THREE DIMENSIONAL STRUCTURE OF MISOCYCLONE ASSOCIATED WITH THUNDERSTORM

P3.40 OBSERVED BY KU-BAND FM-CHIRP FAST SCANNING RADAR

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1. INTRODUCTION

Severe weather, such as heavy rainfall and gusts associated with thunderstorms in an urban area may cause serious damages to social activity. A filed campaign called Tokyo Metropolitan Area Convective Study for Extreme Weather Resilient Cities (TOMACS) aims to understand the processes and mechanisms of severe weather, using dense observation networks in Tokyo Metropolitan Area, Japan.

During the TOMACS field campaign, a misocyclone occurred in Tokyo Metropolitan area was observed from very close range by a Ku-band FM-Chirp fast scanning radar (Ku-band radar) at around 15 Japan Standard Time (JST) on 6 May 2012. The purpose of this study is to investigate detailed three-dimensional structure of the misocyclone and its parent storm using by the Ku-band radar and dense network of twelve automated Weather Stations (AWS).

2. OBSERVATION AND DATA

The Ku-band radar was installed on the roof of the No.10 building of SEIKEI University, Musashino-shi, Tokyo, Japan (Fig. 1). The Ku-band radar was developed by Osaka University and Sumitomo Electric Industries, Ltd. and 15.75 GHz radar with a maximum observation range of 19.5 km (Yoshikawa et al. 2010). This radar transmits and receives wide band signals at Ku-band using pulse compression to give us sufficient energy on a target sufficient energy on a target for detection with high range resolution and good signal to noise ratio. The antenna was upgraded to Luneburg lenses which achieve a 3-dB beam width of 3 deg. This radar makes full volume scans (elevation ranged from 0 to 90 deg.) each 1 minute, and observes reflectivity and Doppler velocity. The radial and azimuthal resolutions are 2.38 m and 3 degree, respectively.

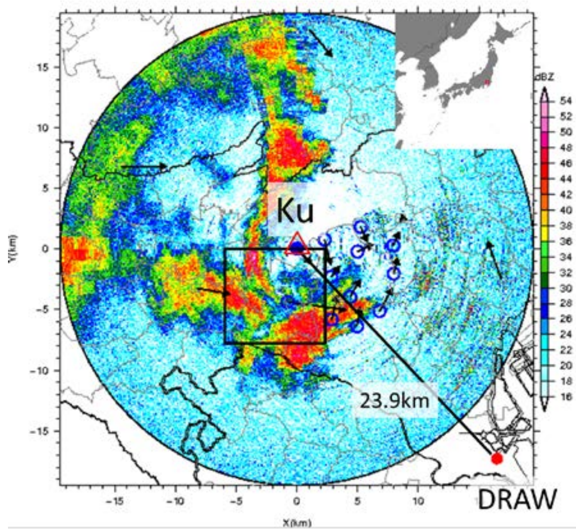

FIG. 1 Map of the Tokyo Metropolitan area, Japan and reflectivity of Ku-band radar at an elevation of 3-6 degree PPI scan at 1500:01 JST on 6 May 2012. The locations marked by the symbols are as follows: the Ku-band radar (red triangle), the DRAW (red circle) and the AWS sites (open blue circle).

The dense network of twelve AWSs was distributed in the study area as shown in Fig. 1 to characterize the fine-scale wind and thermodynamics structures of gusts and storms near surface (Kusunoki et al. 2012).

C-band Doppler radar for airport weather (DRAW), at Tokyo international airport (Fig. 1) was used to investigate wind structure near the surface every 1 minute by dual-Doppler analysis with Ku-band radar. The Doppler velocity of both radars was interpolated into a Cartesian grid system with horizontal spacing of 0.2 km using a Cressman weighting function (Cressman 1959). Dual-Doppler analysis was performed using the method proposed by Ishihara (1986).

In order to analysis three-dimensional structure of misocyclone, vertical vorticity was calculated each PPI scan data of Ku-band radar (2 times the azimuthal shear is equal to the vertical vorticity in the core of a Rankine vortex). The azimuthal shear was also interpolated into Cartesian grid system with

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horizontal and vertical spacing of 0.2 km and 0.1 km using a Cressman weighting function.

3. SURFACE THRMODYNAMICS AND WIND STRUCTURE

Figure 2 shows temperature, reflectivity and Doppler velocity filed around the misocyclone. Reflectivity and Doppler velocity field clearly show hook echo and misocyclone. The diameter of the misocyclone range 500 to 1500 m and its maximum vorticity was 0.12 s^{-1} derived from single-Doppler radar analysis of each volume scans (not shown). The temperature and wind filed exhibited three air-mass region and convergence line. Air-mass of east of the misoclyclone is relatively hot with SW-ly wind. North and west of the misocyclone is relatively cool. Therefore, this convergence lines would be gustfronts.

Figure 3 shows time series of the wind speed, pressure and wind vector observed at A2 station. Three pressure dip (0.9-3.7 hPa) and gust (23.4-25.4 m s^{-1}) events were observed. The wind shifts associated with these events were also observed. These time variations of AWS strongly suggested that several vortices passed at the surface.

In order to the wind structure at the surface, we performed dual-Doppler radar analysis. Figure 4 shows the evolution of wind velocity and vorticity field at 300 m above ground level. The vorticity field at 1458:57 clearly shows three vortices (A, B and C) existed along gust fronts (Fig. 4a). At 1500:01 JST, vortex A and C have merged (Fig. 4b). When second gust event observed, A2 station was located at south of vortex AC and strong westly wind region. By 1501:05 JST, vortex AC and B have merged. A2 station was located at south of vortex ABC. Therefore, three gust events observed at A2 station was consistent with passage of the misocyclones.

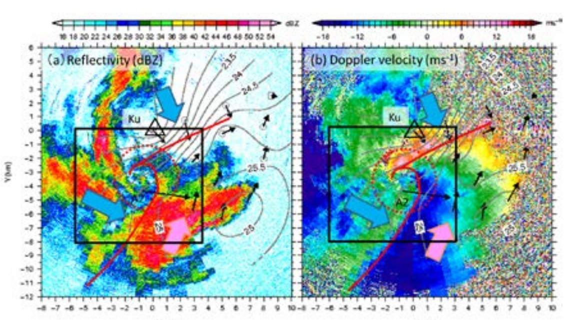

FIG. 2 Gray line contours indicate temperature observed at AWSs at 1500:01 JST on 6 May 2012. Reflectivity (a) and Doppler velocity (b) at elevation 3-6 deg. Red lines show gustfronts estimated from temperature and wind fields. The boxed in regions are dual-Doppler analysis area.

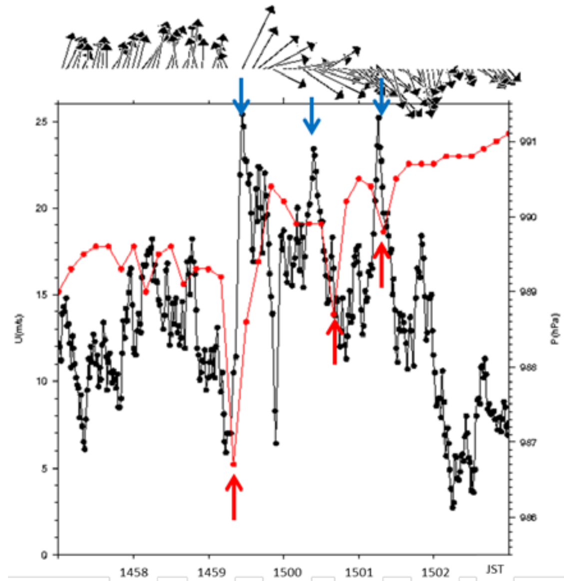

FIG.3 Time variation of wind speed, pressure and wind vectors observed at A2 station. Blue and red arrows indicate maximum wind velocity and pressure dip, respectively.

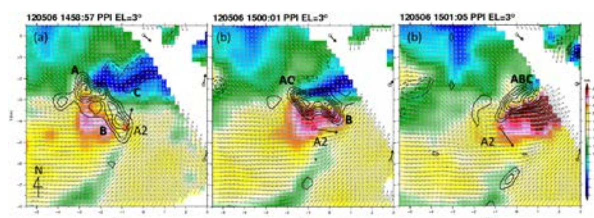

FIG.4 Wind velocity and vorticity fields at 300 m above ground level derived from dual-Doppler analysis and wind vector observed at AWSs at (a) 1458:57 JST, (b) 1500:01 JST and (c) 1501:05 JST. The solid and dashed contours indicate positive and negative vertical vorticity, respectively. The vorticity contour is from 1.0 x10^{-2} s^{-1}, with an interval of 0.5 x10^{-2} s^{-1}.

4. THREE DIMENSIONAL STRUCTURE AND EVOLUTION OF MISOCLYCLONE

In order to investigate three-dimensional structure and evolution of the misocycone, we analyzed azimuthal wind shear derived from single-Doppler radar analysis. We confirmed that vertical vorticity fields derived from single-Doppler analysis is consistent with those derived from dual-Doppler analysis.

Figure 5 shows three-dimensional structure and evolution of the misocyclone and its parent storm. In the early stage of the storm, the isosurface of cyclonic shear was located at near surface gustfronts (Fig. 5a, b). At 1458:57, two misocyclones was detected at 1.0 and 1.8 km height (Fig. 5c, d). Veritcal vortivcity of these vortices of midlevel was 3.6 x 10^{-2} s^{-1}. By 1500:01 JST, isosurfaces of significant vertical vorticity (>3.0 x 10^{-2} s^{-1}) associated with the low-level cyclonic vertical vorticity maximum has grown upward and into the isosurface associated with the midlevel misocyclone (Fig. 5e, f). The maximum vertical vorticity of the misocyclone increased to 5.8 x 10^{-2} s^{-1} at 2.9 km height.

At 1501:05 JST, low-level misocyclone have merged and developed vertically (Fig. 5g, h). Isosurface of reflectivity clearly shows overhang structure (Fig. 5g). By 1502:09 JST, misocyclone has grown upward (Fig. 5i, j). The maximum vertical vorticity is 0.12 s^{-1} at 2 km height. Isosurface of reflectivity exhibited bounded weak echo region and embryo curtain (Fig. 5i). Misocyclone was located at bounded weak echo region, which indicate strong updraft existed in misocyclone. Although these structures are very similar with supercell, the echo overhang and embryo curtain dissipated at next 1 minute (not shown).

5. CONCLUSION

Using the Ku-band radar and the dense network of AWS, we succeeded in observing three-dimensional structure and evolution of misocyclone and its parent storm on 6 May 2012 in Tokyo Metropolitan area.

The surface wind and pressure variations observed by AWS and wind fields derived from Doppler analysis clearly show two misocyclones passed at near the surface. The diameter of the misocyclone range 500 to 1500 m and its maximum vorticity was 0.12 s^{-1}.
Dual-Doppler analysis revealed that misocyclones occurred along gustfronts and they have merged. Single-Doppler radar analysis clearly shows that two misocyclones also formed at midlevel in initial stage of the storm and they merged. Isosurface of radar reflectivity data shows the detailed structure and rapid evolution of “bounded weak echo region” and “embryo curtain ”.

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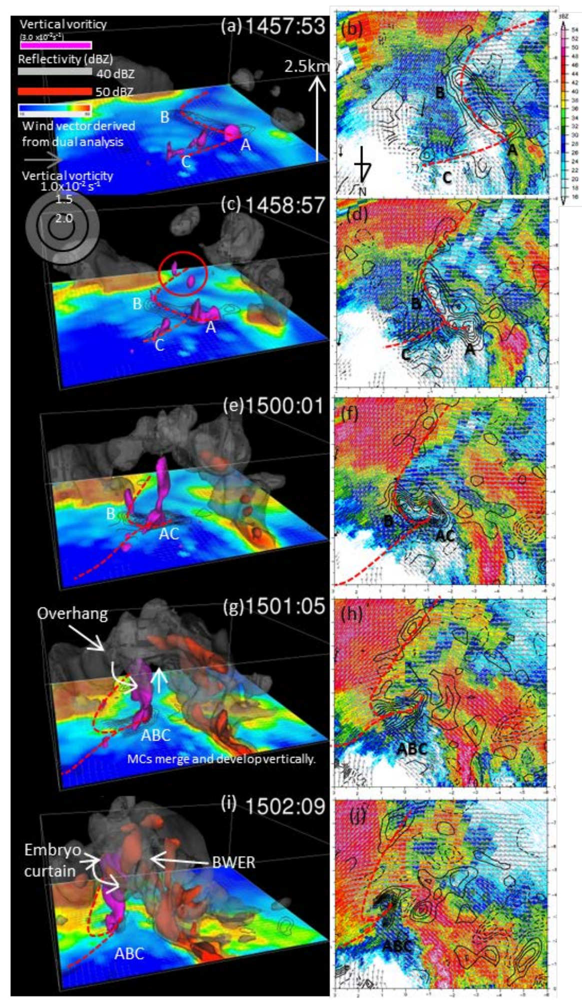

FIG. 5 Three-dimensional structure and evolution of the misocyclone and its parent storm (a, c, e, g, i). Time evolution of wind, voriticy and reflectivity filed at 0.3 km AGL (b, d, f, h, j). The black solid and dashed contours indicate positive and negative vertical vorticity, respectively. The vorticity contour is from 1.0 x10^{-2} s^{-1}, with an interval of 0.5 x10^{-2} s^{-1}. Red dashed lines shows gustfronts estimated from temperature and wind field.