International Civil Aviation Organization

ICAO ASIA/PAC METEOROLOGY / AIR TRAFFIC MANAGEMENT (MET/ATM) SEMINAR

26 – 28 November 2013, Bangkok, Thailand

Discussion Topic 3: Enhancing MET support to ATM

2) Best practices examples from within the region or from adjacent regions, e.g., MET supporting collaborative decision making tools

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

(Presented by Hong Kong, China)

SUMMARY

This paper presents:
(i) an objective methodology to identify common weather avoidance actions based on flight data; and
(ii) preliminary results on a study to quantitatively assess the impact of significant convection on aircraft operations using weather radar parameters.

This paper relates to –

Strategic Objectives:
A: **Safety** – Enhance global civil aviation safety
C: **Environmental Protection and Sustainable Development of Air Transport** – Foster harmonized and economically viable development of international civil aviation that does not unduly harm the environment

Global Plan Initiatives:
GPI-6 Air traffic flow management
GPI-9 Situational awareness
GPI-16 Decision support systems and alerting systems
GPI-19 Meteorological Systems

1. Introduction

1.1 Significant convection has direct impact on Air Traffic Flow Management (ATFM) operation. Extensive convection can severely reduce air space capacity by blocking major flight routes or holding areas. In flight aircrafts need to adjust the flight routes, hold in the holding areas or even divert to alternates when the air space is affected by significant convection. As the demand of air space and airport capacity at the Hong Kong International Airport (HKIA) has been increasing throughout the years, the number of delays due to severe weather and the weather related impact to air traffic also increased. During the past few years, a series of significant convection forecasting products have been developed by the Hong Kong Observatory (HKO) in collaboration with the Civil Aviation Department (CAD) of Hong Kong, China to support ATFM operation (see a separate paper on "Development of Meteorological Products to Support ATFM" for the MET/R TF/3).

1.2 Nonetheless, the relation between convection intensity and the severity of the impact to aircraft was still not well understood. To better understan how convective weather detected by weather radar echoes could affect aircraft operations, in particular on weather avoidance actions, as well as to establish a relation in this part of the world for actual applications, HKO developed an objective methodology to identify common weather avoidance actions based on flight data. The impact of significant convection to aircraft operations is assessed by analyzing the statistics of weather radar intensity, including 3km Constant Altitude Plane Position Indicator (CAPPI) reflectivity and Vertical Integrated Liquid (VIL), when avoidance actions are detected. The analysis was performed with a view to objectively quantifying the impact of significant convection on air traffic.

2. Data Set Used in this Study

2.1 Planned flight routes and the 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 with 6 minutes scanning interval were collected for searching any significant convective activity in the vicinity of the airport and around the position of the aircraft. The data used include:

<u>Planned Flight Routes</u>

2.2 Planned flight routes refer to the paths an aircraft will normally follow when flying to HKIA during fine weather and normal traffic condition. Two common routes were identified for HKIA: "arriving from the east" and "arriving from the northeast". The planned flight routes are represented by blue line(s) in the figures of this paper, such as the blue line in Figure 1.

<u>Actual Flight Routes</u>

2.3 The actual aircraft position data recorded every 5 seconds, were provided by CAD. These are represented by pink line(s) in the figures. An example can be seen also in Figure 1.

<u>Weather Radar Data</u>

2.4 The data from Tai Mo Shan Doppler weather radar operated by HKO were used in this study. Reflectivity factor at 3km CAPPI height within 256km range and the respective VIL were extracted at 6 minutes interval (the update cycle of the radar volume scan). For illustrative purpose, the color thresholds for red, yellow, green in drawing the reflectivity are chosen to be 41dBZ, 33dBZ and 20dBZ respectively.

3. Methodology

3.1 Different types (or patterns) of avoidance action were first identified visually and their characteristics studied. Objective identification algorithms were then developed based on these characteristics. From studying the flight position data, a number of flight avoidance actions, such as "holding", "slow-down", "missed approach", "path-finding" and "deviation", can be identified. Among these, the most well defined types are: "holding", "slow-down" and "missed approach". The "path-finding" and "deviation" are more complicated and were not included in this paper. The weather radar data around the time of initiation of avoidance action was analysed to identify the intensity of significant convection causing the avoidance action. The relationship between weather radar parameters and weather avoidance was then established statistically.

Holding

3.2 "Holding" is a common type of avoidance action. It is initiated usually 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. 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). Figure 1 shows an example of "holding".

Slow-Down

3.3 "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. The key to identify "slow-down" is to detect if there are any large and frequent variation in the aircraft's heading. Figure 2 shows an example of "slow-down".

Missed Approach

3.4 "Missed approach" always occurs in the close proximity of the aerodrome. The key to identify "missed approach" to detect if an aircraft enters the aerodrome and then goes out. Figure 3 shows an example of "missed approach".

Non-impact

3.5 Aircrafts which were not affected by nearby significant convection were classified as "non-impact" type. 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 also included in the statistics. "Non-impact" flights are identified by detecting if the largest distance between the actual flight position and the planned flight position was less than 10km. Figure 4 shows an example of a "non-impact" flight.

Objective Identification Algorithm

3.6 Objective algorithms were devised to trace an aircraft's actual flight positions from where it first enters the 256km radar range till it lands at HKIA. For identification of "holding", each new position of aircraft is checked 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. For identification of "slow-down", a time series of the aircraft's bearing relative to HKIA for the entire route is established. During "slow-down", large and frequent variations should be detected in the time series. For identification of "missed approach", aircraft positions are checked if the aircraft enters an area covering the aerodrome and the short finals and then goes out of the area. It should be noted that more than one avoidance action in an actual flight, for example "holding" followed by "missed-approach", may coexist for the same aircraft. For a "non-impact" flight moving along the "planned flight route", large variations in bearing in the time series should be relatively less frequent and the maximum distance deviated from the planned flight should be minimal.

Data Analysis and Statistics

3.7 The radar 3km CAPPI reflectivity and VIL in an area of around 54km x 54km immediately ahead of the aircraft were extracted to compute the 90th percentile quantities so as to remove any noise. This served as the representative intensity of the convection ahead. Besides the area ahead of the flight path, similar representative convection intensities at and near the aerodrome were also computed. Since avoidance action may due to significant convection over the aerodrome instead of immediately around the aircraft (illustrated in Figure 5), the most intensive one of all these areas was used for compiling statistics on distribution of weather radar intensity for avoidance action taken and not taken. For the period of study from April to July 2011, 212 flights were identified as “holding”, 30 as “slow-down” and 14 as “missed approach”. Another 286 flights were identified as “non-impact”. The distributions of convection intensity for impact and non-impact flights were 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.

4. Preliminary Results

4.1 Figure 6 to 9 show the preliminary results in terms of frequent plot, respectively for non-impact, impact, total (including non-impact and impact) and the probability of impact. X and Y axis are the convection intensities as represented by the 90th percentile of VIL (in mm) and the 90th percentile of 3km CAPPI reflectivity (in dBZ) respectively.

4.2 In Figure 6, it can be seen that the reflectivity values for most (orange and warmer color) non-impact flights were lower than 24dBZ, with VIL lower than 2mm. VIL condition for “non-impact” flights was more clear-cut as there were a very limited number of non-impact flights with VIL more than 3mm.

4.3 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 42dBZ or higher and VIL around 3-4mm or higher. Flights with identified “missed approach” have not been included in this study due to the small number of cases.

4.4 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 36dBZ and 2mm respectively. On the contrary, the probability of avoidance actions taken was more than 50% when reflectivity and VIL was above 39dBZ and 4mm respectively. Note that these thresholds of convection intensity were all referring to the highest of the 90th percentile figures in the 54km x 54km boxes.

4.5 The above preliminary results not only provide an objective ground to assess impact of significant convection to aircraft operations, but also serve as a key component for the future development of probabilistic forecast of capacity of aerodrome/airspace associated with significant convection.

4.6 The next step of this study is to collect more flight position data as well as enhance the objective algorithms to identify other avoidance actions, such as “path finding” and “deviation” and to derive a more robust probability of impact.

5. Action by the Meeting

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

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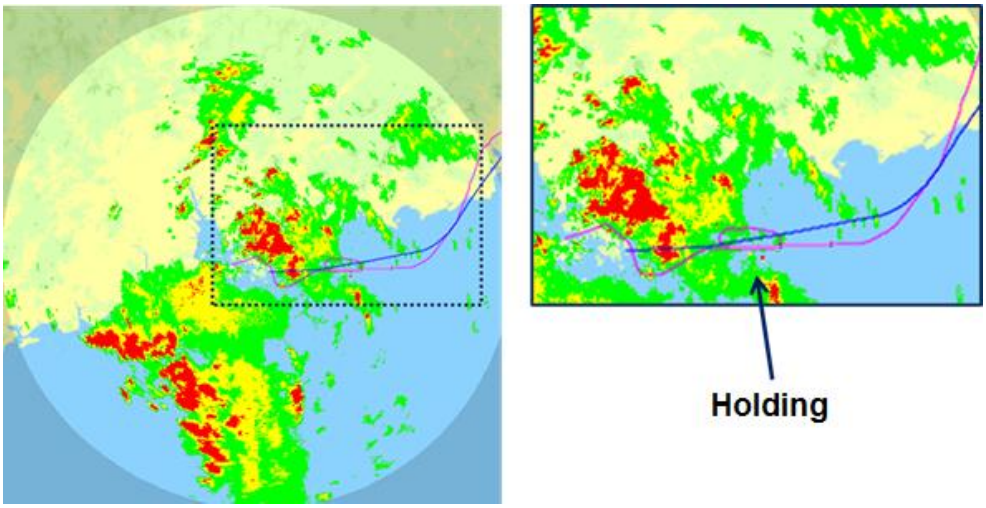

Figure 1. Example of a “holding” path.

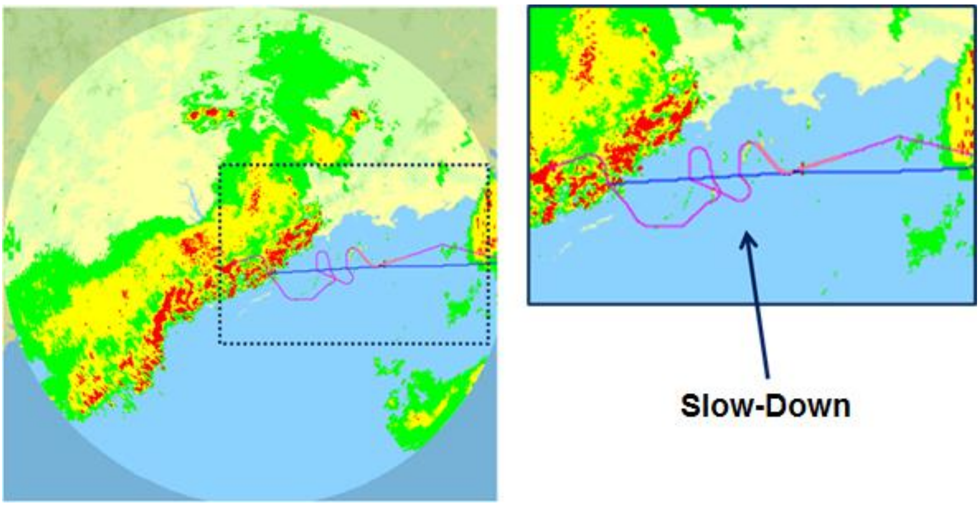

Figure 2. Example of a “slow-down” path.

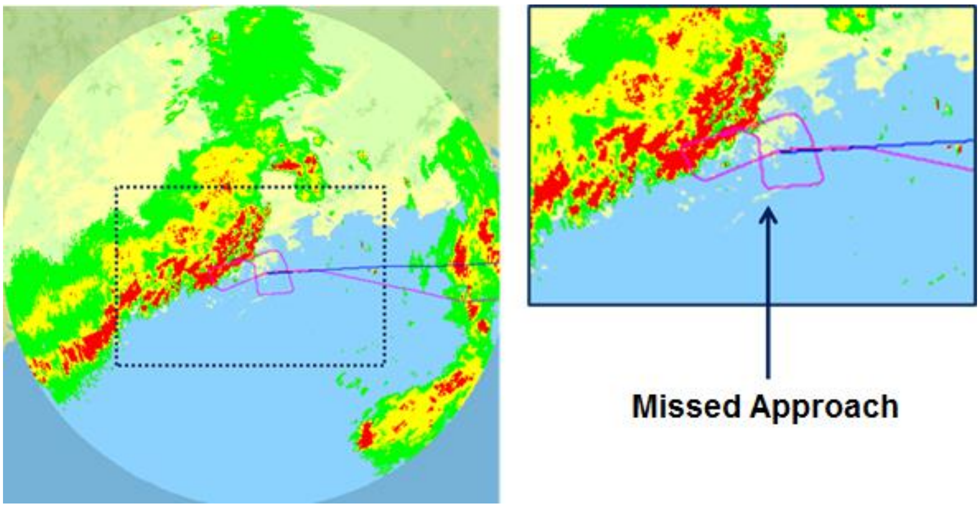

Figure 3. Example of a “missed approach” path.

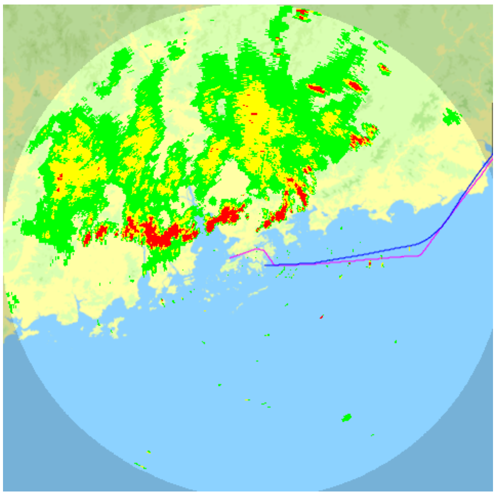

Figure 4. Example of non-impact.

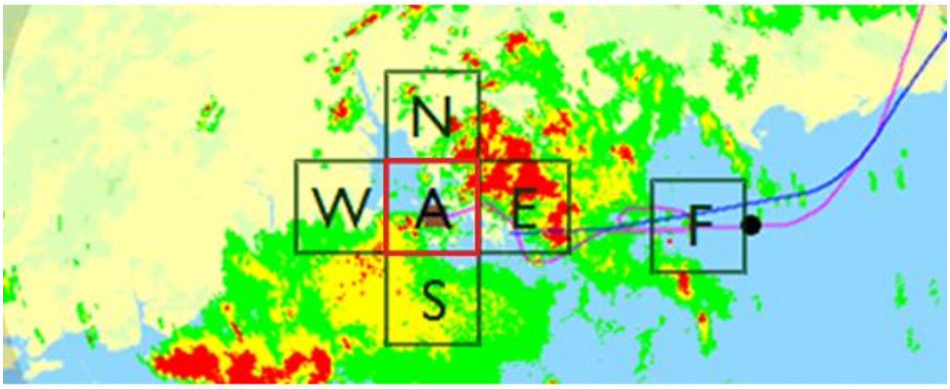

Figure 5. Areas checked for radar parameters. Red box (Box A) marks the aerodrome area. Box F covers the "future" flight path of the aircraft. Each area represents a square of around 54km x 54km.

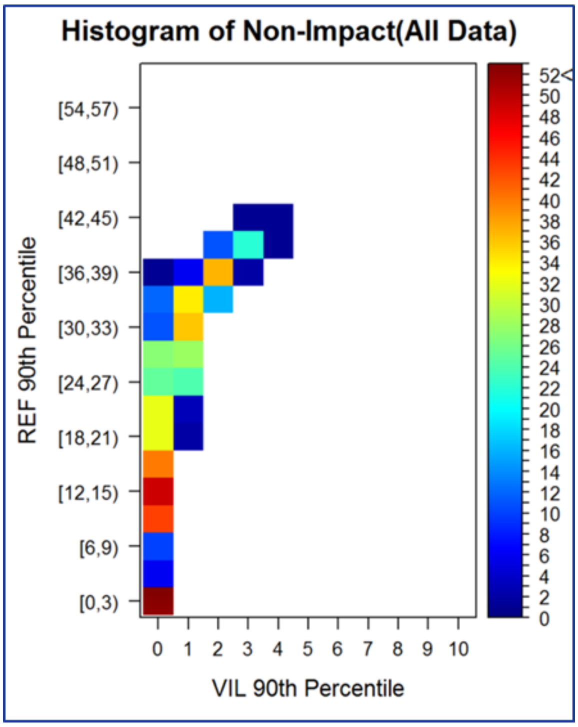

Figure 6. Number of non-impact flights.

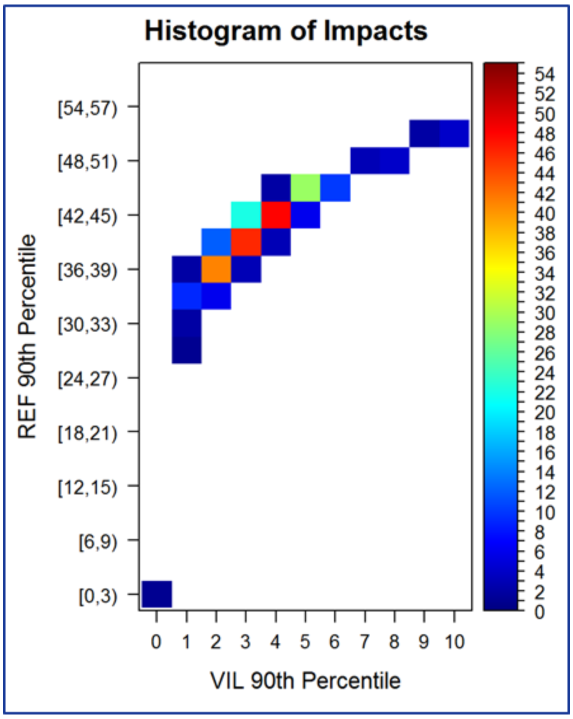

Figure 7. Number of impact flights.

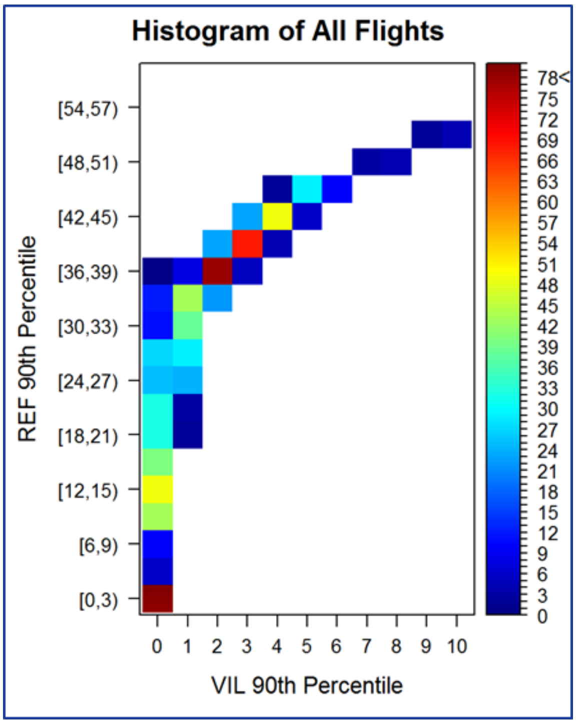

Figure 8. Number of all flights (non-impact and impact).

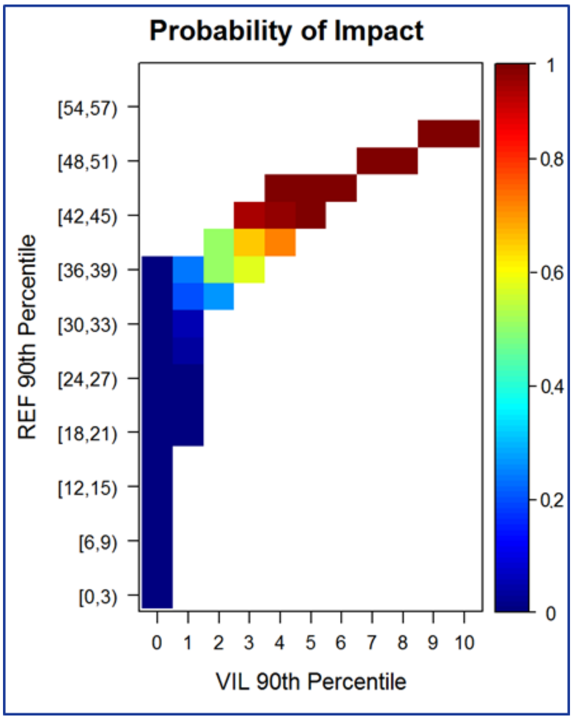

Figure 9. Probability of weather avoidance.