

EXPERIMENTAL USE OF A WEATHER BUOY IN WINDSHEAR MONITORING AT THE HONG KONG INTERNATIONAL AIRPORT

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1. INTRODUCTION

This paper describes the introduction of a weather buoy near the Hong Kong International Airport (HKIA) and presents its applications to windshear monitoring and alerting for aircraft flying in and out of the airport.

The HKIA was opened in July 1998. There are two parallel runways orientated in 070-250 degree direction (Figure 1). It is located on a reclaimed island surrounded by waters on three sides. To the south of it, the rather mountainous Lantau Island has hills reaching 950 m above mean sea level.

The land-sea interaction and the hilly terrain often produce complex airflow patterns in and around the airport. A number of windshear events are known to have resulted from the setting in of sea breeze (Lee and Shun, 2002) and from wind disturbances caused by cross-mountain flow (Lau and Shun, 2000).

In aviation meteorology, windshear refers to a sustained change in headwind or tailwind, resulting in changes in the lift to an aircraft. Apart from sea breeze and cross-mountain flow in the airport environment, windshear can also arise from the passage of a cold front, or a gust front associated with thunderstorms (Lau et al., 2002). For Hong Kong, in the period from July 1998 to December 2001, 0.14% of all flights in and out of the airport reported significant windshear, i.e. windshear reaching 15 knots or more.

In running the windshear and turbulence alerting service at HKIA, the Hong Kong Observatory (HKO) operates a network of land-based automatic weather stations around the airport (Figure 1). HKO also operates remote-sensing equipment including a Terminal Doppler Weather Radar (TDWR) and wind profilers for monitoring the weather and wind pattern there. The radar covers severe weather reasonably well, including thunderstorms and microbursts. An infrared LIDAR (Light Detection And Ranging) system was installed in mid-2002 to cover fine weather situations, and its performance will be evaluated.

HKO installed a weather buoy over the waters to the west of the airport in December 2001. This is the first time a weather buoy was deployed in Hong

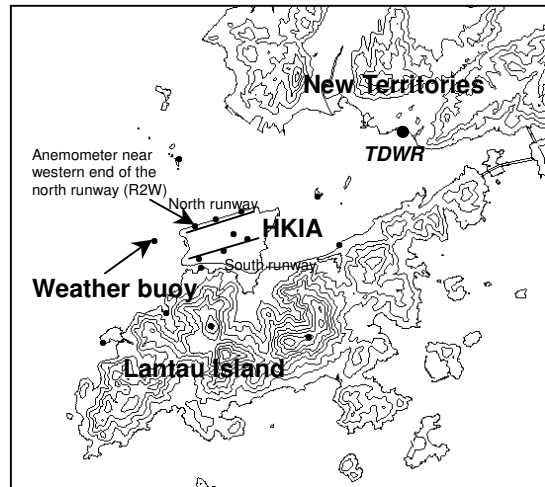


Figure 1 Map of HKIA and the surrounding areas. The weather buoy and the other weather stations around the airport are indicated by dots. Terrain contours are in 100-m intervals.

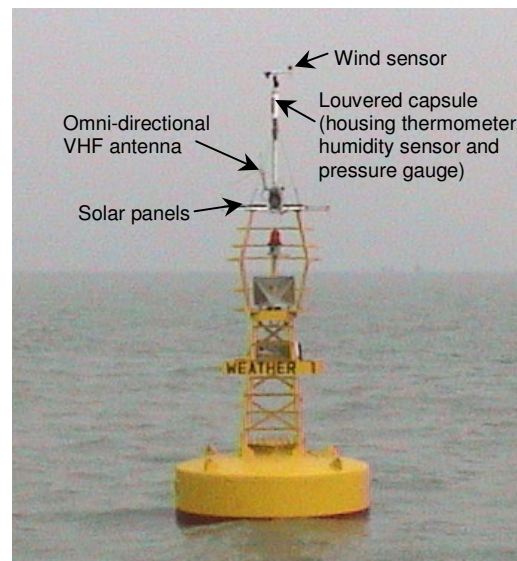


Figure 2 The first weather buoy in Hong Kong.

Kong. The purpose is to fill in a data void over the area and to provide 'ground' truth complementing the remote-sensing equipment.

2. EQUIPMENT SET-UP

Figure 2 shows the weather buoy. Its hull is adapted from a common type of marine navigation buoy in Hong Kong. An automatic weather station specifically designed for use on a buoy is mounted at the top, with a propeller-type wind sensor at the highest point (about 7 m above sea surface), and

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beneath it a louvered capsule housing a thermometer, a humidity sensor and a pressure gauge.

Weather measurements are sent out every 10 seconds to the HKO office at the airport. This is achieved by means of an omni-directional VHF radio antenna alongside the weather equipment.

Time-stamping of the weather data is carried out using a Global Positioning System (GPS) receiver on-board, which provides regular synchronization for the weather equipment. The stated timing accuracy is within 50 nanoseconds of GPS satellite clocks.

The buoy operates solely on solar energy. It is equipped with 6 units of 20-Watt solar panels to support the weather measurements, data transmission every 10 seconds, as well as the navigation light. The battery voltage is also regularly radioed back to enable monitoring of its status.

The performance of the weather buoy has been satisfactory with no major problem since its commissioning in late 2001. So are the solar panels which have maintained the continuous operation of the buoy for up to a week during cloudy spells.

3. APPLICATIONS TO WINDSHEAR MONITORING AND ALERTING

For monitoring windshear, real-time wind data from the relevant stations are used to estimate the change in the headwind. As an example, for an aircraft approach towards the north runway from the west, the component of wind at the weather buoy along the direction of the north runway is subtracted from the corresponding value of the anemometer near the western end of the runway (R2W), giving a value indicative of the horizontal windshear. A resulting vector pointing to 070 (250) degrees implies a loss (gain) of headwind or a gain (loss) in tailwind for the aircraft. Likewise, the difference in headwind between a hill station and a coastal station gives an indication of the vertical windshear.

After detailed studies, two alert levels based on headwind differences were established:

- (a) 10-knot difference – significant windshear is probable, and the forecaster should be on the alert;
- (b) 15-knot difference – significant windshear is very probable, and the forecaster should actively consider the issuance of windshear alerts taking into account other meteorological data.

Since its commissioning in late 2001, the weather buoy has demonstrated a capability for more timely alerting of significant windshear under several different weather conditions. Some examples are given below.

3.1 SEA BREEZE

At the airport, sea breeze is typically characterized by westerly winds setting in over the waters west of the airport (Cheng, 2002). With

easterly winds normally prevailing, the opposing westerly/easterly winds in the vicinity of the sea breeze front sometimes result in significant windshear.

An example of sea-breeze induced windshear occurred on 31 January 2002. Under the influence of an area of high pressure centred over east China, the weather was generally fine in Hong Kong on that day with easterly winds prevailing (Figure 3). As early as 10 a.m. (Hong Kong time = UTC + 8 hours), temperatures at the airport already rose above the sea surface temperature of 17 degrees, favoring the formation of sea breeze.

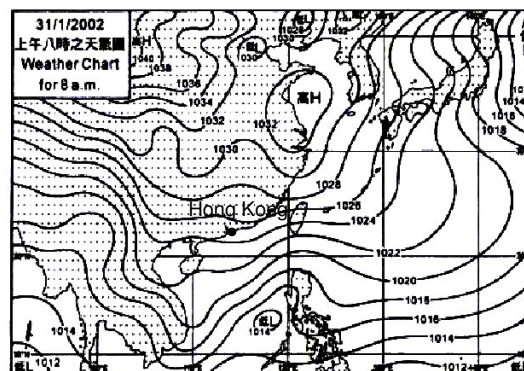


Figure 3 Surface weather chart at 8 a.m., 31 January 2002.

The movement of the sea breeze front was established by using wind velocity data of TDWR, the buoy and the runway anemometers (Figure 4). It can first be analyzed from this data set around noon. The front moved northeastwards past the weather buoy at about 1 p.m. and reached its eastern-most location two hours later over the western part of the airport. The sea breeze front retreated to the west gradually in late afternoon.

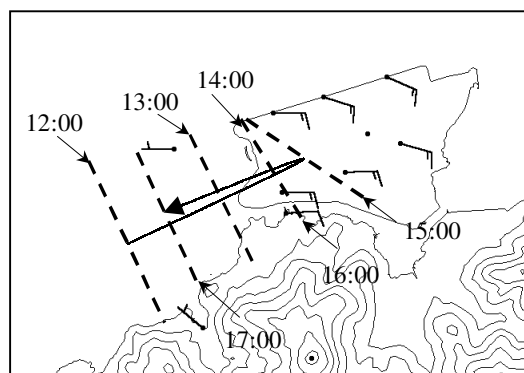


Figure 4 Wind distribution around the airport at 1 p.m., 31 January 2002. Locations and movement of the sea breeze front are overlaid on the map.

The passage of sea breeze front resulted in the change of wind direction of the buoy from easterly to westerly at about 12:45 p.m. As easterly wind still prevailed over the airport, the wind difference between the buoy and R2W anemometer in the 250 direction (i.e. along runway) increased significantly to +20 knots at that time (Figure 5). It stayed above 15 knots occasionally until around 3:45 p.m. During this

period, 15 significant windshear reports were received from aircraft landing at the airport from the west.

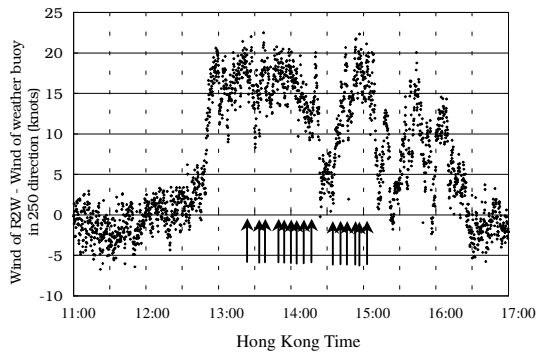


Figure 5 Wind difference between R2W anemometer and the weather buoy, with arrows indicating the times of actual windshear reports by aircraft landing at the north runway from the west.

In the first six months of 2002, there were altogether 38 reports of significant, sea-breeze related windshear by aircraft landing from west of the north runway of the airport. By applying the rules described in the beginning of this section, it was found that windshear alerts could be issued for 30 reports in a more timely manner, with advance alerting possible from 15 to 30 minutes earlier. This result represents a success rate of 79%.

3.2 PASSAGE OF A GUST FRONT

In the morning of 24 March 2002, a cold front moved southwards and crossed the southern coast of China (Figure 6), with bands of rain associated with the front affecting Hong Kong during the day. From the weather radar pictures (not shown), a band of radar echoes with NNE to SSW orientation moved across Hong Kong in the early afternoon. The prevailing easterly wind over the territory gave way to northerly wind at the same time. As it progressed eastwards, the gust front assumed a more or less similar orientation, i.e. NNE to SSW (Figure 7).

At the airport, the wind at the weather buoy backed to northerly abruptly upon the arrival of the gust front. The wind difference between the buoy and R2W anemometer rose abruptly to +20 knots in the space of 5 minutes (Figure 8). This is consistent

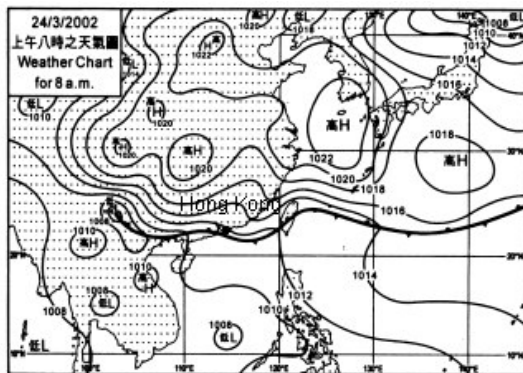


Figure 6 Surface weather chart at 8 a.m., 24 March 2002.

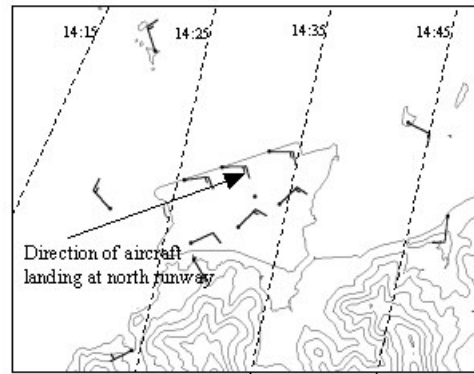


Figure 7 Winds around the airport at 2:25 p.m., 24 March 2002. The gust front's locations at various times are indicated by broken lines.

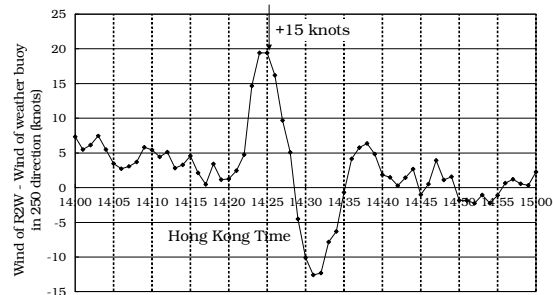


Figure 8 Wind difference between R2W anemometer and the weather buoy between 2 and 3 p.m., 24 March 2002. The time of actual windshear report is indicated by an arrow.

with a windshear report of 15-knot wind gain by an aircraft landing at the north runway from the west around that time. With the passage of the gust front, northerly wind prevailed over the whole airport and the surrounding area and significant windshear no longer occurred.

3.3 WIND DISTURBANCE DOWNWIND OF TERRAIN

When the prevailing wind of Hong Kong is from east through southeast, HKIA lies downwind of Lantau Island. Observational studies revealed that the low-level atmospheric flow downwind of the island could be quite complicated in certain weather conditions (Lau et al., 2002).

An example of terrain-induced windshear occurred in the afternoon of 18 January 2002. Synoptically, a ridge of high pressure ahead of a cold front over south China brought easterlies to the coastal area on the surface (Figure 9), with winds aloft veering to the south on hilltops of Lantau (about 900 m above mean sea level).

Figure 10 shows a time sequence of the wind observations depicting the local wind disturbances near the airport during the period of 3:15 p.m. to 4 p.m. While winds over the airport remained generally easterly, the weather buoy reported winds changing from northeasterly to northwesterly, then southerly and finally northeasterly. This successive change in

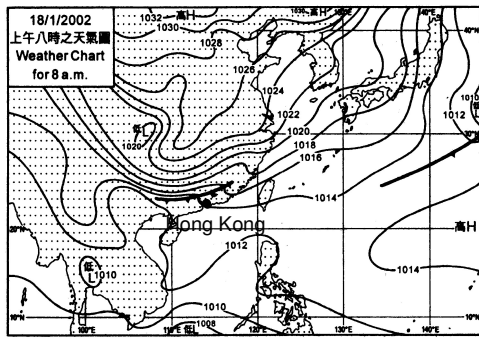


Figure 9 Surface weather chart at 8 a.m., 18 January 2002.

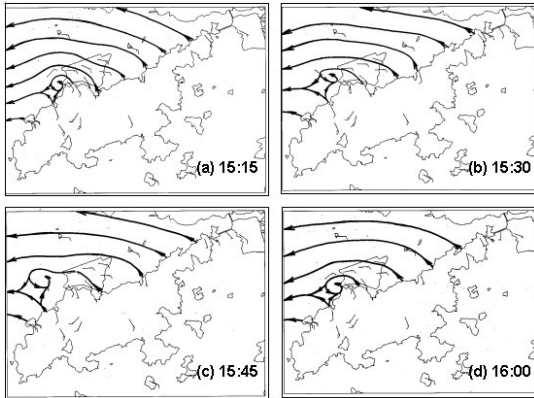


Figure 10 Time sequence of wind observations between 3:15 p.m. and 4 p.m. of 18 January 2002.

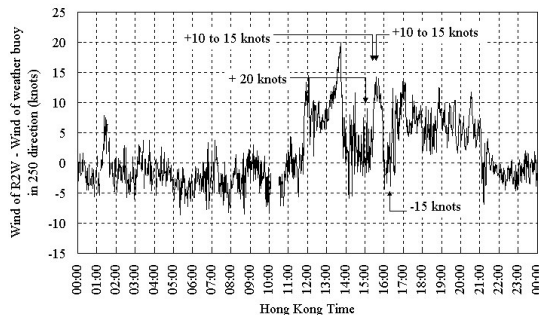


Figure 11 Wind difference between R2W anemometer and the weather buoy on 18 January 2002. The times of actual windshear reports are indicated by arrows.

wind direction at the buoy, against rather steady winds in the background, suggests the existence of small vortices one by one, over the western part of the airport, and their subsequent movement to the northwest. The small vortices brought about changes in the headwind experienced by the aircraft. The wind difference between the buoy and R2W anemometer is shown in Figure 11. Four aircraft reported encountering windshear of -15 to +20 knots during the period while landing at HKIA from the west.

A windshear alert had been issued in advance and we received the compliment from one of the pilots that the alert had got him well prepared to deal with the windshear encounter.

4. CONCLUSION

The HKO deployed the first weather buoy in Hong Kong in late December 2001 to supplement the existing network of land-based automatic weather stations. The buoy is strategically located west of HKIA to make weather measurements in the data-sparse sea area and to monitor the airflow for aircraft moving west of the airport. It transmits weather data in real-time once every 10 seconds.

The buoy has demonstrated its capability in the monitoring of windshear in different weather conditions, including sea breeze, passage of gust fronts and wind disturbance downwind of Lantau terrain. The wind difference between the buoy and the R2W anemometer is used to assess the likelihood of significant windshear over the western approach/departure corridor of the airport. Two alert levels (10-knot and 15-knot wind differences) were found to provide very helpful guidance in the timely issuance of windshear alerts. For instance, for sea-breeze induced windshear alone, the use of the 15-knot alert level is capable of catching about 79% of the significant windshear reports by aircraft landing from west of the airport in the first six months of 2002.

References

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