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APPLICATIONS OF A SHORT-RANGE LIDAR AT THE HONG KONG INTERNATIONAL AIRPORT

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ABSTRACT

A short range LIDAR with a spatial resolution down to 30 m was tried out at the Hong Kong International Airport (HKIA) in the summer of 2009 to study microscale airflow disturbances, e.g. in association with buildings at the airport. It performed generally satisfactory during the test period and was used to capture many interesting features of the low-level winds that were not observed with the existing LIDAR systems at HKIA, which have lower spatial resolution and are mainly used to monitor windshear features with spatial scale more than several hundred metres. This paper presents some preliminary study results with the short-range LIDAR, namely, the observation of "bursts" (or jets) in the south to southwesterly flow that may be related to windshear encountered by the aircraft, short waves (with a spatial scale of about 100 m) in the southwesterly flow that seems to be associated with low-level wind effects of the buildings, and turbulent flow based on the eddy dissipation rate (EDR) maps as determined from the radial velocity measured by the LIDAR. Future developments in the application of short-range LIDAR would also be discussed.

1. GENERAL SPECIFICATIONS

Two Doppler LIDAR systems of the Hong Kong Observatory (HKO) have been operating at HKIA for the detection and alerting of low-level windshear. Terrain-disrupted airflow and sea breeze are two major causes of windshear at HKIA. There is also concern about the low-level wind effects of the buildings at the airport. The LIDAR systems in use at HKIA have a spatial resolution of 105 m, which may not be fine enough to resolve the airflow disturbances in association with the buildings. As such, an initial study was conducted by HKO in July – August 2009 to find out the performance and application of a short-range LIDAR (with a measurement range up to 1500 m only vs. 10 km of the existing LIDAR systems) with a high spatial resolution (down to 30 m).

The short-range LIDAR (model LR-FI) uses a laser beam with a wavelength of about 1.5 microns. It worked generally stably during the study period before the breakdown of the communication channel of the scanner in late August 2009. This paper summarizes the results of some initial analysis of the observations of the short-range LIDAR.

2. SETUP OF THE LIDAR

The appearance of the LIDAR is shown in Figure 1(a). The locations of the LIDAR on the rooftop of AsiaWorld-Expo and the 25RA glide path are given in Figure 1(b). The LIDAR provides line-of-sight (radial) velocity data at 20 range gates. The size of each range gate is selectable between 30 and 75 m. As such, the measurement range of the LIDAR could be varied between 600 and 1500 m. The LIDAR made horizontal scans at a height of about 29 m above mean sea level and the laser beam was located below the landing aircraft around AsiaWorld-Expo (aircraft height between 84 and 99 m).

3. JETS IN SOUTH TO SOUTHWESTERLY AIRFLOW

An example of burst (or jet) occurred when Typhoon Molave affected Hong Kong on 19 July 2009. At that time, the LIDAR was configured to have a range gate size of 75 m (and thus a measurement range of 1500 m) with data updated every 3 minutes or so. A sequence of radial velocity imageries provided by the LIDAR is shown in Figure 2. It could be seen that, in the south to southwesterly airflow, there were occasionally some "bursts" of stronger winds embedded in the flow and affecting the 25RA runway corridor. In fact, there was a pilot windshear report over 25RA at 0518 UTC on that day (B744, windshear gain of 15 knots and moderate turbulence at about 300 feet), which was consistent with the occurrence of a "burst" (or jet) of southwesterly flow observed by the LIDAR, albeit observed at a lower altitude. From its spatial extent (in the region of several hundred metres), it is not clear whether the jet was related to microscale weather features in the southwesterly flow or airflow disruptions generated by the buildings. It is noted that such a "burst" could not be measured by the existing LIDARs at the airport, probably because (i) it occurred for only a short while and (ii) the laser beam from the north runway LIDAR is more or less parallel to the runway orientation of 25RA corridor and may not capture the wind features occurring at a larger angle to the runway direction. As such, the pilot report at 0518 UTC was not captured by the existing LIDAR Windshear Alerting System (LIWAS) algorithm [1].

4. WAVES IN SOUTH TO SOUTHWESTERLY AIRFLOW

There was an example of waves on 2 August 2009. At that time, the LIDAR was configured to have a range gate size of 30 m and thus a measurement range of 600 m. The date update frequency was set to be 20 seconds. The LIDAR's radial velocity could be processed through some sophisticated algorithms (provided by the LIDAR manufacturer, [2]) to give the distribution of 2D winds. A sequence of the temporal variation of the 2D winds is given in Figure 3. It could be seen that some waves were identified in the light to moderate southwesterly flow. The waves had a spatial extent of the order of 100 m and might be related to airflow disruptions arising from the buildings. They could not be captured by the existing LIDARs at the airport probably because of their short life spans (within a minute or so) and small spatial extent (comparable to the range gate size of about 105 m of the existing LIDARs). Probably because of the light winds, there were no pilot reports of significant windshear during the occurrence of the waves.

5. TURBULENCE INTENSITY

The radial velocity of the LIDAR could be used to calculate turbulence intensity, namely, eddy dissipation rate (EDR) which is the internationally adopted metric for turbulence alerting in aviation weather services. Two examples of EDR map obtained from the short-range LIDAR data are shown in Figure 4. In the first case (Figures 4(a) and (b), same as the case in Figure 3), light south to southwesterly flow affected the northeastern part of the airport. EDR was less than 0.2 $m^{2/3}s^{-1}$. Its value was larger at the closer ranges (in the first couple of hundred metres from the LIDAR). This distribution pattern of $EDR^{1/3}$ could be expected because the airflow should be more turbulent closer to the building (disruption of the winds after climbing over the building). The second case (Figures 4(c) and (d)) was the moderate to fresh southeasterly winds associated with Severe Tropical Storm Goni on 5 August 2009. The airflow was more turbulent than the first case and $EDR^{1/3}$ was in the region of 0.3 – 0.6 $m^{2/3}s^{-1}$. Once again, the EDR value was larger at closer ranges of the LIDAR.

In both cases under study, the EDR magnitudes and spatial distributions appear to be reasonable. The short-range LIDAR is more suitable for EDR calculation than the existing LIDAR systems at the airport because of its higher spatial resolution (a range gate size of about 30 m vs. 105 m of the existing LIDARs) and more frequent data update (about 20 seconds vs. 2 minutes of conical scans of the existing LIDARs).

6. CONCLUSIONS

The short-range LIDAR at AsiaWorld-Expo was found to provide some interesting observations that could not be obtained with the existing instruments at the airport. Such data could be useful for improving windshear and turbulence alerting over 25RA. However, the study period in summer 2009 was short (two months as originally scheduled, further shortened to 45 days due to breakdown of the LIDAR scanner) and the number of 25RA windshear reports was significantly less than those received in 2005 - 2007. As such, the benefits of a permanent installation of a short-range LIDAR for improving 25RA windshear and turbulence alerting could not yet be established. The possibility of arranging another trial of this equipment in summer 2010 will be explored.

REFERENCES

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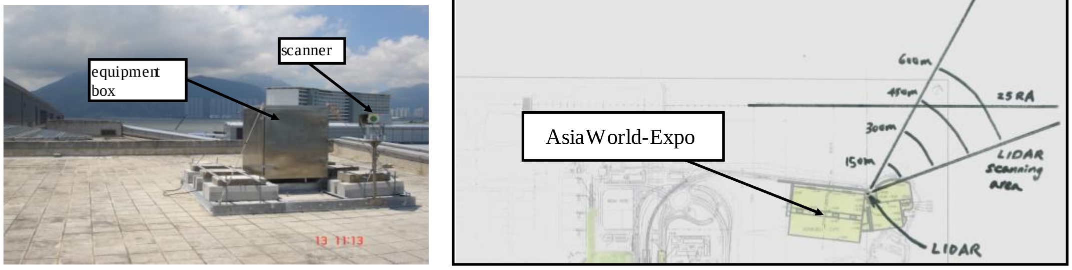
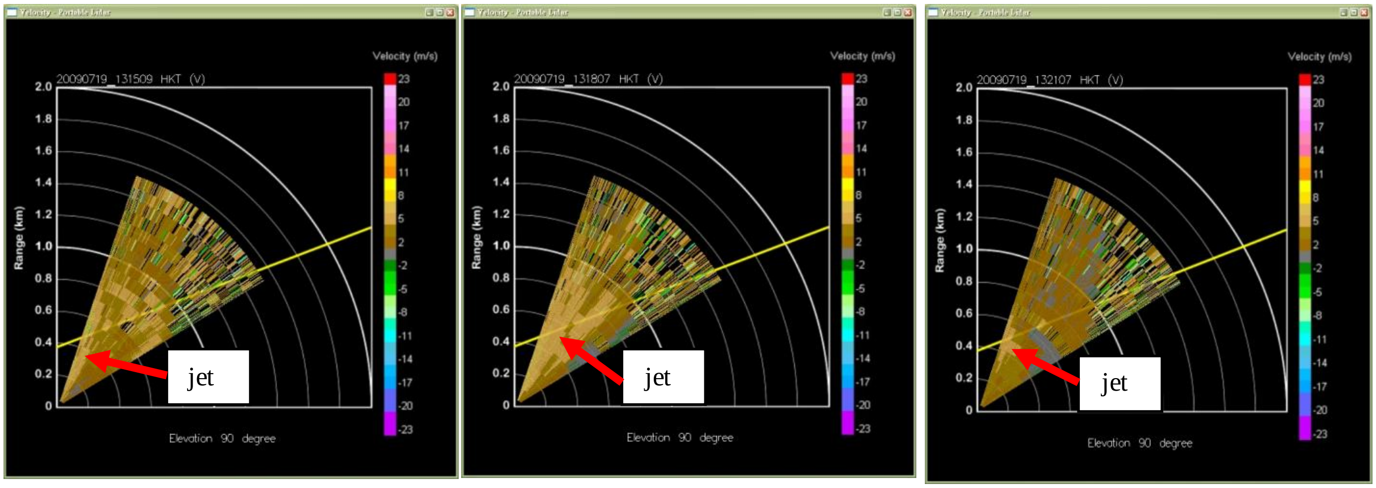
[2] Ando, T., S. Kameyama, Y. Hirano, 2008: All-fiber coherent Doppler LIDAR technologies at Mitsubishi Electric Corporation, *IOP Conf. Series: Earth and Environmental Science*, **1**, no. 012011.

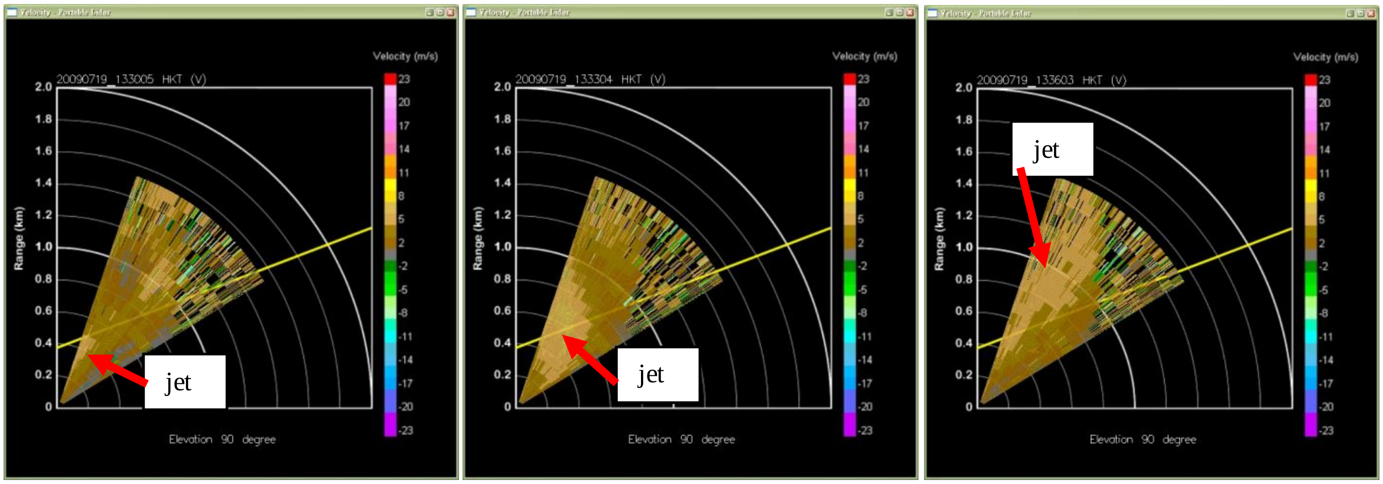


(a) (b)

Figure 1 Appearance of the LIDAR (a), and the location of the LIDAR at the airport (b).

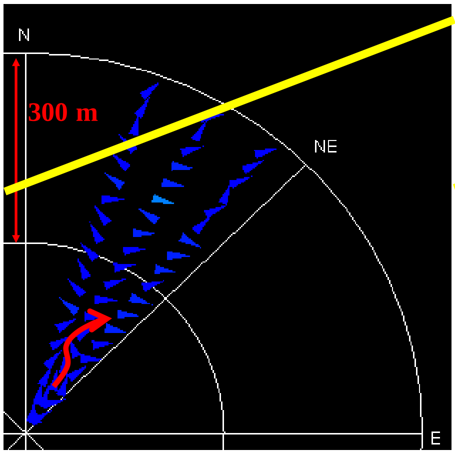


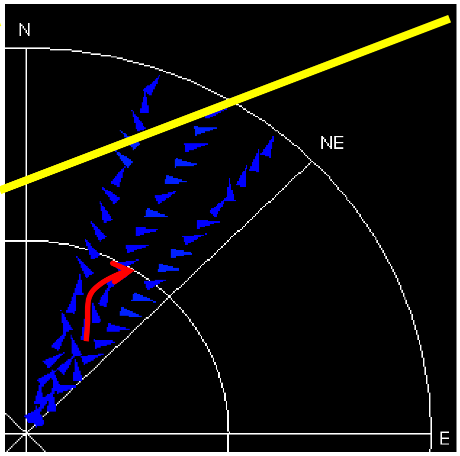
05:15 UTC 05:18 UTC (time of pilot report) 05:21 UTC



05:30 UTC 05:33 UTC 05:36 UTC

Figure 2 Time sequence of the evolution of the jets in a case of south to southwesterly airflow as observed by the LIDAR. The yellow line represents the flight path of 25RA.





Legend: wind vector (m/s)

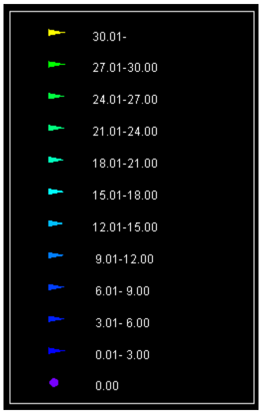


Figure 3(a) Figure 3(b)

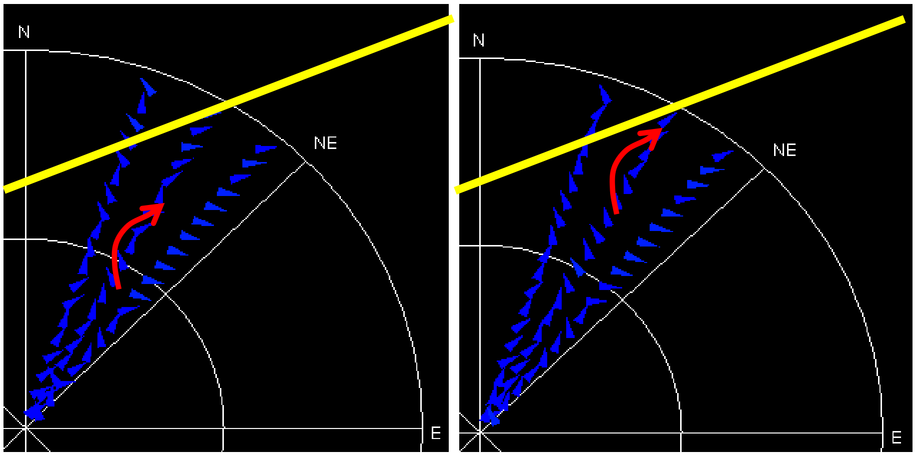
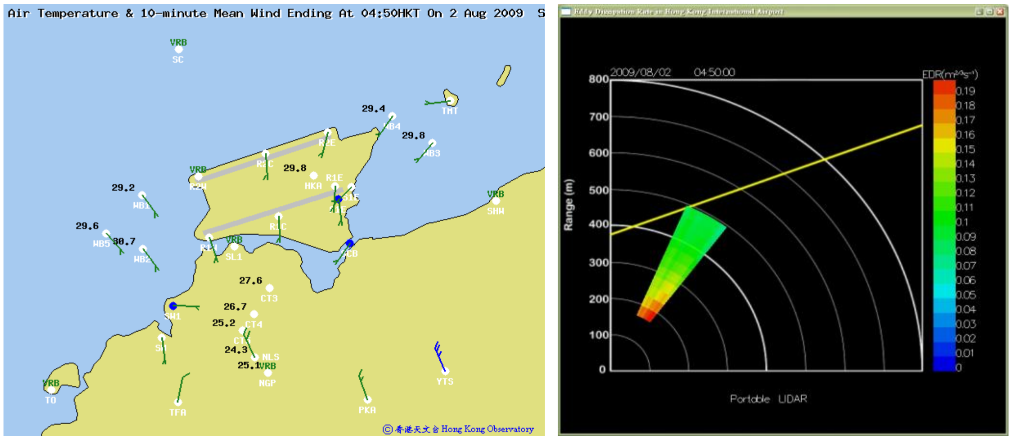
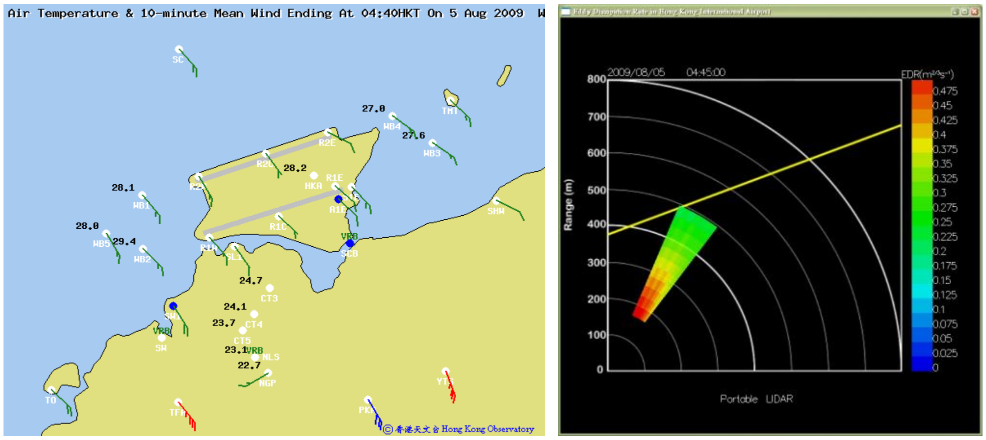


Figure 3(c) Figure 3(d)

Figure 3 Time sequence of the evolution of a wave in a case of southwesterly flow as observed by the LIDAR. The yellow line represents the flight path of 25RA.



(a) Surface wind at 04:50 HKT, 2 August 2009 (b) EDR map
(based on LIDAR data between 04:45 – 04:50 HKT)



(c) Surface wind at 04:40 HKT, 5 August 2009 (d) EDR map
(based on LIDAR data between 04:40 – 04:45 HKT)

Figure 4 Surface wind observations and LIDAR-derived EDR plots for two cases. The yellow line in (b) and (d) represents the flight path of 25RA.