“Up-Hill Effect” on Winds at the Hong Kong International Airport in Strong Northerly Winds Associated with Tropical Cyclones

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“UP-HILL EFFECT” ON WINDS AT THE HONG KONG INTERNATIONAL AIRPORT IN STRONG NORTHERLY WINDS ASSOCIATED WITH TROPICAL CYCLONES

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Abstract: The Hong Kong International Airport (HKIA) is built on a reclaimed island surrounded by complex terrain from the E to SW directions. It is however exposed to the Pearl River Estuary to the N and NW. Given this geographical setup, it may be expected that, in northwesterly airflow, the effect of the complex terrain in the vicinity of HKIA would be insignificant and the winds over the airport would be rather uniform. Nevertheless, uneven wind distribution on the airfield has been observed in strong northwesterly winds associated with tropical cyclones. For instance, the winds at the north runway were found to be stronger than those over the south runway by as much as 10 – 15 knots. The uneven wind distributions over HKIA in strong northwesterly winds associated with tropical cyclones are studied in this paper. They appear to arise partly from an “up-hill effect” when winds are forced to climb over the mountainous Lantau Island to the south of the airport. High-resolution numerical simulation is performed using the Weather Research and Forecasting (WRF) model version 2.2. The model successfully reproduces the wind speed difference between the north and the south runways of the airport.

Keywords: up-hill effect, tropical cyclone, WRF

1 INTRODUCTION

The Hong Kong International Airport (HKIA) is situated to the north of the mountainous Lantau Island. It is exposed to the Pearl River Estuary to the north and northwest. With this geographical setup, airflow disturbances are expected to appear in the airport area due to terrain disruption when east to southwesterly winds prevail, whereas more uniform winds may occur over the airport for north to northwesterly airflow. However, rather uneven wind distribution is observed over HKIA for strong northwesterly winds associated with tropical cyclones or winter monsoon. The winds at the two runways of the airport (locations in Fig. 1) may become very different in those situations. The wind speeds measured at the anemometers over the north runway were found to be larger than those over the south runway by as much as 10-15 knots. This could have significant implications for aircraft operation. For instance, the crosswind at the north runway may be too strong for aircraft to land. As such, the aircraft may need to land at the south runway, which is closer to the terrain. This may render the wind more turbulent.

The uneven wind distribution over the airport in northwesterly winds associated with tropical cyclones is presented in this paper. Its cause is studied by high-resolution numerical simulation.

2 UNEVEN WIND DISTRIBUTION IN TYPHOON NURI

In the morning of 22 August 2008, Typhoon Nuri was situated to the southeast of Hong Kong bringing gale force north to northwesterly winds to the territory. The wind distribution around HKIA at about 10 a.m. on that day is shown in Fig. 1. It can be seen that there is quite significant wind difference between the two runways of the airport. The north runway recorded north-northwesterly gales of about 35-40 knots. On the other hand, the south runway had strong winds of only about 25 knots. Normally, aircraft would land at the north runway of HKIA. However, because of the gale-force crosswind at that runway, they could only opt to land at the south runway from the west. The airflow turned out to be quite turbulent near the threshold of the south runway (cube root of eddy dissipation rate of about 0.4 m\(^{3/2}\)s\(^{-1}\), as determined by onboard flight data, indicating moderate turbulence) for the aircraft to operate. After a couple of hard landing events, it was decided to stop the aircraft operation until the wind subsided or changed direction.

The time series of the anemometer data at the two runways of HKIA in Typhoon Nuri case (22 and 23 August 2008) are shown in Fig. 2. The measurements from the pair of anemometers at the eastern end, near the middle and at the western end of HKIA are compared. It could be seen that, for wind directions of about 300 to 360 degrees, the wind speed difference between each pair of anemometer becomes larger. In general, this difference is more pronounced for the anemometer pair at the western part of the airport. These anemometers are closer to the terrain of Lantau Island (Fig. 1) and it seems that the wind difference may be related to terrain effect on the airflow in northwesterly winds.

3 OTHER TROPICAL CYCLONE CASES WITH STRONG NORTHWESTERNLY WINDS

The wind data of other tropical cyclone cases since HKIA opened in 1998 have also been reviewed to see whether or not the wind difference as noted in Section 2 above occurred only in the case of Typhoon Nuri. Two
other strong northwesterly wind cases due to tropical cyclones were identified, namely, Typhoon Sam and York in August and September 1999 respectively. The wind records for Typhoon Sam are shown in Fig. 3. It could be seen that, similar to Typhoon Nuri, wind speed differences between the anemometer pairs were the largest in north to northwesterly winds. Moreover, this difference was slightly larger for anemometers near western end of HKIA.

4 NUMERICAL SIMULATION

The uneven wind distribution over HKIA is studied numerically using the Weather Research and Forecasting (WRF) model version 2.2. Three nested domains are used, from southern China to areas around Lantau Island. The innermost domain has a spatial resolution of 200 m. The Typhoon Nuri case is considered and the winds near the airport in gale-force north to northwesterly wind condition are shown in Fig. 4. It could be seen that the wind speed differences between the two runways, viz. about 10 knots at the western end and about 5 knots for middle and eastern end, are reasonably reproduced. A sharp gradient of surface wind speed is successfully simulated near the foothill of Lantau Island, which covers the southern part of the airport. The model simulation results suggest that the wind speed difference could be due to “up-hill effect” on the airflow when the winds start to climb up the mountains of Lantau Island. Similar “up-hill effect” has been discussed in the literature (e.g. Stull (2004)).

5 CONCLUSIONS

Uneven wind distribution between the two runways of HKIA is observed in the strong northwesterly wind cases associated with tropical cyclones in Hong Kong. The difference is in the order of 10-15 knots and could have significant implication to aircraft operation. Based on WRF simulation results, it could be related to “up-hill effect” as the winds start to climb over the mountains of Lantau Island.

REFERENCES