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Radar analysis of two tornadoes occurred in the outer rainband of Typhoon 'Neoguri'

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1. Introduction

Most of tornadoes occur in Japan are non-supercell type. The seashore from Kochi city to Aki city is a hot spot of non-supercell tornadoes (Sassa et al. 2011). Some typhoons, however, cause mini supercell tornadoes (Suzuki et al. 2000). Typical case is the Nobeoka mini supercell tornado caused by Typhoon 'Shanshan' on 17 September 2006 (Mashiko et al. 2009). The Nobeoka tornado occurred in the outer rainband of the Typhoon 'Shanshan'.

Two tornadoes simultaneously occurred near Kochi airport when the outer rainband of 'Neoguri' passed through the Kochi plain on 10 July 2014 (Fig. 1). One of the damaged areas was more than 8 km, which is longer than those due to the other tornadoes in the Kochi plain. If the parent cloud of two tornadoes is supercell, it will be the first observed case of supercell in Kochi. The present study aims to clarify the characteristics of tornadoes and their parent cloud.

2. Analysis and data

We observed the parent cloud of tornadoes by two polarimetric X-band Doppler radars of Kochi University (Asakura Radar and Monobe Radar) and the Muroto C-band Doppler radar of Japan Meteorological Agency (JMA). As shown in Fig.2, observation ranges of the Monobe, Asakura and JMA Muroto radars are 30 km, 80 km and 200 km, respectively. For Asakura radar, we made 16 PPI scans (elevation angles are 2.1 deg. to 40.0 deg.) and 2 RHI scans every 5 minutes and 7 PPI scans (elevation angles are 0.0 deg. to 12.0 deg.) every 1 minutes for Monobe radar. JMA Muroto radar operated 17 PPI scans (elevation angles are -0.1 deg. to 25.0 deg.) every 5 minutes. We obtained reflectivity and Doppler velocity from each PPI scan data and detected vortices based on dipole signal of Doppler velocity. Then we calculated the vorticity and the diameter of vortices.

We also made damage investigation in Kochi plane for 3 days.

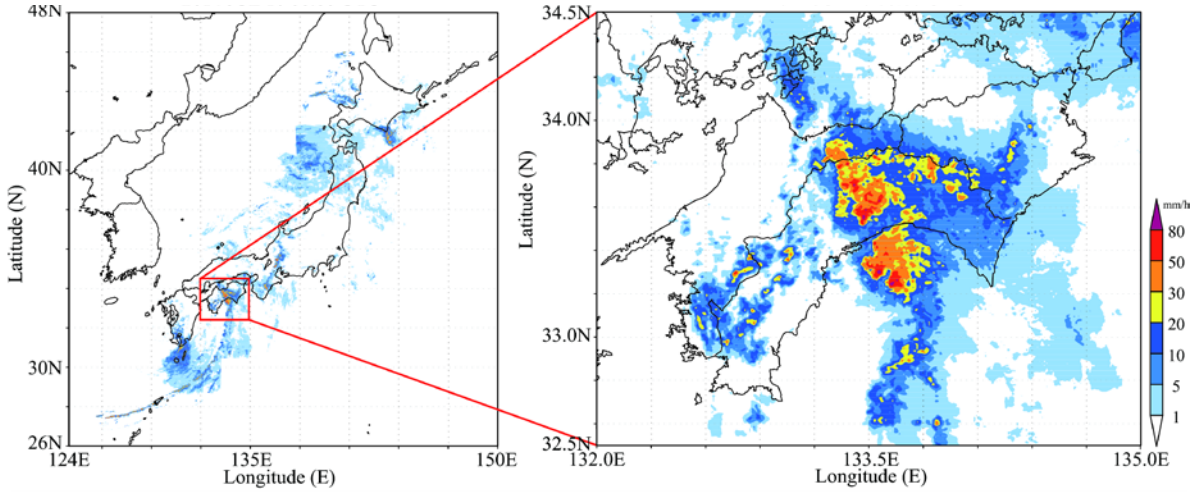

Fig.1 JMA-Radar echo at 06:00 JST

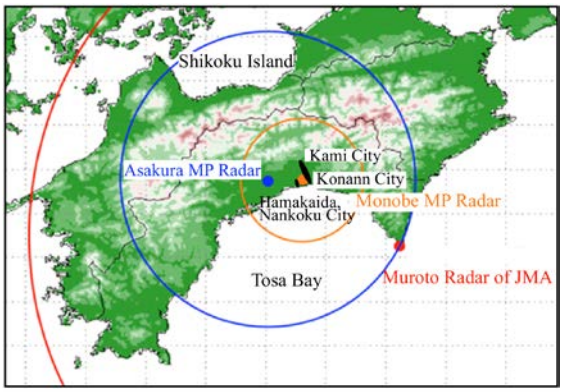

Fig.2 Observation areas of Radars. Black ovals indicate the damaged areas.

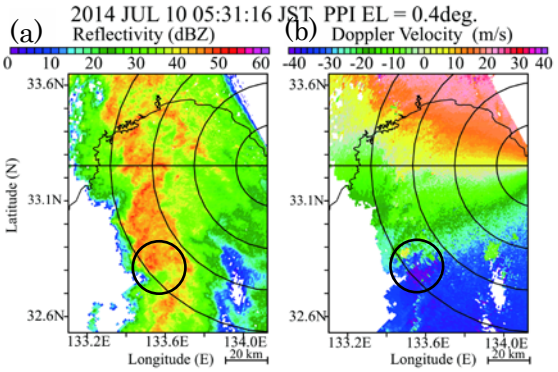

Fig.3 Muroto radar at 0531 JST. (a)Reflectivity, (b)Doppler velocity.

3. Results of damage investigation

In Hamakaida district of Nankoku city, band-like damaged area from south to north was 600 m in length and 40 m in width. Roof tiles were blown out and greenhouses were crushed. We estimated that the Fujita scale of this tornado was F0.

The damage area from Konann city to Kami city was 8 km long and 200 m wide. It was slightly inclined to north-west. Its length is the longest in the other 25 cases occurred for 20 years in the Kochi plane. The mean length of the other cases was only 0.7 km. Damages were also observed in roofs and greenhouses in this area. The most severe damage was the blown-out wall of storehouse at north side of the damaged area. Though its DOD (Degree of Damage) showed F1, we estimated the Fujita scale of this tornado as F0 from the total DIs (Damage Indicator). Flow patterns of convergence and rotation were observed in falling grasses and crops.

The Monobe radar locates between two damaged areas. Two vortices observed by the radar located just above the damaged areas.

4. Results of radar analysis

Figure 3 shows in the Muroto radar data. The first vortex (mc1) was observed at 0531 JST. It appeared 80 km offshore from the coastline of Nankoku city. Its diameter was 10km and it corresponds to a mesocyclone. It located at the south edge of strong echo region of more 40 dBZ in the outer rainband.

Second vortex (mc2) appeared just east of the mc1 at 0541 JST. Then two vortices moved northward parallel with each other along the outer rainband.

When the vortices landed, gust front was observed in the south edge of strong echo region as shown in Fig.4a. However, its arrangement showed that the gust front was different from the rear and forward flank gust fronts of supercell. In spite of rain attenuation, Monobe radar also observed two vortices (Fig.4b). The mc2 moved fast across the gust front. The echo pattern did not show hook-like shape, bounded weak echo region, and then the parent cloud is found not to be supercell at this time.

Figure 5 shows in Trajectories of the vortices. Two vortices moved northward parallel with each other along the outer rainband. Their moving velocity was about 28 m/sec. during they traveled offshore. After their landfall at 0621 JST, the mc1 rapidly slowed down to be 11 m/sec. whereas the

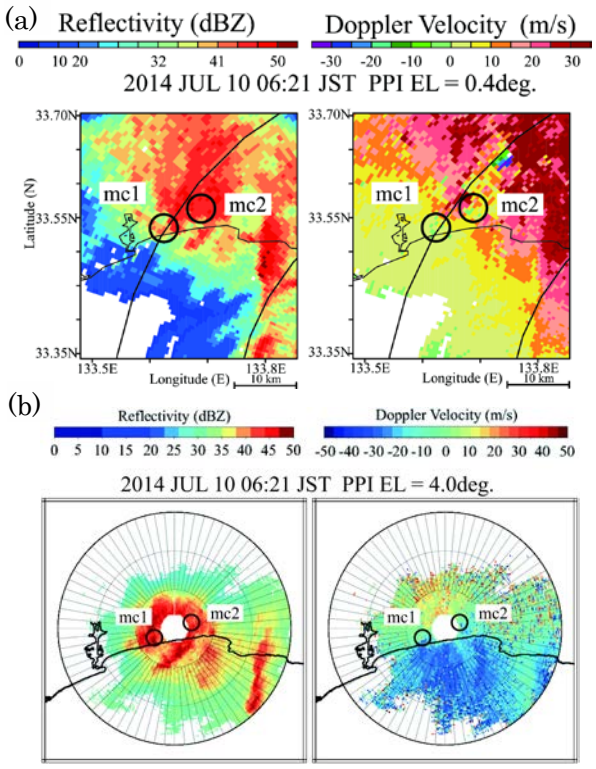

Fig.4 Reflectivity and Doppler velocity at 06:21 JST, observed by (a) Muroto radar at 700m and (b) Monobe radar at 350m.

mc2 kept its speed until at 0623 JST and then slowed down. Lifetime of the vortices was about 1 hour. The fact that mc2 lived long after landfall and yielded long damaged area may be because that the strong horizontal shear was kept in the outer rainband.

Vorticity of mc2 was larger than that of mc1 before landing, but mc1 became stronger after landing as shown in Fig.6a. The vertical distribution of the vortex diameter was almost uniform at 0617 JST as shown in Fig.6b. But after landing, the vortices became smaller in the lower layer due to surface friction.

5. Conclusions

Vortices appeared from 80km offshore from the coastline of Nankoku city. They moved above two damaged areas. The damage area from Konan city

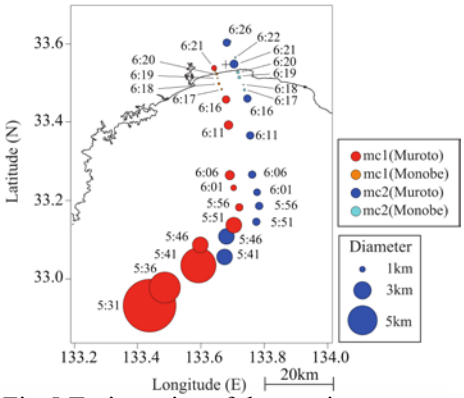

Fig.5 Trajectories of the vortices.

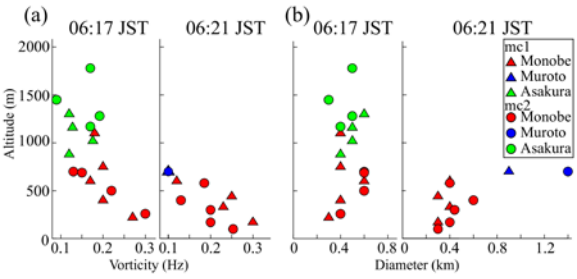

Fig.6 Vertical distributions of (a) vorticity and (b) diameter of vortices observed by Monobe.

to Kami city was 8 km long, which is longest in all cases occurred in the Kochi plain. Though the parent cloud of two tornadoes located in the outer rainband of typhoon, it had not the feature of supercell. The vortices became smaller in the lower layer after landfall.

Acknowledgments

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