DEVELOPMENT OF A LIGHTNING NOWCASTING SYSTEM FOR HONG KONG INTERNATIONAL AIRPORT

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1. INTRODUCTION

The Hong Kong Observatory has developed a lightning nowcasting system for detecting and forecasting lightning activities over the Hong Kong International Airport (HKIA) with a view to protecting personnel and aircraft on the ground from being hurt or damaged by lightning strikes. The system is consisted of two components, namely the detection module and the prediction module. The system, named the Airport Thunderstorm and Lightning Alerting System (ATLAS), will automatically generate RED and AMBER alerts whenever cloud-to-ground lightning (CG) strikes are detected or predicted to occur over the aerodrome. This paper presents the system design and the performance of ATLAS.

2. LIGHTNING DETECTION SYSTEM OVER HKIA

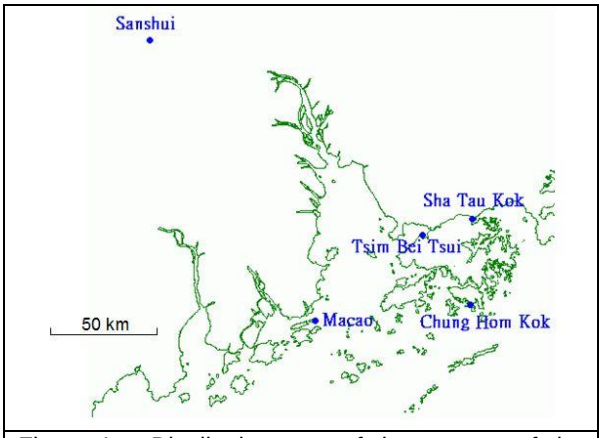

Figure 1 – Distribution map of the sensors of the lightning location network covering Hong Kong, Macao and Guangdong Province of China.

In mid-2005, the Hong Kong Observatory (HKO) set up a Lightning Location Information System (LLIS) with a network of five lightning location sensors covering Hong Kong, China and its vicinity in collaboration with the meteorological services of Mainland China and Macao, China.

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LLIS provides lightning information, including time, location, type (i.e. cloud-to-cloud or cloud-to-ground) and polarity (i.e. positive or negative) within approximately 140 km of HKIA (Figure 1). Through the Observatory's web-based Aviation Meteorological Information Dissemination System (AMIDS), real-time lightning location information has been made available to airlines and other aviation users.

Meanwhile, since 2003, the Airport Authority of Hong Kong (AAHK) has been providing a lightning alerting service over the airport, in addition to the Observatory's aerodrome warning services, for airport personnel. In cooperation with AAHK, HKO has developed an Airport Thunderstorm and Lightning Alerting System (ATLAS) based on the Observatory's nowcasting system Short-range Warning of Intense Rainstorms in Localized Systems (SWIRLS) (Li *et al.* 2004a, 2004b) and LLIS information to detect and predict in short-term (12 minutes or shorter) lightning over HKIA to enhance the lightning alerting service.

3. LIGHTNING NOWCASTING SYSTEM - ATLAS

ATLAS has two components – a detection module and a prediction module. In the detection module, the latest updated LLIS information including the latitude & longitude and the type of each lightning strike detected by LLIS are ingested into ATLAS. If any of these

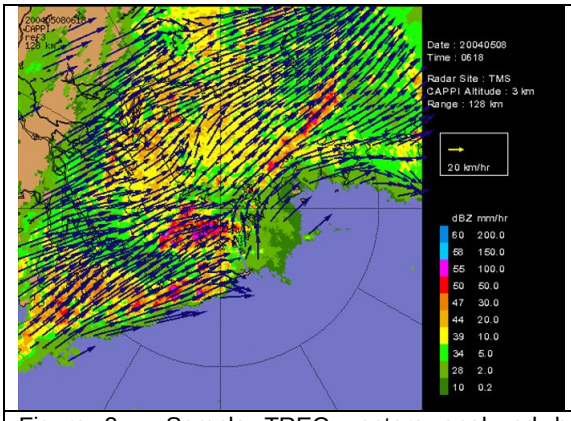

Figure 2 – Sample TREC vectors analyzed by SWIRLS

cloud-to-ground (CG) lightning strike falls within 1 km from the airport boundary (hereafter referenced as the 1-km domain), ATLAS will immediately issue an RED lightning warning. If, however, any CG strike falls beyond the 1-km domain but within 5 km from the centre of the airport (hereafter referenced as the 5-km domain), an AMBER lightning warning will be issued instead. The purpose of the AMBER warning is to provide forewarning regarding the potential of RED alert.

In the prediction module, all the latest CG strikes detected within 15 km of HKIA are grouped into clusters in the form of ellipses. The movements of the ellipses are tracked by the storm motion vector provided by the Observatory's nowcasting SWIRLS. SWIRLS is a radar-based thunderstorm nowcasting system which identifies and tracks the movements of intense thunderstorms by using the pattern recognition method TREC (Tracking Radar Echoes by Correlation) (Fig.2). The radar used in SWIRLS is the Doppler weather radar located at the top of the Tai Mo Shan mountain at approximately 1 km AMSL. In ATLAS, the future position of each ellipse is extrapolated along the TREC vector to determine if any of them falls within the 1-km domain or the 5-km domain.

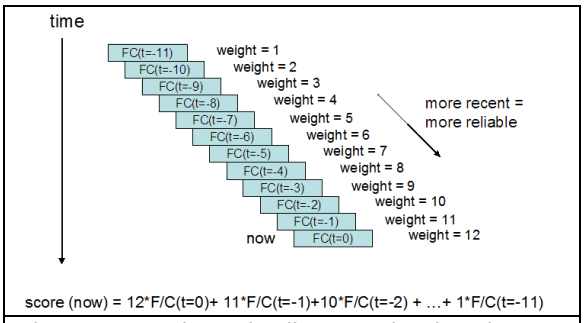

Figure 3 – Schematic diagram showing the WE algorithm. The weighting factors are linearly decreasing with time, i.e. the latest forecast is allocated 12 marks while the oldest forecast is allocated 1 mark

To take into account the possible rapid development nature (sometimes transient and sporadic, though they have very tight correlation with the development of their associated thunderstorms) of lightning, two algorithms were developed to enhance the accuracy of the extrapolation results and to automatically determine if any of the above mentioned forecast ellipses falls into the AMBER or RED alerting regions.

The first one is named the Weighted Ensemble (WE) algorithm which collects all available 12-minute forecast ellipses, assigns different weightings (linearly decreasing backward with time) and sums them up to arrive at a total score (Fig.3). If the score is above some predefined threshold, the system will automatically issue a predicted AMBER or RED alert depending on the predicted location of the ellipse(s). WE was tested to be rather efficient for alerting persistent and wide-spread thunderstorms.

Another algorithm, namely the Time Lagged Ensemble (TLE), sums the 1-minute forecasts valid at the same time from the twelve 1-minute forecasts provided in the past 12 minutes to come up with a total score. Similar set of weighting factors as in WE is applied during the summation process. Since the total score comes from a group of "time lagged" ensemble, therefore the name TLE. Experiments showed that besides persistent and wide-spread thunderstorms, TLE was more skillful in predicting rapidly developing, small or wide-spread thunderstorms than WE. In the current setup, TLE is adopted in ATLAS for operation. If TLE predicts any ellipse to enter the 1-km or 5-km domain, ATLAS will issue respectively the RED and AMBER alert appropriately. The forecast module in ATLAS is updated every 1 minute.

4. PERFORMANCE OF ATLAS

The performance of ATLAS has been tested using historical lightning data between Jul 2005 and Aug 2006. The POD and FAR for the RED alerts issued by ATLAS are respectively 91% and 61%. The alert duration percentage (i.e. the total number of minute of RED alert issued divided by the total number of minute in the study period) is 0.20%.

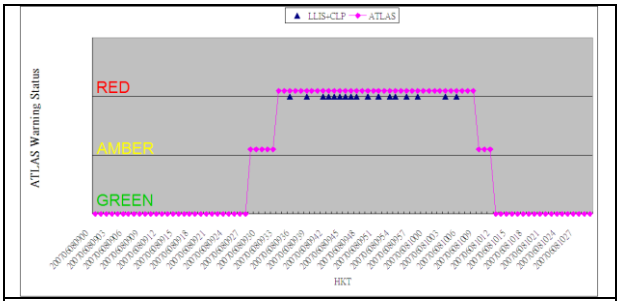

Figure 4 – Sample ATLAS alert sequence of a thunderstorm case over HKIA on 8 Jun 2007. Pink diamonds indicate the ATLAS alert status while the blue triangles show the time where lightning strikes were detected within the 1-km domain

Figure 4 shows the time sequence of ATLAS's alert status of one of the testing cases of 8 Jun 2007 (based on TLE method). Side-by-side plotted is the respective time

sequence of the actual lightning strikes over HKIA. In this case, ATLAS predicted very well the occurrence of lightning strikes in the 1-km domain. The RED and AMBER alerts have about 2 and 7 minutes lead-time respectively before the lightning strikes materialized over HKIA. The alert level dropped from RED to AMBER about 3 minutes before the cessation of all alerts at the end of the lightning episode.

A prototype webpage showing the latest products of ATLAS has been developed and made available to AAHK via the Observatory's AMIDS (Fig.5) by Jul 2007. On the webpage, not only the latest ATLAS alerting status is available, but also the actual and forecast LLIS and radar images over the surrounding areas of HKIA are provided. The alert status is updated every second while the images are updated in 1 minute interval. Facility is also provided on the webpage for the user to extract historical ATLAS alert status issued in the past couple of months. The webpage is currently under trial operation mode and is expected to become full operation by the rainy season in 2008 after further algorithm tuning and optimization.

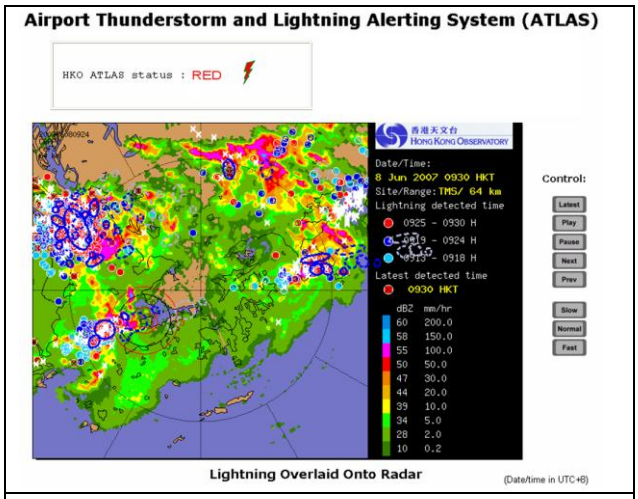

Figure 5 – A snapshot of ATLAS webpage. The top panel shows the latest ATLAS alert status while the bottom panel shows the actual position of the lightning ellipses (solid line) and the predicted ellipses (dashed line), 12-minute forecast in blue while 30-minute forecast in grey.

5. CONCLUSIONS

The Observatory has developed a lightning alerting and nowcasting system ATLAS which helps to detect and predict the likelihood of lightning activity over the HKIA. Studies using historical lightning data and radar TREC data show that ATLAS performed satisfactory during wide-spread and persistent thunderstorms cases in the vicinity of HKIA. However, there are two kinds of thunderstorm cases in which ATLAS still needs to be improved, namely overhead thunderstorm and "out-from-the-blue" lightning. As ATLAS employs extrapolation technique which can only provide forecast for lightning strikes already in existence, it is therefore not able to predict lightning developed overhead. On the other hand, since the "out-from-the-blue" lightning strike falls outside of the thunderstorm area as depicted by the radar, the forecast capability of ATLAS for this type of lightning is rather limited.

A number of development efforts are underway to further enhance ATLAS for tackling the above mentioned issues. In specific, thermodynamical instability information derived from a rapidly updated high resolution 3D data analysis system will be ingested into ATLAS to predict the potential of thunderstorm development/dissipation overhead of HKIA. Meanwhile, a microwave radiometer is being acquired for providing low level temperature and moisture profiles which would provide useful inputs for this purpose. Furthermore, the correlation between the probability of "out-from-the-blue" lightning and the moving directions of their associated thunderstorms will also be studied. These results, when available, could further enhance ATLAS capabilities of predicting the potential of these lightning events.

Acknowledgement

The authors would like to thank Ms. Sharon S.Y. Lau for her early development work of ATLAS and Mr. C.M. Shun for his comments on this manuscript.

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