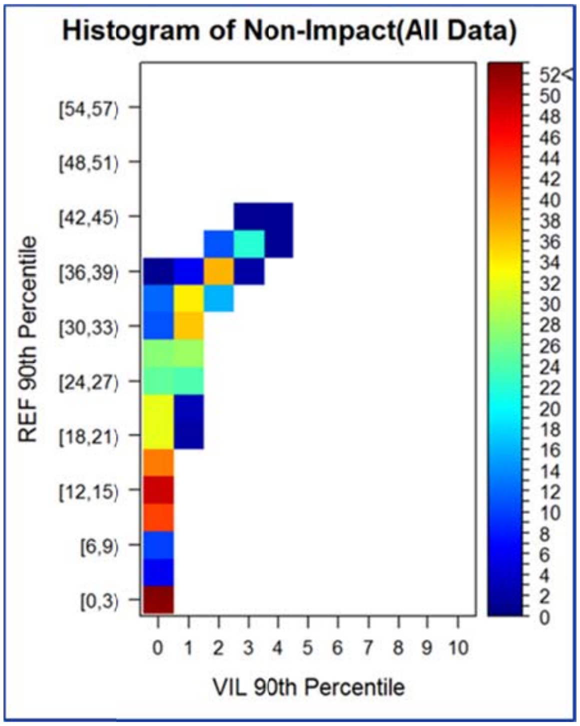

Figure 6. Number of non-impact flights.

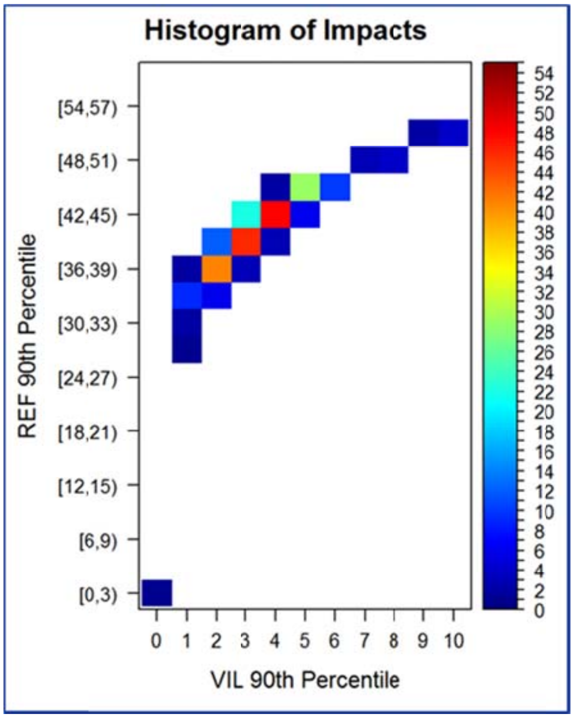

Figure 7. Number of impact flights.

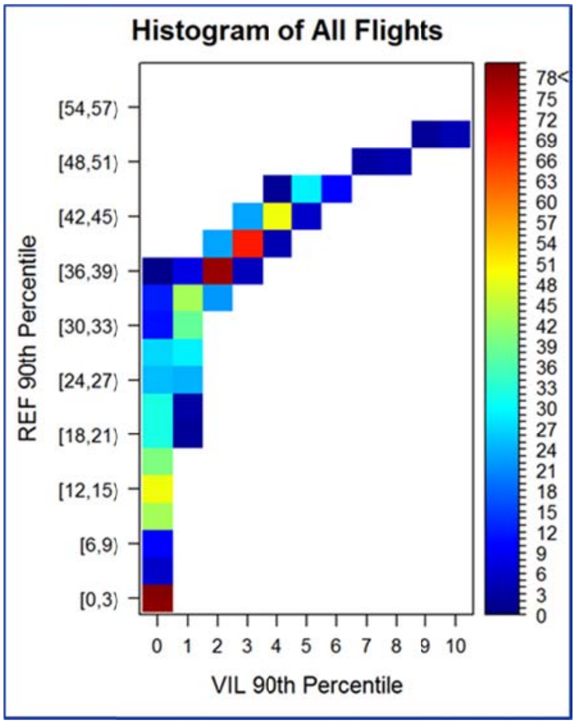

Figure 8. Number of all flights (non-impact and impact).

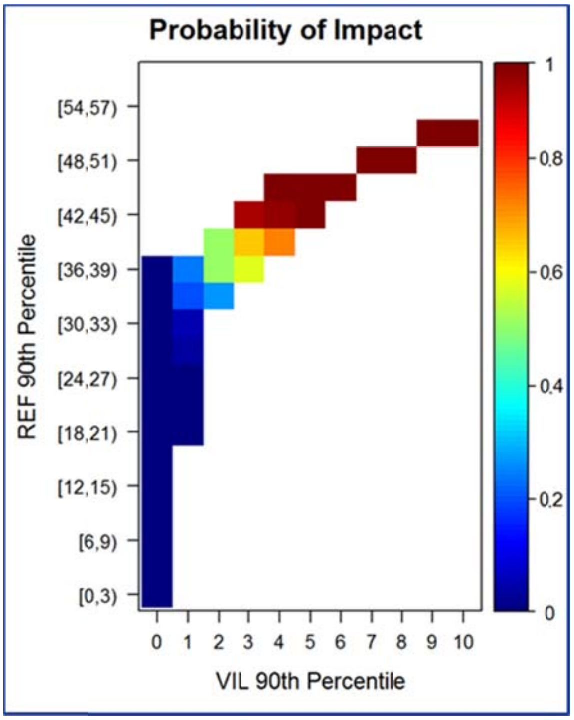

Figure 9. Probability of weather avoidance.

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