# ANALYSIS OF THE TORNADO AT THE HONG KONG INTERNATIONAL AIRPORT (HKIA) ON 20 MAY 2002 USING DATA FROM THE TERMINAL DOPPLER WEATHER RADAR (TDWR)

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## I. INTRODUCTION

At about 8:30 p.m., 20 May 2002 (local time = UTC + 8 hours), a tornado occurred at HKIA. It swept across the eastern side of the airport, resulting in damages including falling of trees and dislocation of rubbish bins. Based on the reported damages, this tornado belongs to F0 on the Fujita Scale. This paper documents the observations of the tornado by the Hong Kong TDWR and other meteorological equipment, and gives an analysis of its structure based on the radar data.

## II. SYNOPTIC CONDITION

In the middle of May 2002, a trough of low pressure lingered along the coast of southern China, bringing rainy weather to the region. At 850 hPa, cyclonic flow associated with a southwesterly jet affected the region. Short waves could be depicted in the southwesterly flow in the middle troposphere. At 200 hPa, airflow divergence could be analyzed near Hong Kong. The synoptic setup favoured the occurrence of intense convective weather. Indeed, in the upper-air ascent at 12 UTC, 20 May, the K index reached about 40 and SWEAT index got to 436, indicating the high convective instability of the atmosphere.

## III. TDWR

A TDWR has been in operation at about 12 km to the northeast of HKIA for detecting thunderstorm-induced windshear over the airport since 1998. It is a C-band radar with a wavelength of 5 cm. The antenna is located at about 60 m above mean sea level. TDWR provides radial velocity and reflectivity at a resolution of about 1 degree in the azimuthal direction and 150 m in the range gates.

## IV. TDWR AND OTHER OBSERVATIONS

TDWR captured the evolution of the tornado on 20 May very well. Cores of opposing Doppler velocity were detected, indicating the location of the centre of the tornado (Figure 1). Secondary maxima of opposing Doppler velocity could also be observed at about 3 – 4 km away from the tornado centre. In the reflectivity plot (Figure 1), hook-shaped radar echoes were depicted in association with the tornado. The track of the tornado as analyzed from TDWR data is shown in Figure 2. The barometer at HKIA recorded a pressure drop of about 1.5 hPa when the tornado passed nearby. The surface anemometers near the airport (at 10 m above ground) measured maximum wind gust of about 22 m/s in the event (namely, the wind sensor at Tai Mo To, an island about 2 km east-northeast of HKIA).

## V. GBVTD ANALYSIS

The structure of the tornado is studied in detail by carrying out Ground-Based Velocity Track Display (GBVTD) analysis of the tornado using the TDWR data. GBVTD method is described in detail in Lee et al. (1999).

Figure 3 shows the pre-tornadic state at about 12:24 UTC. Note that the low levels are characterized by inflow toward the centre of the circulation. This inflow turns upward as it nears the centre and then begins to turn outward as it approaches 3 km (top of the domain). Figure 4 shows the circulation about five minutes later, at 12:29 UTC. All wind components have strengthened. An eye has formed in the centre, complete with a downdraft. Inflow continues at low levels all the way into the core, and the updraft continues upward past the top of the domain without diverging. Figure 5 shows the tornado at its maximum strength. By about 12:35 UTC (not shown), outflow dominates the low levels near the tornado. Inflow is forced upward well before reaching the tornado centre. The weakening process continues afterwards (not shown).

The cyclostrophic pressure drop during the strongest phase of the tornado (Figure 5) is analyzed. The maximum drop at this time is 8 hPa at a height of 2 km. The calculated surface pressure drop is about 5 hPa, which is larger than the measurement at the airport, probably because the pressure gauge at HKIA is located at about 1 km away from the tornado centre.

## VI. AUTOMATIC DETECTION

We also consider a tornado detection algorithm which searches for shear features which are classified as a tornado detection contingent on the exceedence of a threshold Doppler velocity difference (delta-V, or DV) at a constant range from the radar. For more detailed study of the tornado evolution, the DV threshold was set to 30 m/s for detecting a potential tornado vortex, instead of the usual 40 m/s. As a check of the applicability of the detection algorithms, the tornado's track, its inbound and outbound wind maxima and its radius were determined by manual inspection for the lowest sweeps (0.6 degree). Results are shown in Figure 6. Agreement between automatic and manual methods is good.

Methods have been developed to adjust the maximum wind as a function of the aspect ratio considering the sample-volume size of the radar and the radius of the tornado. The aspect ratio correction is about 1.14 and it is applied to the maximum DV of about 40 m/s. The resultant DV is about 46 m/s. Moreover, the translation speed of the tornado is accounted for. As a rough estimate, we have DV/2+ V(translation) = 46/2 + 5 m/s = 28 m/s, at about 120 metres above ground. The results are shown in Figure 6. The true surface wind at a standard height of 10 m above ground may be as much as 20% weaker depending on surface roughness, i.e. about 22 m/s. This agrees very well with the anemometer measurement.

## VII. CONCLUSIONS

The tornado at HKIA on 20 May 2002 is analyzed using TDWR and other meteorological data. The maximum velocity at the surface as measured by anemometer and analyzed from TDWR is about 22 m/s, which is consistent with the F0 scale from damage analysis. The evolution of the tornado's structure shows up very well in the GBVTD analysis of the TDWR data.

## VIII. REFERENCES

Lee, W., B. Jou, P. Chang, S. Deng, 1999: Tropical cyclone kinematic structure retrieved from single-Doppler radar observations. Part I: Interpretation of Doppler velocity patterns and the GBVTD technique. Mon. Wea. Rev., 127, 2419-2439.

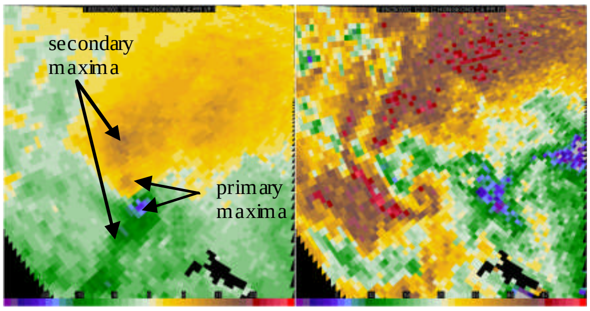


FIG. 1: Radial velocity (left) and reflectivity (right) plot of TDWR observation of the tornado at 12:30 UTC, 20 May 2002.

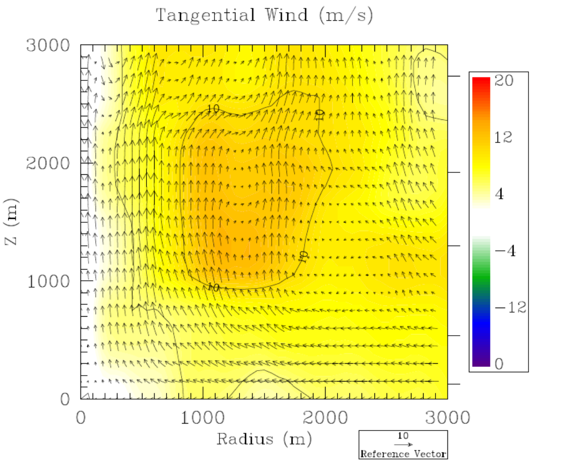


FIG. 3: Wind field of the tornado as a function of the distance from the tornado centre and height at 12:23:51 UTC. Tangential wind (m/s) is shown in colour. The radial and vertical winds are shown as arrows, scaled by the reference vector (m/s).

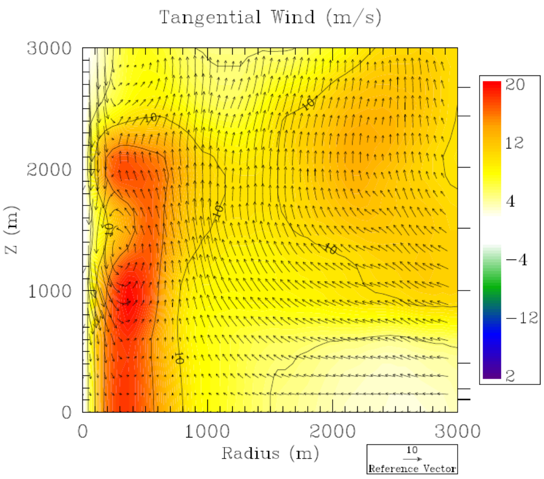


FIG. 5: Same as FIG. 3 but at 12:31:02 UTC. This is during the strongest phase of the tornado.

FIG. 2: Track of the tornado based on TDWR data, using automatic algorithm (blue) and manual tracking (red). The times are minutes after 12 UTC.

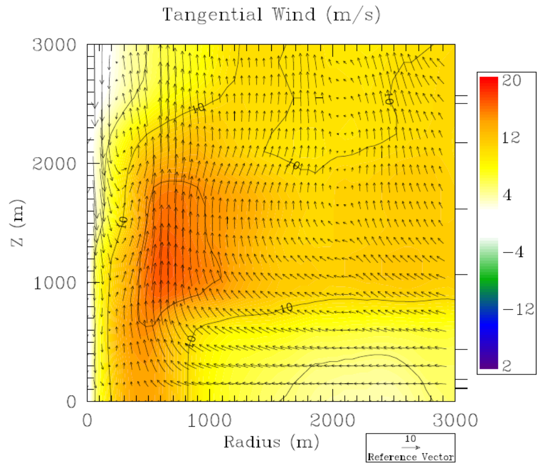


FIG. 4: Same as FIG. 3 but at 12:29:15 UTC.

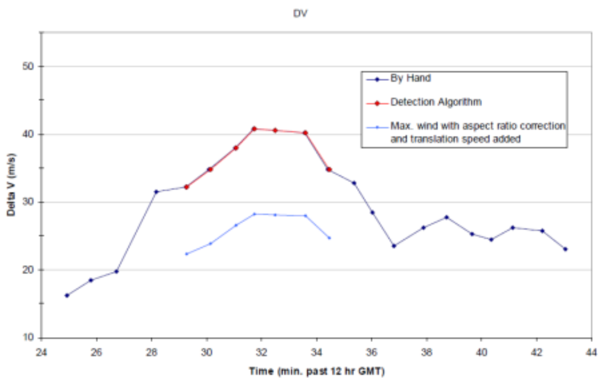


FIG. 6: Time series of DV of the tornado as retrieved by the automatic detection algorithm and manual method. Only the lowest-level scans (elevation = 0.6 deg.) are shown here. In addition the maximum ground-relative wind that would be experienced at radar height resulting from the adjustment due to aspect ratio and addition of the translation speed of the tornado is shown in light blue, with a maximum of approximately 28 m/s.