P2.18 **Application of a Microwave Radiometer to Study Terrain-induced Airflow Disturbances at the Hong Kong International Airport**

P.W. Chan * and C.M. Shun
Hong Kong Observatory, Hong Kong, China

1. INTRODUCTION

The Hong Kong International Airport (HKIA) is located on a reclaimed island to the north of the mountainous Lantau Island with peaks rising to nearly 1000 m separated by gaps as low as 400 m. The thermodynamic profile in the atmospheric boundary layer, especially the presence of low-level temperature inversion, is an important factor in the airflow modifications over HKIA due to the Lantau terrain. In Chan et al. (2006), a microwave radiometer placed downstream of Lantau Island was found to provide useful hints in the occurrence of terrain-induced airflow disturbances. The present study focuses on the applications of the radiometer in the monitoring of airflow disruption when it is placed upstream of the terrain.

The radiometer data collected in the field experiments in Hong Kong in 2004 (Chan and Tam 2005) and 2006 (Chan et al. 2006) are considered in the study. The instrument was placed at the Observatory's headquarters (Figure 1) to provide the thermodynamic profile upstream of Lantau Island. The upstream wind profile was measured by a 1299-MHz radar wind profiler at Cheung Chau (Figure 1). The terrain-disrupted airflow downwind of Lantau Island was observed using a Doppler LIDAR at HKIA (Figure 1).

Two approaches are adopted to illustrate the application potential of an upstream radiometer:

(a) observational study of the relationship between the occurrence of mountain wake in the airport area and the upstream temperature profile as measured by the radiometer – to be discussed in Section 2; and
(b) numerical modelling study initialized by the data from the radiometer and the wind profiler to predict the occurrence of jump-like flow across the gaps on Lantau Island – to be discussed in Section 3.

Conclusions of the study are given in Section 4.

2. OBSERVATIONAL STUDY

The easterly wind case in the period 17 – 19 January 2006 is studied in this paper. It is a typical spring-time case of the veering of the easterly airstream in the boundary layer.

With the establishment of a ridge of high pressure along the southeastern coast of China, a fresh easterly airstream reached Hong Kong in the morning of 17 January 2006. Winds were observed

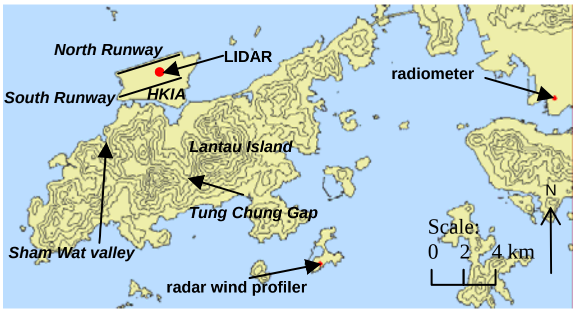

Figure 1 Map of HKIA, Lautau Island and the adjacent areas. Height contours are in 100 m. Equipment locations are indicated by red dots.

to pick up in the boundary layer from the wind profiler measurements (Figure 2). The easterly airstream was of continental origin and brought cooler weather to Hong Kong. The radiometer data (Figure 2) showed that there was a temperature drop of a couple of degrees in the boundary layer upon the arrival of the easterly, and an isothermal layer appeared between 200 and 1000 m. Since the wind component across Lantau terrain (about 160^o) was not significant in the first several hundred metres above ground, the easterly flow was rather uniform over the runway corridors of HKIA on that day with the wake of Lantau terrain located further away to the west (not shown). There were just 4 pilot reports of significant windshear (viz. headwind/tailwind change of 15 knots or more) from the aircraft arriving at HKIA from the west on that day.

The wind in the boundary layer veered gradually on the following day with significant cross-Lantau component (southeasterly wind of about 12 m/s, Figure 2). The boundary-layer temperature profile was basically an isothermal and later on showed an inversion between 100 and 400 m (Figure 2). The stable atmosphere tends to force the air to flow around the mountains on Lantau Island instead of climbing over them. From the LIDAR imagery (lower left inset in Figure 2), a broad mountain wake (reversed flow in green and tangential flow with respect to the LIDAR in grey) extended to about 6 km downstream of Lantau Island, affecting the two runway corridors to the west of HKIA. There were 25 reports of significant windshear from arriving aircraft on 18 January, the largest number on a single day in this easterly wind episode.

The easterly wind subsided gradually on 19 January (Figure 2). The boundary layer remained stable, with a temperature inversion occurring occasionally between 100 and 400 m (Figure 2). The mountain wake persisted to the west of HKIA, though not so extensive compared to that on the previous day (lower right inset in Figure 2). There were 7 windshear reports from the aircraft landing HKIA from the west. The easterly episode ended on 20 January with the arrival of a replenishment of the northeast monsoon.

* *Corresponding author address:* P.W. Chan, Hong Kong Observatory, 134A Nathan Road, Hong Kong email: pwchan@hko.gov.hk

In summary, it is observed from this easterly wind case that:

(a) the upstream temperature/stability profiles can vary rapidly in a matter of a few hours, affecting the behaviour of the terrain-induced flow downwind of Lantau;
(b) the mountain wake becomes the most extensive when there are significant cross-Lantau airflow (fresh to strong southeasterly wind within the first several hundred metres above ground) and a stable temperature profile (isothermal /inversion) reaching the peaks of Lantau Island (about 1000 m);
(c) though the prevailing southeasterly flow has moderated, terrain-induced airflow disturbances could still occur over HKIA as long as the boundary layer remains stable.

3. NUMERICAL STUDY

The easterly wind episode discussed in Section 2 is related to the gradual veering and weakening of the wind, in a varying stability environment. The descending of the southeasterly jet is another feature that could be associated with terrain-disrupted airflow over HKIA because it affects the jump-like flow across the gaps on Lantau Island in a stable boundary layer. Banta et al. (2006) pointed out the significance of monitoring the jump-like flow in the assessment of terrain-induced windshear at HKIA. In this paper, the possibility of predicting the flow pattern across the gap is studied using homogeneous initialization of a numerical weather prediction model (Szeto and Chan 2006) based on the upstream temperature and wind profiles.

The jet-descending case on 24 February 2004 is considered here. At about 00 UTC on that day (8 a.m. in Hong Kong time, with HKT = UTC + 8 hours), the southeasterly jet of about 10 m/s was located between 800 and 1500 m AMSL. There was a temperature inversion of about 3.5 degrees between 500 and 1000 m from the radiometer. From the LIDAR's Range-height Indicator (RHI) scan across Tung Chung Gap (location in Figure 1), the jet (coloured light blue in Figure 3a) showed a jump-like feature after crossing the gap, but did not get below 500 m over the airport area. The reversed flow below the jet remained close to the hills on Lantau Island and did not affect HKIA. The easterly flow over HKIA was uniform and no windshear reports were received.

About 4 hours later, the jet descended to 600 – 1200 m AMSL. The temperature inversion also lowered to 400 – 900 m as measured by the radiometer, with a magnitude of about 1.5 degrees. From LIDAR's RHI scan (Figure 3b), the jet again showed a jump-like feature after crossing Tung Chung Gap, but it got down to about 300 m with reversed flow below in the airport area. Mountain wake appeared over HKIA and five aircraft landing from the west reported encountering of significant windshear.

The above jump-like feature and reversed flow are reasonably well predicted by the numerical model (Figures 3c and d). Moreover, the model results give insights into the flow across Sham Wat valley (location in Figure 1) where LIDAR observations are not available due to geometrical limitation. As shown in Figure 4, jump-like feature is also found in the gap flow at Sham Wat, as postulated in Banta et al. (2006). At this location, the reversed flow below the jet reaches higher altitude (about 600 m) compared to that at Tung Chung Gap. It also penetrates northwards to the area west of the north runway, which is consistent with the reporting of windshear encounter by the arriving aircraft.

4. CONCLUSIONS

A radiometer placed upstream of Lantau Island is found to provide valuable information in the study of terrain-disrupted airflow and the assessment of windshear at HKIA in prevailing east to southeasterly. Observational and numerical methods are employed in this paper. Mountain wake of Lantau Island is found to have close relationship with the temperature profile of the prevailing flow. It becomes the most extensive when isothermal/temperature inversion extends to about the maximum height of the Lantau terrain (1000 AMSL). With the moderation of cross-Lantau flow, mountain wake and terrain-induced windshear could still occur in the presence of low-level temperature inversion. Numerical simulations initialized with the radiometer and wind profiler data are shown to give good predictions of the flow across the gaps on Lantau Island. The height of the jump-like feature and the northward penetration of the reversed flow, which are considered crucial in the assessment of terrain-induced windshear, are well captured.

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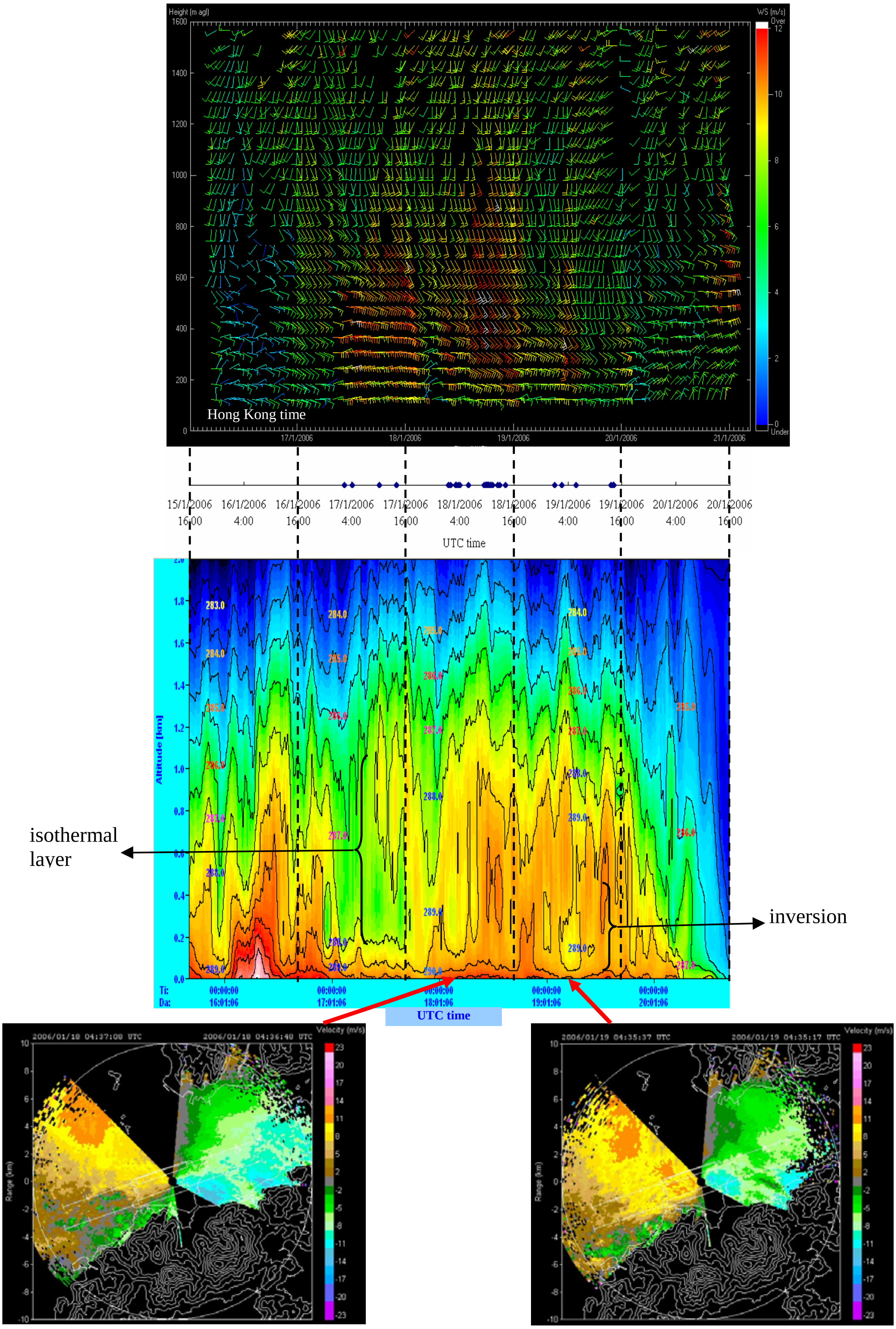

Figure 2 Wind profiler measurements in the period 16-20 January 2006 (upper panel), times of windshear reports from aircraft landing HKIA from the west (middle panel) and the time-height plot of boundary-layer temperatures from the radiometer in the same period (lower panel). The insets at the lowest part of the figure show the radial velocity imageries in 1-degree conical scan of the LIDAR at the indicated times.

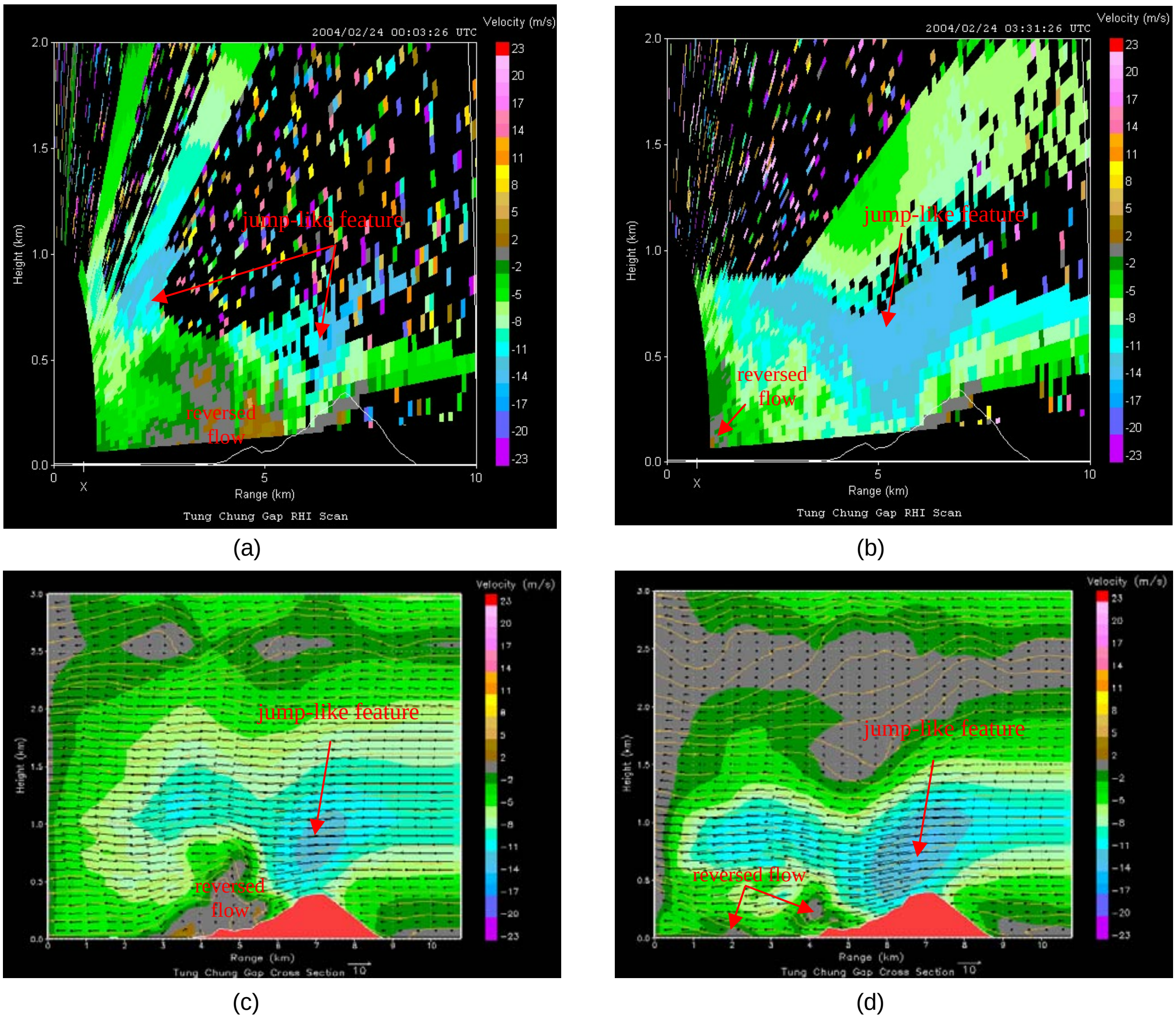

Figure 3 LIDAR's RHI scans of the radial velocity towards Tung Chung Gap at 8:03 a.m. (a) and 11:31 a.m. (b), 24 February 2004. Results from homogeneous initialization simulations are shown in (c) and (d) respectively (vertical velocity multiplied by 10 in the plots).

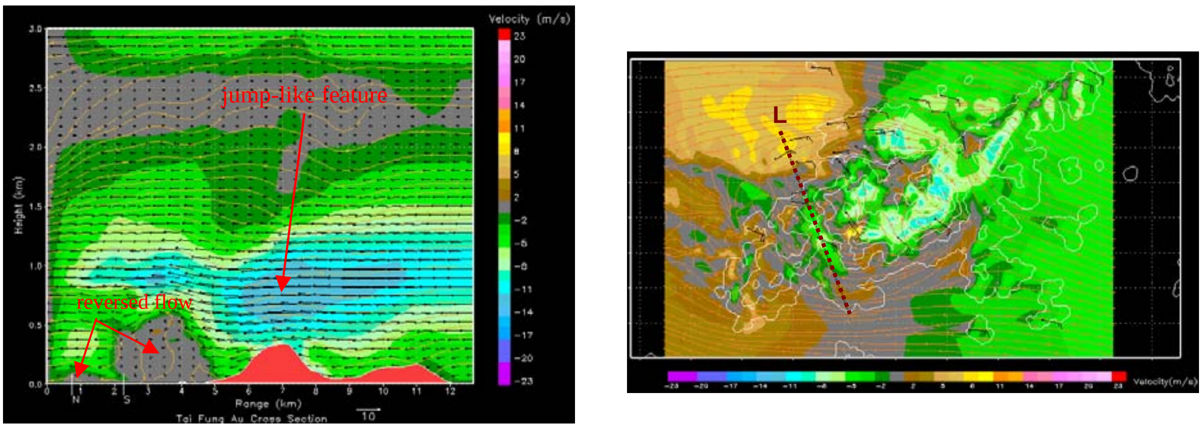

Figure 4 The model-simulated winds (from homogeneous initialization run) projected on the vertical cross section across Sham Wat valley (left panel). Vertical velocity is multiplied by 10. The colour contours refer to the radial velocities "observed" by a fictitious LIDAR at location "L" on the right panel, which also gives the model simulated wind field at 50 m.