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Meteorology (MET) Divisional Meeting
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Commission for Aeronautical Meteorology
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Agenda Item 2: Improving the safety and efficiency of international air navigation through enhanced meteorological service provision
2.1: Enhancement of existing meteorological service provision to support current strategic, pre-tactical and tactical operational decision-making (including ASBU Module B0-AMET)

DEVELOPMENT OF WINDSHEAR ALERTING SERVICE AT THE HONG KONG INTERNATIONAL AIRPORT

(Presented by China)

SUMMARY

This paper provides information on the development of windshear and turbulence alerting service at the Hong Kong International Airport and highlights the importance of local expertise and collaboration with ATC, airlines, pilots and airport management on the enhancement of the service.

1. INTRODUCTION

1.1 Low-level windshear and turbulence are hazardous to the operation of the arriving and departing aircraft at an airport. Timely alert of low-level windshear and turbulence is crucial to ensuring the safety of airport operation. Aviation systems block upgrade (ASBU) module B0-AMET on meteorological information supporting enhanced operational efficiency and safety, presented in MET/14-IP/1|CAeM-15/INF. 1, called for the enhancement of meteorological information from aerodrome meteorological office in the form of windshear warnings (provided to pilots through ATIS) and alerts (including those generated by automatic meteorological systems, provided to pilots through radio communication) and contribute to improving safety.

1.2 Apart from issuance of windshear and turbulence warnings by aviation forecasters, the Hong Kong International Airport (HKIA) has installed a suite of ground-based and remote-sensing meteorological equipment, including a doppler light detection and ranging (LIDAR) based windshear alerting system (LIWAS), an anemometer-based windshear alerting rules – enhanced (AWARE) and a terminal doppler weather radar (TDWR) to provide timely alert of such hazardous weather phenomena. The alerts from these individual systems are integrated and prioritized to provide the overall alert to pilots. Two of these windshear alerting systems, namely LIWAS and AWARE, were developed by the Hong Kong Observatory (HKO). In addition, the HKO tested the use of X-band weather radar in detecting windshear. This paper presents an overview of the various windshear and turbulence alerting algorithms at HKIA, focusing on the in-house developed windshear alerting systems. It also presents the latest work in addressing crosswind changes due to airport infrastructures and points to future work being planned to further mitigate these risks.

(10 pages)

2. EXISTING WINDSHEAR AND TURBULENCE ALERTING FACILITIES

2.1 LIWAS

2.1.1 The first LIDAR was installed at HKIA in 2002. At first, conventional plan position indicator (PPI) and range height indicator (RHI) scans as used in weather radar were implemented to capture windshear features, but they were found not efficient in monitoring the fast-evolving windshear on the flight paths. A special scanning strategy was then developed, namely, the glide-path scan, in which the elevation and azimuth change at the same time and at matching speeds so that the laser beam would slide along the flight path (a slanted line in the 3-dimensional space). A windshear algorithm called GLYGA (glide-path scan windshear alert generation algorithm) was developed to capture the windshear features along the flight path based on the glide-path scan data. It was put into operation in 2005, the world-first operational implementation of LIDAR-based windshear alerting service.

2.1.2 With the introduction of the second LIDAR to HKIA in 2006, dual LIDAR operation mode was implemented in 2007. Each of the two parallel runways of the HKIA is served by a LIDAR located near the middle of the runway, which looks at both directions of the runways to measure the headwind profiles in the two directions. In switching between these two directions, each LIDAR also makes a PPI scan providing an overview of the wind distribution inside and around HKIA which can assist the weather forecasters in considering the issuance and cancellation of windshear warnings. The LIDAR windshear alerts are runway specific so that windshear alerts in force can be different for a particular arrival runway corridor and the corresponding departure runway corridor.

2.1.3 The LIDARs at HKIA are eye-safe. They can measure a maximum range of 10 km with a spatial resolution (along the line of sight) of about 100 m. Data are captured at 0.1 second interval. Each LIDAR spends about 6 to 8 seconds in making glide-path scan along a specific runway corridor. As such velocity data at high spatial resolution are obtained. The revisit time for a particular corridor, namely, the period in between two successive glide-path scan of the corridor, is about 2 minutes.

2.1.4 The LIDARs have become a major component of windshear detection at HKIA. For the most used arrival runway corridor (07LA), the LIDAR alone captures about 70% of the pilot windshear reports. A typical example of terrain-induced windshear as observed by the LIDAR could be found in Figure 1. This case reveals that there were a couple of high-speed streaks emanating from the gap of nearby mountains along the runway corridor. In between the high-speed streaks, there were areas of lower wind speeds. As the aircraft flew through the areas of higher and lower wind speed, significant windshear would be experienced. In fact, in that particular morning, a number of flights conducted missed approach on arriving at the south runway of HKIA from the west, and some had eventually diverted to other airports.

2.1.5 Apart from windshear, low-level turbulence intensity is also calculated based on the LIDAR’s radial velocity data. By assuming isotropic turbulence, the cube root of eddy dissipation rate (EDR), which is the turbulence intensity metric being used in international civil aviation, is calculated. Two kinds of products are generated, namely, the EDR profile along the flight path, and the EDR map giving an overview of turbulence intensity distribution inside and around HKIA. The data display of EDR could be found in Figure 2. The EDR data so calculated are used as reference by the aviation weather forecasters at the moment, and it is hoped to put them into operational turbulence alerting in the future.

2.2 AWARE

2.2.1 As the HKIA is opened to the sea on 3 sides and is adjacent to major marine traffic route, it would be very difficult to install the many anemometers required for effective windshear detection based on the Low Level Wind Shear Alert System (LLWAS) architecture. Moreover, given the maritime climate of Hong Kong, chances of dry microburst, of which LLWAS-III was specifically designed to detect, is highly unlikely. Instead the major causes of low-level windshear under non-rainy conditions are sea breezes and terrain. The AWARE algorithm was thus developed to compare the headwinds as measured by pairs of anemometers inside and anemometers (including weather buoys) around HKIA aligned closed to the runway centreline.

2.2.2 Due to the limited heights of anemometers (10 m above ground) and weather buoys (about 7 to 8 m above sea surface), AWARE could only capture windshear features that occur close to the ground/sea and is less effective in capturing windshear occurring in the middle of the atmospheric boundary layer that might not extend all the way to the surface such as those due to terrain. A typical example of sea breeze induced windshear that was captured by AWARE is given in Figure 3. The background wind in Hong Kong was easterly, and sea breeze occurred as westerly on the western part of HKIA. AWARE captured this windshear successfully, consistent with the pilot reports.

2.2.3 Some anemometers are also set up on the mountain tops and valleys of Lantau Island. Data up to a temporal resolution of 1 second are available from the mountain/valley as well as the airfield anemometers. The cube root of EDR is calculated from these anemometer data and the values are shown in a display (Figure 4) to the forecasters for reference. The performance of such anemometer-based EDR is being evaluated with a view to complement those derived from LIDAR.

2.3 Weather radar

2.3.1 The strongest windshear over the airport terminal areas is usually associated with microbursts induced by thunderstorm activities. For detection of changes in the winds along the runway direction, a Terminal Doppler Weather Radar (TDWR) was installed about 12 km from the airport for effective monitoring of low-level windshear. The TDWR was installed in 1996 and has been in operation since airport opening in 1998. The TDWR, using the automatic algorithm developed by MIT/LL, is very effective in detecting microburst and windshear.

2.3.2 After serving the airport for more than 15 years, the current TDWR has already exceeded its design life-time. A new TDWR will be installed and tested in 2014 succeeding the current one for provision of thunderstorm-related microburst and windshear alerts. To fill the gap when the existing TDWR has to be switched off for testing of the new TDWR, an experimental dual polarization X-band Doppler weather radar (X-band radar) was installed in 2012 as a stop-gap measure to support the windshear alerting services for HKIA.

2.3.3 The X-band radar is comparatively inexpensive and easy to deploy because of its much smaller size. While the X-band radar comes with an automatic windshear detection algorithm, a more sophisticated detection algorithm was developed anew in-house. Performance of the X-band radar was studied during a series of thunderstorms in 2013. In spite of the inherent limitations of rapid attenuation due to the use of higher frequency electromagnetic waves and less favourable site location as compared with the current TDWR, alerts from the X-band radar exhibited similarity to those generated by the current TDWR (Figure 5a and 5b).

3. CROSSWIND VARIATIONS

3.1 Apart from headwind changes, significant crosswind variations invariably add complications to landing safety. Airport infrastructures, such as passenger terminal and hangers, could lead to building-induced airflow disturbances including variations in crosswinds if these infrastructures are close to the runway. A two-prone approach, namely real-time detection for existing buildings and low level wind study for new infrastructure, is being taken forward to mitigate the hazard.

3.2 For real-time detection, since the building-induced airflow disturbances occur on very fine spatial as well as temporal scales, the conventional long-range LIDAR may not be able to pick them up readily. The Observatory conducted field experiments to observe such airflow disturbances using a short-range LIDAR installed on the rooftop of the building. Based on the field study data collected in a number of years, this kind of LIDAR is found to be capable of capturing the small-scale airflow disturbances. A typical sequence of building-induced airflow disturbance obtained by the short-range LIDAR is given in Figure 6. While the short-range LIDAR may be capable of detecting the occurrence of such airflow disturbances, issues still remain in how the pilots could be alerted given the very short temporal scale and would require more work.

3.3 For further development of HKIA, it is inevitable that new infrastructures would be built at the aerodrome. Since around 2007, every new building/structure inside the airport is required to go through a low level wind study. Computational fluid dynamics model is employed to examine the effect of the new building/structure on the airflow along the flight path, particularly the effect on the crosswind. The result of the low level wind study would be discussed with the aviation stakeholders, including the airport management, civil aviation authority, pilots and the building developer concerned, in order to determine if mitigating measures should be put in place. To increase the awareness of the relevant stakeholders at HKIA to the low level wind effects, a pamphlet has been developed and promulgated (Figure 7).

4. CONCLUSION

4.1 The paper presented a number of recent developments in windshear and turbulence alerting service at HKIA. The systems/algorithms in general are found to work very effectively for windshear detection in Hong Kong. Based on pilot reports relayed via ATC, more than 90% of windshear occurrence at HKIA has been given alerts/warnings in advance. In addition to verification using pilot reports relayed operationally via ATC, through arrangement with the local airlines, onboard wind data measured by the aircraft of are also used in the development and verification of the windshear detection algorithms.

4.2 The windshear alerting service in Hong Kong highlights the importance of local data and expertise in understanding the windshear phenomena specific to the local environment. Through understanding the causes of the windshear phenomena and the nature of the airflow disturbances themselves, systems/algorithms were implemented to specifically target the alerting for these phenomena to ensure that the solution would be the most cost-effective.

4.3 The contribution from pilots, local ATC and other aviation stakeholders in the whole process must never be understated. In particular, pilot reports, collected through ATC, form the basis for the development and verification of windshear and turbulence alerting algorithm. Their feedback was also important in defining the alerting criteria and phraseology.

4.4 The windshear/turbulence work at HKIA is still on-going. Cutting down false alarms and alert durations would continue to be a focus. The LIDAR, radar and anemometer-based turbulence products would also be tried out in real time to see if they could be implemented operationally. Furthermore, there are new developments on studying the benefits of windshear alerts specific to each aircraft type, based on the windshear hazard factors for each of the aircraft types.

5. ACTION BY THE MEETING

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

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APPENDIX

FIGURES

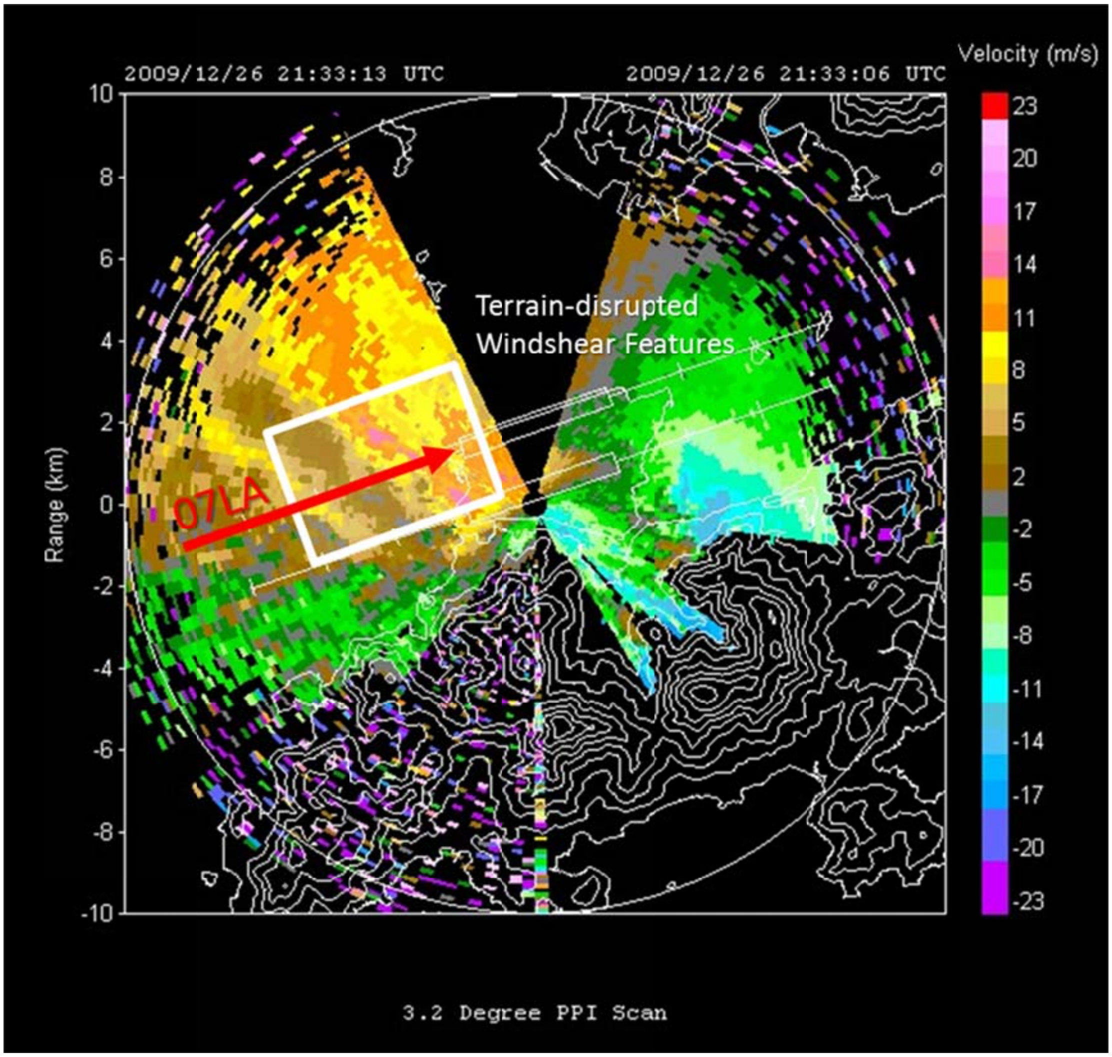
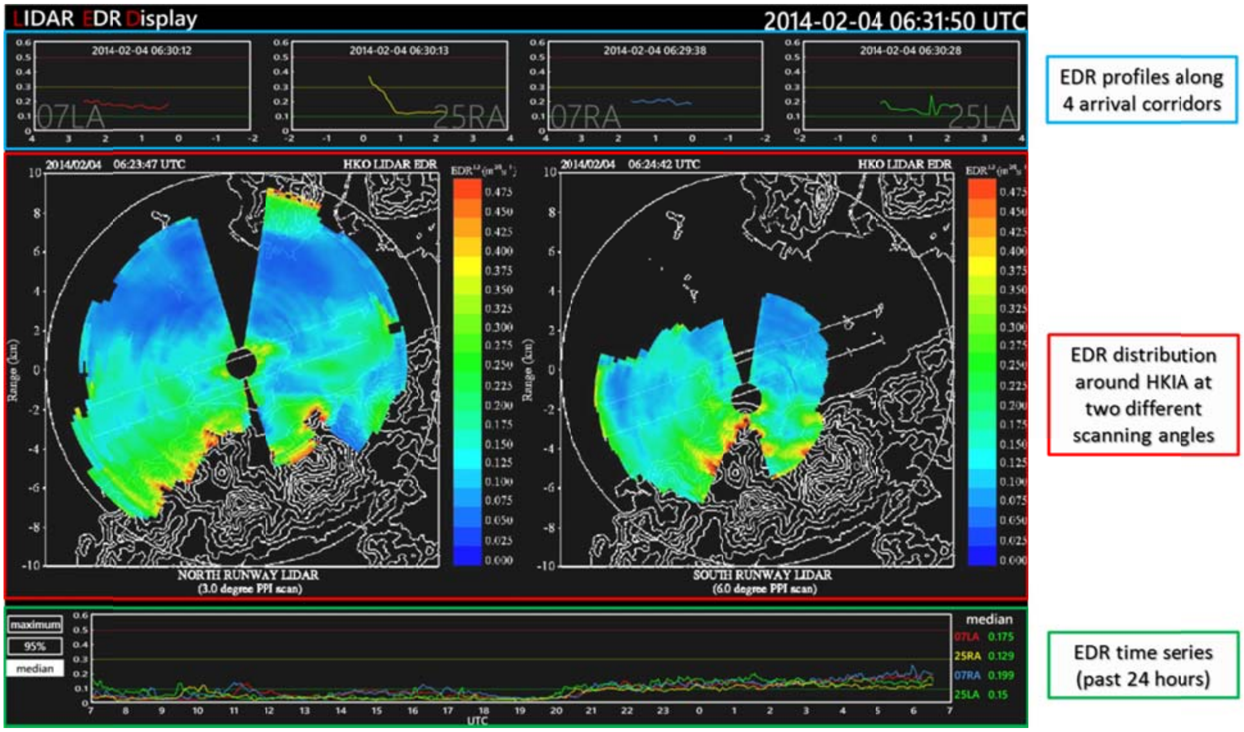


Figure 1. A typical case of terrain-induced windshear as observed on the LIDAR

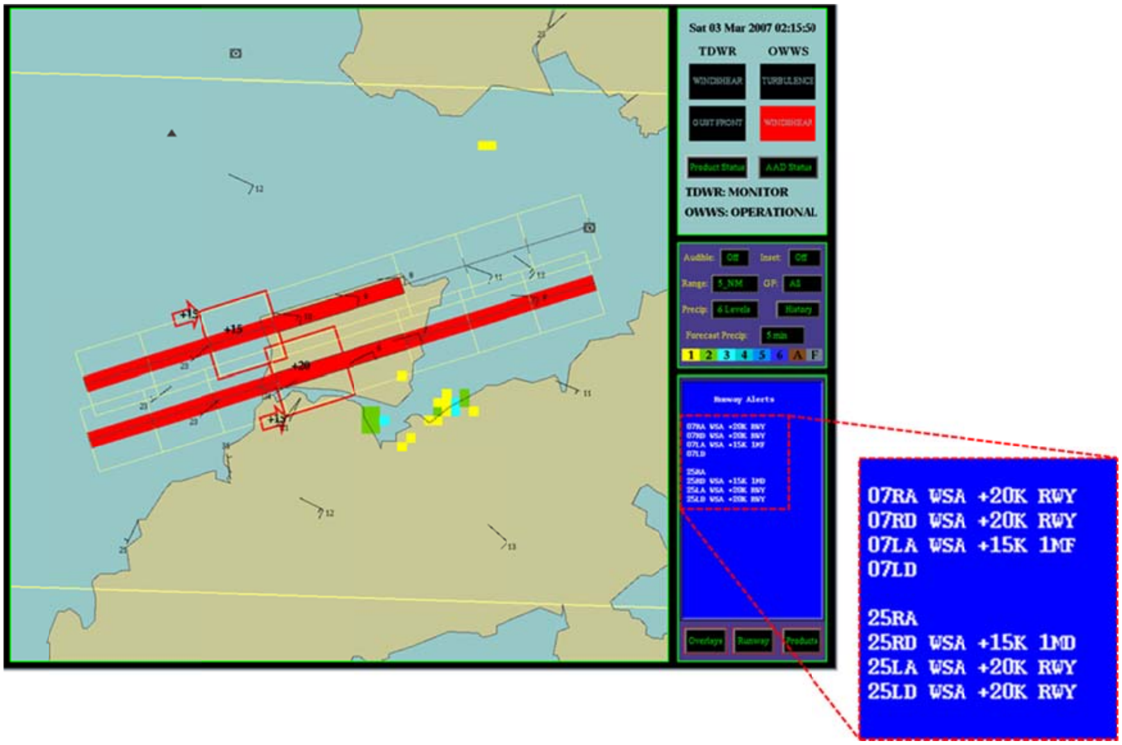


EDR profiles along 4 arrival corridors

EDR distribution around HKIA at two different scanning angles

EDR time series (past 24 hours)

Figure 2. Real-time display of EDR around HKIA as calculated from LIDAR data



07RA WSA +20K RWY
07RD WSA +20K RWY
07LA WSA +15K 1MF
07LD

25RA
25RD WSA +15K 1MD
25LA WSA +20K RWY
25LD WSA +20K RWY

Figure 3. A typical case of windshear due to sea breeze as captured by AWARE

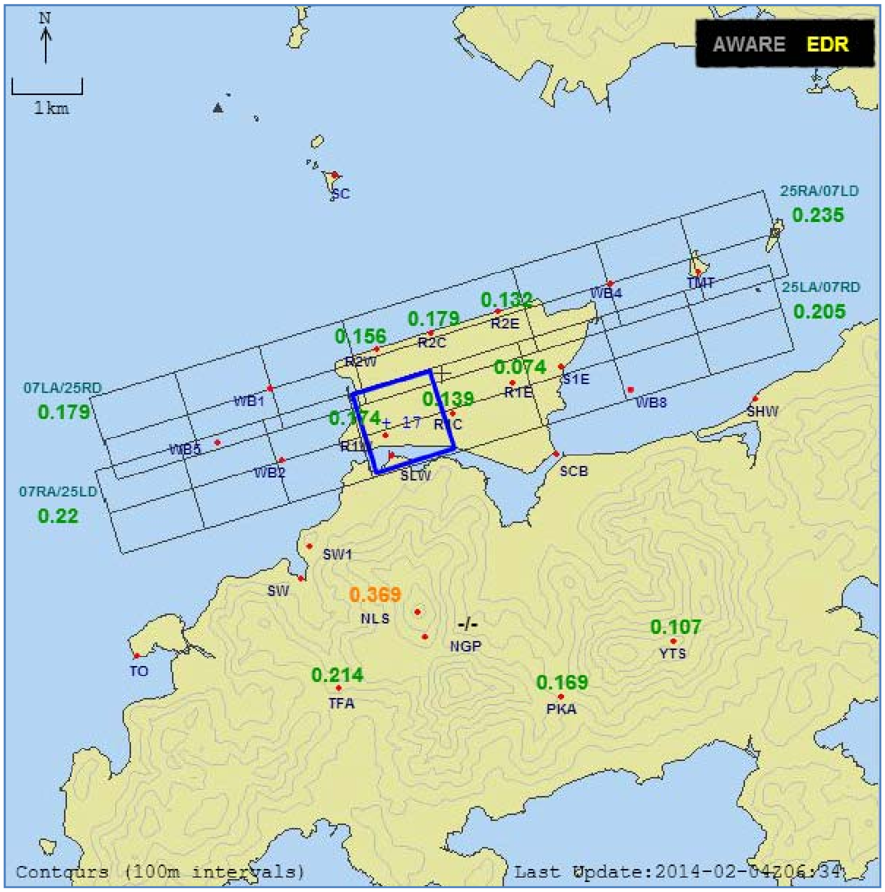


Figure 4. Distribution of EDR around HKIA as calculated from anemometer data

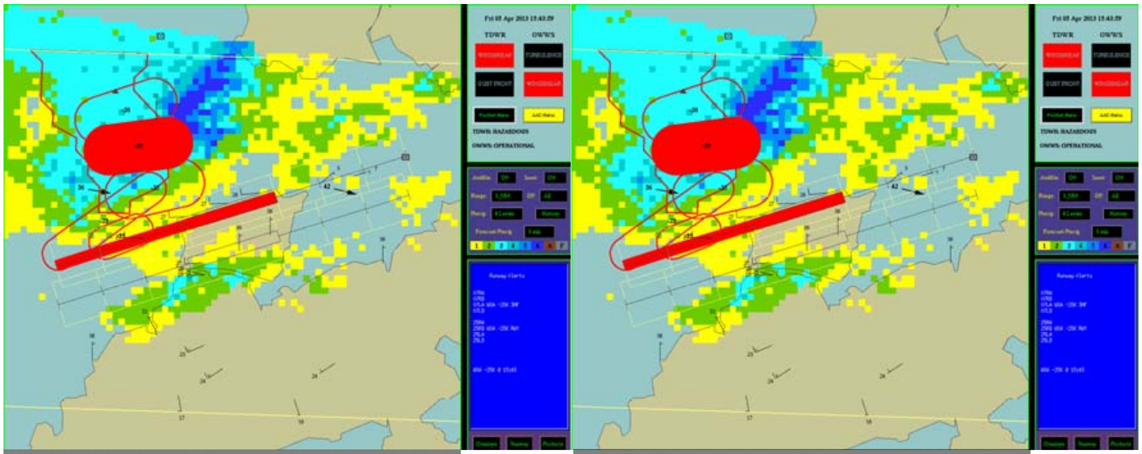
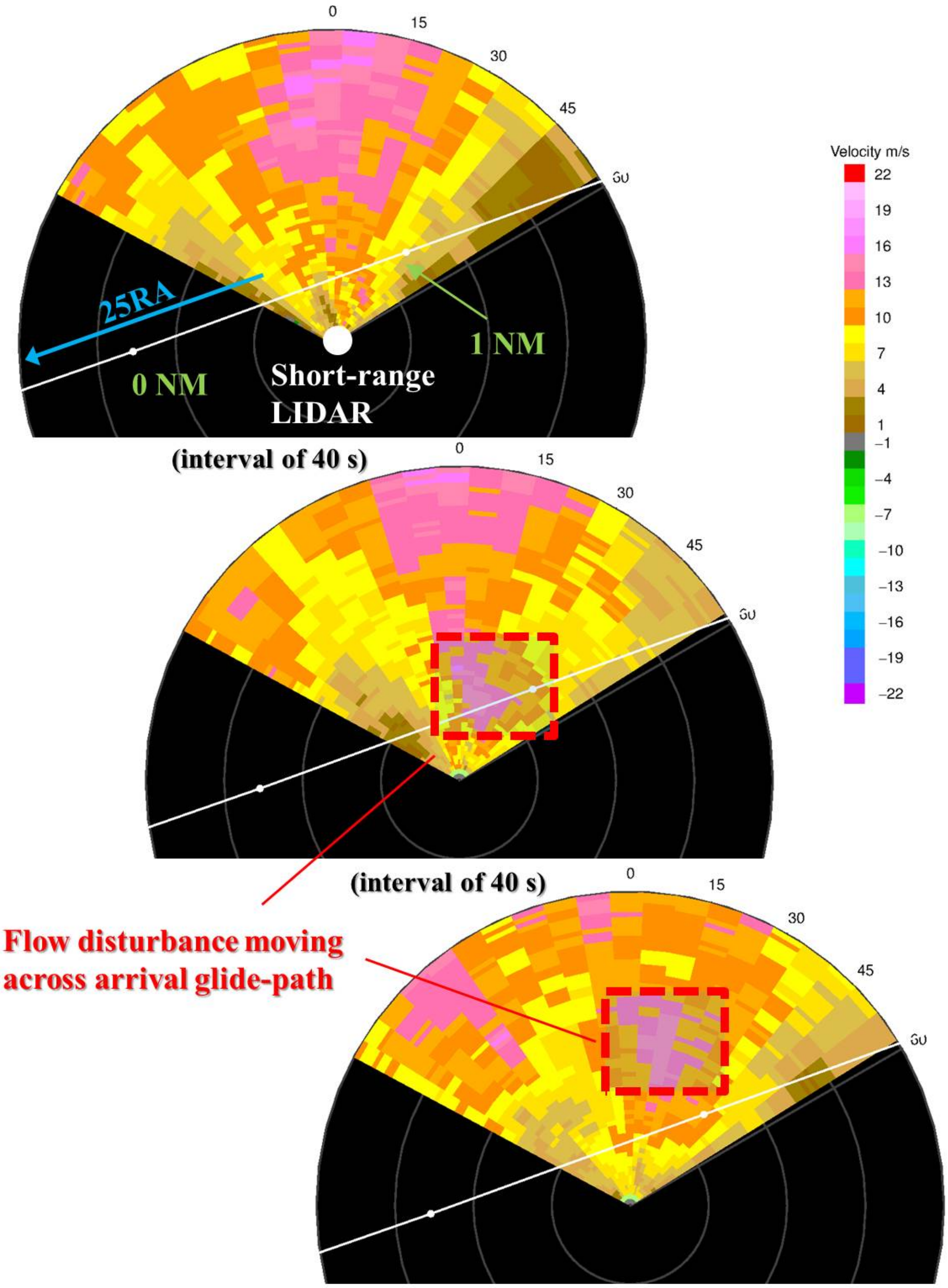


Fig 5a Microburst and windshear alerts from the X-band Radar

Fig 5b Microburst and windshear alerts from the TDWR

Figures 5a and 5b. Microburst and windshear alerts from the X-band radar and the TDWR on WTWS respectively at around 1544 UTC on 5 April 2013, showing a good alignment between the alerts from the two radars. Light brown area indicates the attenuated region of the X-band radar.



(interval of 40 s)

(interval of 40 s)

Flow disturbance moving across arrival glide-path

Figure 6. Typical pattern of windshear features (highlighted) as observed by the short-range LIDAR

香港天文台
HONG KONG OBSERVATORY

LOW LEVEL WIND EFFECT
AT AIRPORTS

— INFORMATION FOR PILOTS AND
PLANNERS OF NEW BUILDINGS

Simulation of air particles flowing over and around a building

HONG
KONG

Figure 7. A pamphlet on the low level wind effect jointly prepared by HKO, HKALPA and GAPAN

— END —