DEVELOPMENT OF A THUNDERSTORM NOWCASTING SYSTEM IN SUPPORT OF AIR TRAFFIC MANAGEMENT

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1. INTRODUCTION

Thunderstorms are known to bring adverse effects to flight safety and airport ground operations. They could also bring significant impact on air traffic efficiency in the terminal area. In regions with rapid growth in air traffic where thunderstorms become a major weather factor bringing disruption to flight operation, the air traffic management (ATM) personnel needs rapidly-updated, real-time information on the location and intensity of thunderstorms, as well as short-term forecast of their movements and intensity change for tactical decision-making within the terminal area.

The Hong Kong Observatory (HKO) has been collaborating with the local aviation community to develop thunderstorm nowcasting products to support airline and ATM operations near the Hong Kong International Airport (HKIA). The products are developed based on the Observatory's nowcasting system, viz. the SWIRLS (Short-range Warnings of Intensity Rainstorm in Localized System) for automatically tracking and prediction of the future movement of thunderstorms based on Doppler weather radar information and artificial intelligent methods. The arrival and departure routes and other significant ATC points, such as corner posts, holding points, etc., are also overlaid onto the forecasts to provide graphical as well as tabular depiction of when and where thunderstorms would impact on these routes/points.

This paper illustrates the concept of the aviation thunderstorm nowcasting products under development.

2. HKO NOWCASTING SYSTEM - SWIRLS

HKO has been operating since 1998 SWIRLS to automatically track and predict the future movement of radar reflectivity echoes based on Doppler weather radar information. The system uses artificial intelligent methods, especially the Pattern Recognition technique, to automatically track the past movements of thunderstorms (Li 2004a, 2004b). It is one of the most advanced nowcasting system operating in weather centres/services in the world. Figure 1 shows the sample motion vectors (named TREC winds) of an area of thunderstorms affecting HKIA and its neighbouring regions. It shows nicely the different movements of the individual thunderstorm areas.

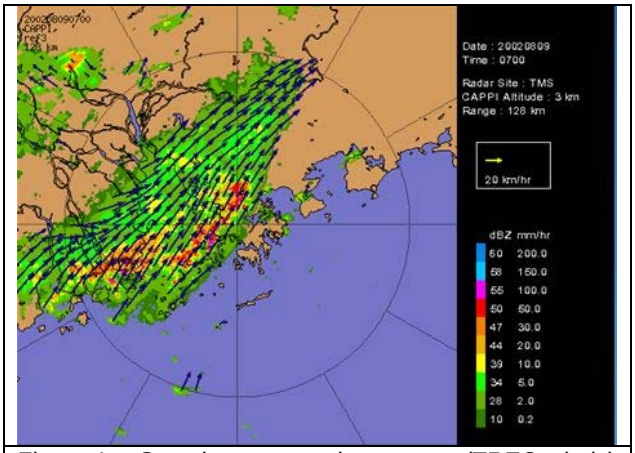

Figure 1 – Sample storm motion vectors (TREC winds) generated by the Observatory's thunderstorm nowcasting system SWIRLS.

Utilizing the TREC winds, SWIRLS is able to predict the future locations of the individual storm cells by projecting them along the TREC winds directions 60 to 120min ahead. The projection is done via a sophisticated numerical integration algorithm named the Semi-Lagrangian Advection Scheme, which is one of the most advanced convection schemes used in a number of Numerical Weather Prediction models operating in the world. One of the major advantages of this scheme is its capability of conserving the circulation signature of a storm and therefore useful in nowcasting the evolution of curving or rotating storms. Figure 2 shows the sample TREC winds of thunderstorm areas associated with a tropical cyclone. The circulation pattern of the rainband around the eye of the tropical cyclone was neatly analyzed by SWIRLS. The TREC winds were generated by SWIRLS based on 3km CAPPI (Constant Altitude Plan Position Indicator) and updated every 6 minutes in accordance with the update schedule of the radar

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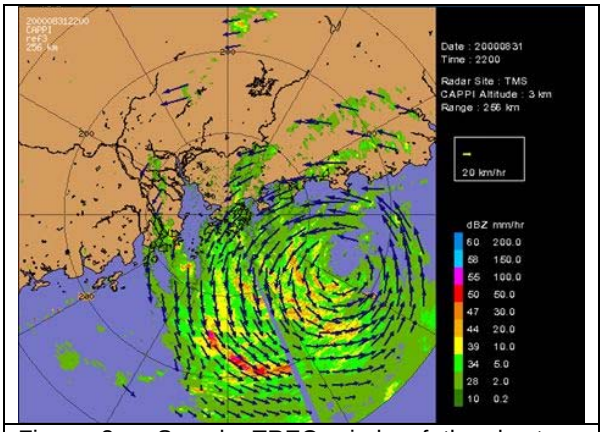


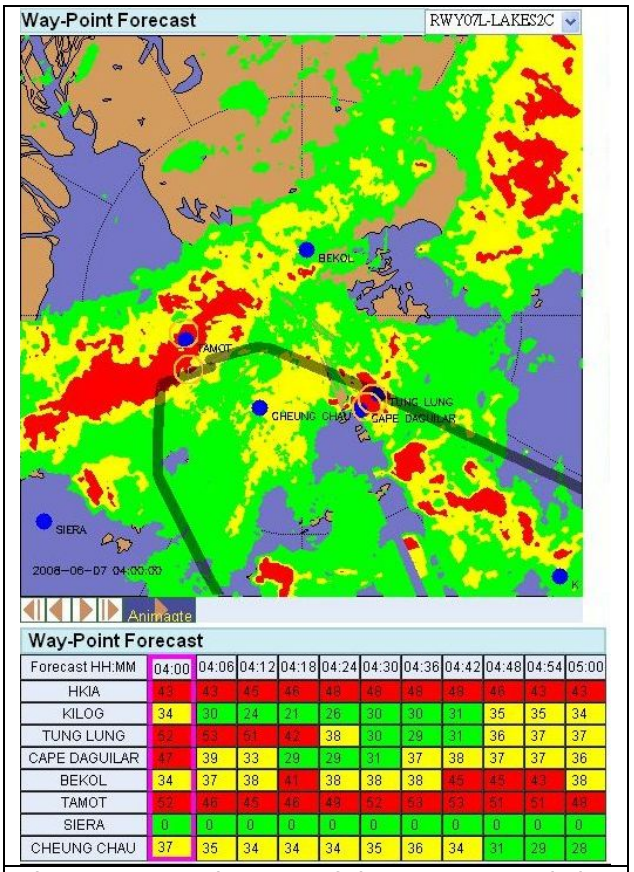
Figure 2 – Sample TREC winds of thunderstorm areas associated with a tropical cyclone as analyzed by SWIRLS

3. DEVELOPMENT OF THE AVIATION THUNDERSTORM NOWCASTING PRODUCTS

Based on the SWIRLS technology, HKO has developed a thunderstorm nowcasting system for alerting thunderstorm and lightning at HKIA (Li 2008) and the system was put into operational use in March 2008. The nowcasting system has recently been extended to cover a much larger region covering the terminal area. A prototype product has been demonstrated and discussed with the local ATM office. Figure 3 shows example of the prototype product. It shows the present and forecast positions one-hour ahead, in a time interval of every 6 minutes, of the thunderstorms affecting HKIA and the vicinity region. The arrival and departure routes are overlaid onto the thunderstorms. Various colours are used to represent the intensity (or severity) levels of the thunderstorm to aircraft – red being severe, yellow being moderate and green being light.

Besides the graphical presentation (upper part of Fig.3), a time series indicating the predicted impact of the thunderstorm at various way-points of interest (blue dots in the graphics) are also provided in a tabular format (bottom part of Fig.3). The update frequency of the nowcasting product is every 6 minute.

Using the product, ATM could obtain a concise picture about the intensity and the locations to be affected by thunderstorms over the terminal area. Work is now underway to setup a reliable computer system to provide a real-time system for trial operation to local ATM offices for evaluation and fine-tuning of the products.



Forecast HH:MM	04:00	04:06	04:12	04:18	04:24	04:30	04:36	04:42	04:48	04:54	05:00
HKIA	43	43	45	46	48	48	48	48	48	43	43
KILOG	34	30	24	21	26	30	30	31	35	35	34
TUNG LUNG	52	53	51	42	38	30	29	31	36	37	37
CAPE DAGUILAR	47	39	33	29	29	31	37	38	37	37	36
BEKOL	34	37	38	41	38	38	38	45	45	43	38
TAMOT	52	48	45	46	49	52	53	53	51	51	48
SIERA	0	0	0	0	0	0	0	0	0	0	0
CHEUNG CHAU	37	35	34	34	34	35	36	34	31	29	28

Figure 3 –Sample page of the prototype aviation thunderstorm nowcasting product. Blue dots are the selected way-points while the two bold lines represent one of the standard arrival and departure flight routes from HKIA.

4. APPLICATIONS OF THE AVIATION THUNDESTORM NOWCASTING PRODUCTS

The applications of the aviation thunderstorm nowcasting products can be demonstrated via a few thunderstorm cases in 2007 and 2008. Figure 4a shows the predicted weather condition (the left panel) and the corresponding actual weather condition (the right panel) at various way-points on 27 Jun 2007. Thunderstorm activities over the airfield on that day brought a halt to arrivals for 18 minutes but resulting in extensive holding for the next 3 hours before the backlog of traffic could be cleared. The aviation nowcasting tool in this case forecast there would be a 25RA arrival blockage for 30 minutes by the thunderstorm between 20-35km away from the airport (roughly 4-7min before touch down). It also forecast the blockage between 15-25km

along 25LD departure would be cleared about 18 minutes later. Both arrival and departure forecasts were verified by the actual conditions. The way-point forecast (left panel) was also verified by the actual conditions (right panel).

Figure 4b shows another case on 7 June 2008. The rainstorm on that day brought torrential rainfall to the territory and affected a number of landing and departing aircraft. From the forecast time series, it can be seen that the space and time distribution of the predicted severe storms (the red boxes) are matched nicely with the actual situation within 15km from the airport, up to 60 minutes ahead. Its performance was still reliable up to 12 minute ahead within a range of 50km from the airport. However, it slightly over-forecast the severity of the storm impact starting from 30min at location beyond 60 km from the airport. Nonetheless, for tactical and landing/departure planning purposes, the products provide rather useful information. Based on the promising results demonstrated, HKO are liaising with the local ATM office with a view to establishing a real-time trial for providing the prototype aviation nowcasting products for ATM personnel's evaluation in mid 2009.

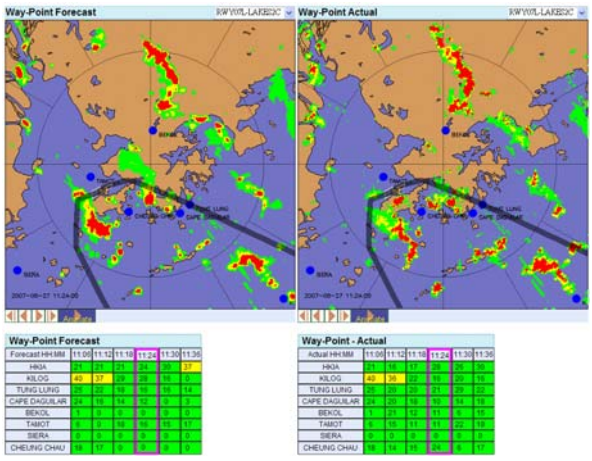


Figure 4a – A snapshot of the aviation nowcasting product (way-point forecast) on 27 Jun 2007.

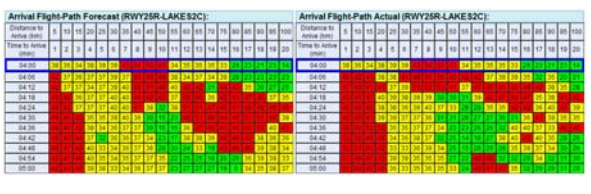


Figure 4b – A snapshot of the aviation nowcasting product (flight path forecast) on 7 Jun 2008.

5. ON-GOING DEVELOPMENT

To further enhance and improve the quality and the reliability of the aviation thunderstorm nowcasting products, a number of studies are being carried out. These include the production of the actual and forecast height of cloud top, actual and forecast intensity of the vertically integrated liquid water amounts, their relationship with turbulence, and the probability of lightning, etc. Meanwhile, to facilitate the users to appreciate the weather and the GIS information, an enhanced version of the aviation nowcasting tool which utilizes the Google Map technology is being developed (Figure 5). Besides the usual GIS information such as the latitude/longitude, terrain height and boundary information, users can also add/delete way-points of their choices, read out the storm intensity (radar reflectivity value), cloud top as well as maximum reflectivity value of a vertical column of the atmosphere at a particular location. This information would be very useful to ATM during flight planning operations.

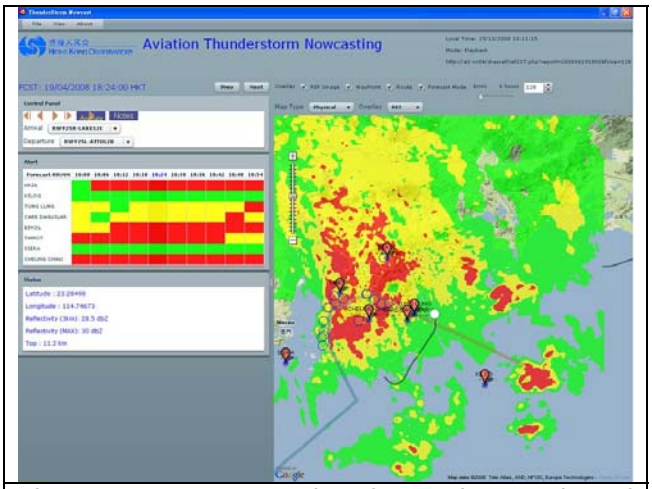


Figure 5 – An example of Google Map-based Aviation Nowcasting Product under development.

Another area which requires further study is the growth and dissipation of thunderstorm. The simple extrapolation scheme is limited in providing information about the rapid development of thunderstorm. This has been well recognized within the meteorological community worldwide as one of the most difficult and challenging subject which need inputs from sophisticated techniques such as numerical weather prediction (NWP). The aviation nowcasting products would keep improving with the latest development of NWP and other relevant technologies.

In summary, the aviation nowcasting products under development are designed to

provide ATM and airline users an overall picture at a glance of the anticipated impact of thunderstorms to flight routes and significant ATC points. This will enable their Collaborative Decision Making (CDM). With future advancement in weather information uplink technology, graphical products from the thunderstorm nowcasting system could also be transmitted to the cockpit in near-real-time for CDM by pilots.

Acknowledgement

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