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DEVELOPMENT OF SIGNIFICANT CONVECTION FORECAST PRODUCT AND SERVICE FOR AIR TRAFFIC FLOW MANAGEMENT IN HONG KONG

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1. INTRODUCTION

In the Asian region, the development of organized significant convection is usually associated with frontal systems in spring, monsoon trough and tropical cyclones in summer. Significant air traffic disruption will occur when significant convection affects key Air Traffic Control (ATC) areas such as major holding areas for arrival flights to the east and south of Hong Kong as well as the boundary zones over the northern and southern parts of the HKFIR where flight level selection is required for in-bound and out-bound flights in severe weather situations.

The Hong Kong Flight Information Region (HKFIR) spans over the northern part of the South China Sea. With increasing air traffic in the region, close coordination between ATC flow control units of adjacent FIRs is inevitable. To better plan and manage the air traffic flow within the FIR, appropriate flow control measures need to be taken by the responsible ATC with a view to reducing flight delays and diversions, maximizing capacity and optimizing the flow of air traffic within the FIR.

At the request of ATC in Hong Kong, China, the Hong Kong Observatory (HKO) provides regular weather briefings to cover significant convection forecast for HKFIR for the next 12 hours with a focus on the key ATC areas and the next 6 hours on a trial basis commencing June 2010. The objective is to facilitate ATC personnel in planning of Air Traffic Flow Management (ATFM) and making informed decisions on exercising flow control measures in anticipation of significant weather in the next few hours.

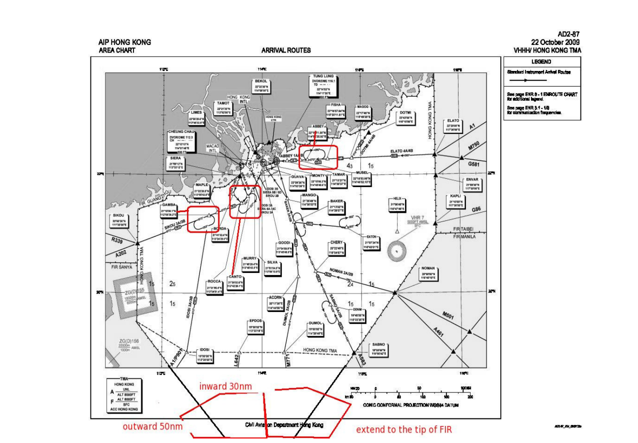

Fig. 1 Arrival route for the HKFIR (HKAIP, 2010). Key holding areas for arrival flights highlighted in red.

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To facilitate the conduct of weather briefings, a new "Significant Convection Forecast" product and an integrated web-based monitoring and forecast display were developed in consultation with ATC. This paper presents the latest development of significant convection forecast product and the integrated web-based monitoring and forecast display.

2. SIGNIFICANT CONVECTION FORECAST PRODUCT

Convective weather, especially over major significant points and holding points, could cause significant impact to ATM operations and air space capacity. To enhance effectiveness and efficiency of the briefing, a significant convection forecast product was developed providing 12-h forecast of significant convection over key air traffic control areas at 3-h intervals (Fig. 2). The 12-h forecast range is divided into four time blocks, each 3 hours, with the starting time (in UTC) marked beside the block. Different colours (green / yellow / red) shown in the block indicate different levels of chance (low / medium / high) of having significant convection over the specified area within the 3-h time block.

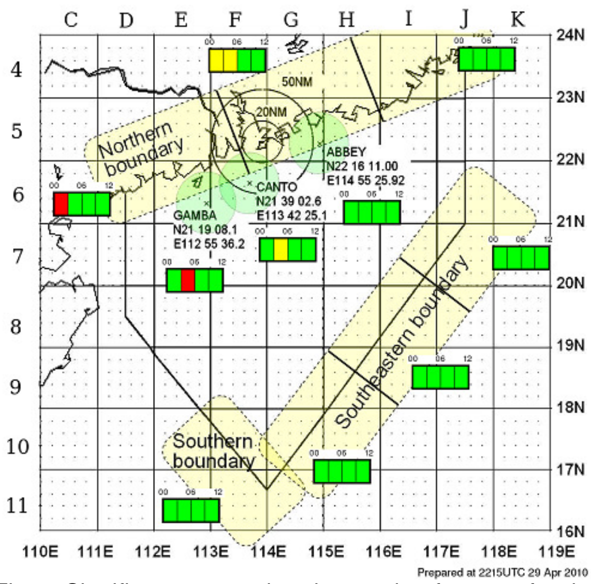

Fig. 2 Significant convection time series forecast for the coloured areas at 3-h intervals up to 12 hours ahead. Different colours (green / yellow / red) indicate various levels of chance (low / medium / high) of significant convection over the specified area within the 3-h time block.

The criteria for determining the occurrence of significant convection in a 3-h time slot are as follows:

- Red alert requires two or more radar images in the 3-hr time slot having pixels of reflectivity of at least 33dBZ covering more than 1/5 th of the area, and pixels of reflectivity of at least 41dBZ covering more then 1/10 th of the area;
- Yellow alert requires three or more radar images in the 3-h time slot having pixels of reflectivity of at least 33dBZ covering more than 1/30 th of the area, and pixels of reflectivity of at least 41dBZ covering more than 1/100 th of the area.

The above criteria are determined in consultation with ATC by making reference to a few known cases of weather related air traffic disruption. They will be reviewed when more severe weather cases are collected in the future. Sample radar images satisfying above thresholds are shown in Fig. 3 as a manifestation of the severity of convection in the alerts.

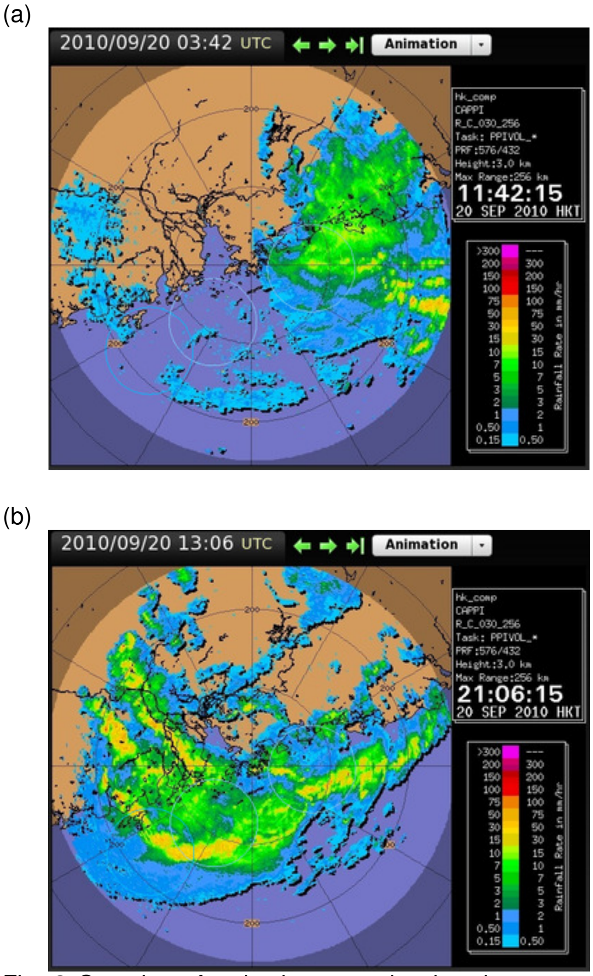

Fig. 3 Samples of radar imagery showing the convection severity relating to (a) Yellow for the holding area ABBEY, and (b) Red for all the three key holding areas ABBEY, CANTO and GAMBA as marked by circles in Fig. 2..

The trial significant convection forecast product is basically generated automatically from objective guidance including numerical weather prediction model outputs from the European Centre for Medium-Range Weather Forecasts (ECMWF). The product will normally be updated every 3 hours at around 00, 03, …, 21 UTC.

The HKO has been acquiring 0.25-deg resolution ECMWF model outputs at 3-h intervals since July 2009. Using around 10 months of historical model outputs, the thresholds for automatic generation of significant convection forecast were first devised subjectively based on forecasters' experience, and then tuned objectively based on the "observed". As a first start, model 3-h rainfall forecasts are used to generate the convection forecast product and the following thresholds are adopted in the summer months:

- Red alert forecast requires at least 8mm of rainfall forecast for not less than 6 grid points within the specified area;
- Yellow alert forecast requires at least 2mm of rainfall forecast for not less than 9 grid points within the specified area.

To align with forecaster's assessment based on meteorological observations and analysis including radar and satellite observations, manual adjustment may be applied to the automatically generated forecast for the first few hours of forecast.

The significant convection forecasts for the next 6-9 hours are also presented in a pictorial format (Fig.4 (a) or (b)). Normally, the presentation format in (a) will be used. If there is human intervention to the forecast product, the presentation format in Fig. 4 (b) may be used.

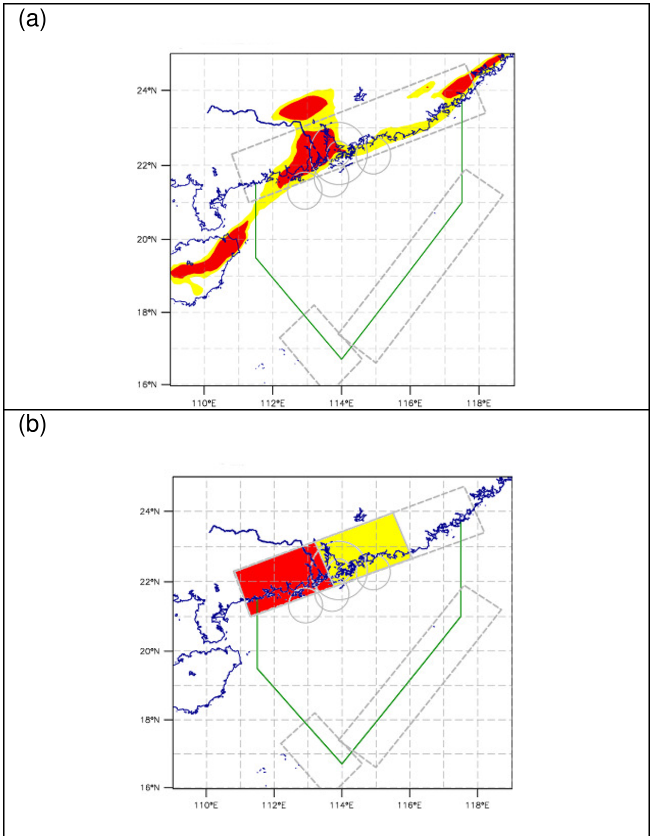

Fig. 4 Significant convection forecast for the next 3 hours (red and yellow indicate high and medium chance over the coloured regions respectively). The presentation in (a) mimics the convective weather pattern while (b) shows the overall chance of significant convection within each boxed or circled area.

3. VERIFICATION OF SIGNIFICANT CONVECTION FORECAST

To assess the performance of the product, systematic verification was conducted for the period of July 2010 to November 2010. The forecasts updated every 3 hours with and without human intervention during the period were verified.

Actual observations of convective weather are derived from 3-km CAPPI radar reflectivity data of 256-km range at 6-min intervals. Considering the importance of key holding areas and the limited spatial coverage of radar data, only forecasts for ABBEY, CANTO, and GAMBA areas (marked by three circles on the right bottom picture in Fig. 4) were verified.

All forecast products, including automatically generated ones and those after human intervention, during the verification period with different forecast valid times and forecast ranges were mapped to the corresponding actual observations stratified by forecast range (0-3 h, 3-6 h, 6-9 h and 9-12 h). A set of contingency tables was then constructed for derivation of verification scores.

It is note-worthy that since the update frequency of the product is 3 hours, there will be normally 4 forecasts for the same valid time period. As such, one missed convective episode by the model might then attribute to 4 misses. Similarly, an over-estimated episode might lead to 4 false alarm cases.

The verification results of Critical Success Index (CSI) or Threat Score) of both automatic and human forecasts for different forecast ranges are given in Table 1.

CSI	Red Alert		Yellow Alert	
	Automatic	Human	Automatic	Human
0-3 h	0.08	0.27	0.25	0.39
3-6 h	0.09	0.24	0.25	0.29
6-9 h	0.11	0.12	0.26	0.27
9-12 h	0.11	0.11	0.24	0.24

Table 1. Verification scores for July - November 2010.

It showed that forecasters added value to the forecast product as the scores for the human-intervened product were significantly higher than the automatically generated ones for the first 6 hours. Forecasters would normally adjust forecasts not more than 6 hours based on nowcasting techniques. Plots of probability of detection (POD) and false alarm ratio (FAR) are show in Fig. 5.

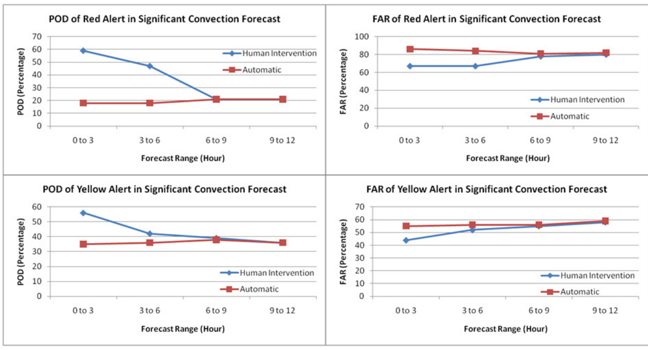

Fig. 5 POD and FAR of the significant convection forecast during July – November 2010.

More air traffic flow data for significant weather events are needed for tuning the trial product. After accumulating sufficient data, tuning of the algorithms for defining the colour scale of the alert will be performed in coordination with ATC in the future.

4. INTEGRATED SIGNIFICANT CONVECTOIN MONITORING AND FORECAST PAGE

In support of the weather briefing on significant convection forecast, other weather information useful for ATFM will also be provided including real time data display of radar, lightning location information and satellite imageries. All these observational data and the forecast product are integrated into the webpage for Significant Convection Monitoring and Forecast to facilitate communication between ATC personnel and aviation forecaster. The layout of the webpage is given in Fig. 6.

Animation of past hour radar image at 6-min intervals with the inclusion of ATC sector boundaries and significant points are displayed on the webpage. Users can select overlay of lightning location data onto different ranges (64-km and 256-km) of radar image. It facilitates the monitoring of the development and movement of significant convection in the vicinity of the aerodrome and key holding areas for arrival flights.

The webpage also contains a composite product overlaying radar images onto satellite image of potential deep convection highlighting in bright white color (So, 2009). The composite images are animated at half-hourly intervals for the past 3 hours. In tropical cyclone situations, the analysed position of the tropical cyclone and the latest forecast track issued by HKO will also be overlaid with a toggle function.

As a one-stop shop of significant convection forecast, the radar-based HKO's Aviation Thunderstorm Nowcasting System (ATNS) (Li, 2009) which provides the present position and 1-h forecast position of thunderstorms affecting HKIA and its vicinity at 6-min intervals, and a link to its full GIS version are also made accessible on the integrated webpage. A sample of the full GIS version of the ATNS is given in Fig.7.

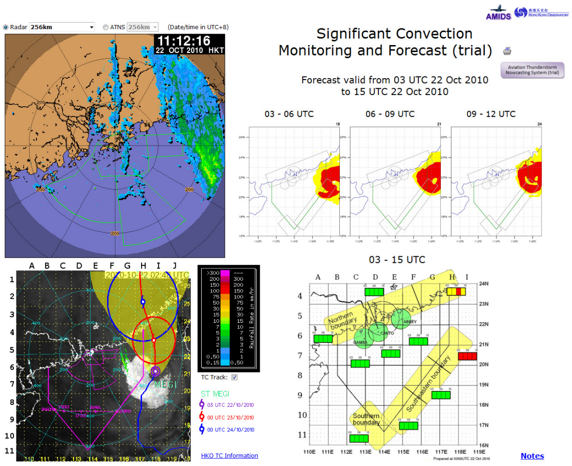

Fig. 6 Layout of the integrated web-based display of significant convection monitoring and forecast. The webpage contains significant convection forecast in pictorial and time series forms, animated sequence of weather radar imagery overlaid with lightning data, as well as animated satellite deep convection product overlaid with radar data and tropical cyclone forecast track (in tropical cyclone situations).

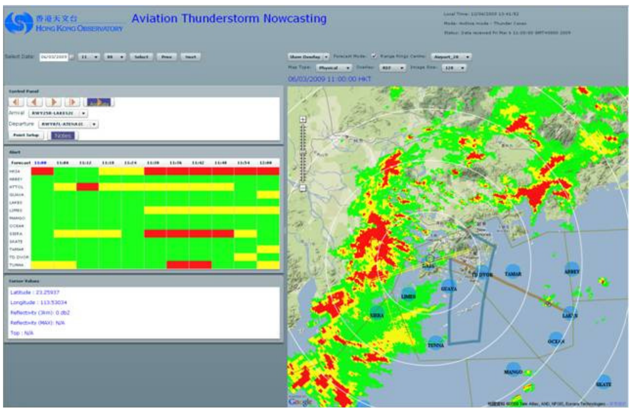

Fig.7 A sample display of the HKO's Aviation Thunderstorm Nowcasting System.

5. CONCLUSION AND FUTURE WORK

HKO provides regular weather briefings to ATC personnel focus on significant convection development for the HKFIR in the next 12 hours with particular focus on the key ATC areas in the next 6 hours to facilitate ATFM related planning and exercising flow control measures. To facilitate the conduct of weather briefings, trial significant convection forecast product and an integrated web-based monitoring and forecast display were developed in consultation with the ATC personnel.

Objective verification of the significant convection forecast product for three key holding areas for arrival flights based on pre-defined thresholds of radar reflectivity and area of coverage over the verification area was performed during the period of July - November 2010.

The objective method for generating the first guess of convection forecast will be enhanced with the use of additional model outputs and the combined use of nowcasting techniques based on radar, satellite, radiometer, surface and upper-air observations. The algorithms will also be seasonal dependent. Ways to better evaluate the performance of significant convection forecast in terms of the degree of weather related air traffic disruption will be pursued together with ATC with a view to enhancing the effectiveness of the forecast service.

ACKNOWLEDGEMENT

The authors would like to thank Mr. Lucius W T Fan and his ATC colleagues of the Civil Aviation Department of HKSARG for their comments from user perspective during the development of the significant convection forecast product.

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