13A.7 Fine structure of gustfront observed by Doppler radar, Doppler sodar, surface weather station and photogrammetry

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1. INTRODUCTION

The structures of a gustfront have been discussed from field observations, laboratory experiments and numerical simulations (e.g., Charba 1974, Goff 1976, Wakimoto 1982, Droegemeier and Wilhelmson 1987, Klingle et al. 1987, Ralph et al. 1993, Martner 1997). However, the detailed structures of a gustfront are not well known, such as gusts neat the surface, the structure of the arc cloud and the hear rotation. This paper presents a case study of a gustfront observed with Doppler radar, Doppler sodar, weather station and video cameras at Yokosuka, Japan. The fine structure of a gustfront was observed at the passage of the Yokosuka observation site on July 11, 2004.

2. OBSERVATIONS AT YOKOSUKA

Doppler radar (wavelength of 3 cm, henceforth referred to as NDA radar) observations were conducted at Yokosuka (National Defense Academy, 100 m ASL) from July to September to fully understand the Cb development mechanism around the Tokyo metropolitan area. The NDA radar had a radial range of 64 km. Constant Altitude PPI (CAPPI) of 20 steps and RHI (355° from the north) mode observations were conducted at 8-minute intervals. Additionally, Doppler sodar (Kaijo AR410), a weather station system (Kona system), and video cameras were set up at the Yokosuka site. Doppler sodar data were recorded at 30-second intervals, while 1-minute averaged data was used for analysis.

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3. GUST FRONT ON JULY 11, 2004

3.1 EVOLUTION OF MCS

After 11:00 JST, cumulonimbus generated around the Kanto Plane on July 11, 2004. The cloud system corresponded with the band-shaped echo that formed near synoptic scale cold front (Fig.1). Developing radar echoes formed near Yokohama and the band echo was organized at 12:00 JST. The maximum horizontal size of the band echo was approximately 50 km in length and 10 km in width. Bow echo developed at the south edge of the band echo in mature stage. After the descending of an echo core (downburst), which had maximum intensity of 40 dBZ, the propagation of a gustfront was detected by Doppler radar. Doppler sodar and visual observations were carried during the passage of the gustfront at the radar site.

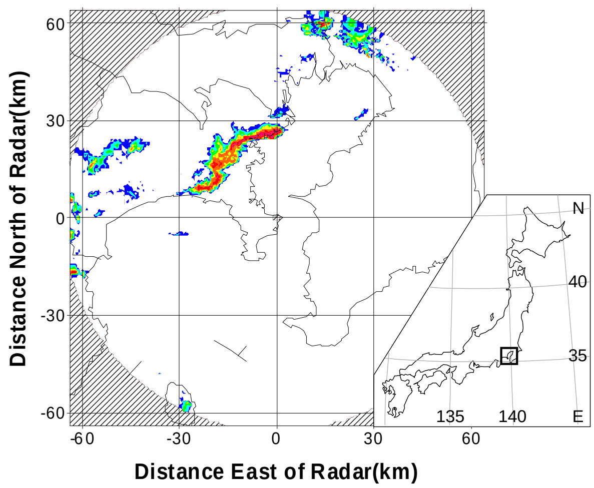

Fig.1 Radar echo pattern of CAPPI 1 km (intensity) on 12:47 JST July 11, 2004.

3.2 PROPAGATION OF GUSTFRONT

Figure 2 shows the time sequence of the Gustfront (GF), which was determined by the Doppler velocity patterns. GF was caught by Doppler velocity pattern as a line ahead of the main band shaped radar echo. Lower PPI scan (from elevation 1° to 2°) detected the gustfront during 40 minutes. GF propagated to the southeastward at the average speed of 12 m/s, which was larger than the movement speed of the band echo (11 m/s), and run about 30 km. The propagation speed increased from 12:47 to 13:07 JST and that decreased from 13:07 JST. The maximum speed was 14.8 m/s (12:57 ~ 13:07 JST). The horizontal scale of GF reached about 15 km at 12:57 JST. GF disappeared over the Tokyo Bay.

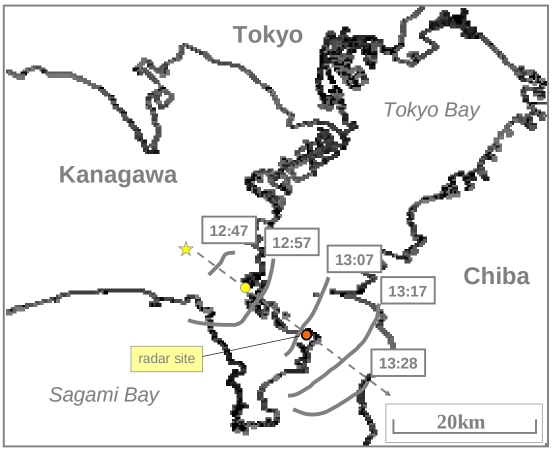

Fig.2 Time change of the gustfront from 12:47 to 13:28 JST. Circles and star mark denote surface observation site and generation point of the downburst, respectively.

Fig.3 Arc cloud just before the passage of the radar site (13:01JST).

3.3 STUCTURE OF ARC CLOUD

Figure 3 shows a photograph of arc cloud, which was taken just before the passage of the gustfront at the radar site. The arc cloud suddenly developed after the touchdown of downdraft (12:50 JST). The cloud top and cloud base of the arc cloud were about 600 m and 300 m ASL (200 m at the leading edge), respectively. The thickness of cold air was estimated using the surface observational data. The depth of the gravity current was 570 m and corresponded well with the height of cloud top (600 m).

Updraft was observed at the leading edge of GF and new cloud was continued to generate according to video image. "Skirt-shaped" structure was dominant at the front of the arc cloud (Fig.3). The angle of the frontal surface was estimated about 30 degree. Also, strong turbulence was observed below the cloud base. A line of bulbous cumulus was observed at the rear of the arc cloud. Behind the cumulus line, downdraft was observed in the cloud free area.

The movement of GF observed by the radar corresponded well with that of the arc cloud shown in Fig.3. The existence of the arc cloud (cumulus) may made possible to detect by the X-band Doppler radar as GF patterns shown in Fig.2.

3.4 GUST AT THE SURFACE

Two successive gusts occurred at the passage of GF (Fig.4). Figure 5 shows temporal changes of pressure, temperature, wind direction, wind speed, and mixing ratio measured at 10-second intervals at the radar site before or after the passage of GF. The passage of GF was defined as the time when the leading edge of the arc cloud passed at the site (broken line in Fig.5). 3 minutes after the GF passage, first gust (13:13 JST) observed and second gust (13:21 JST) occurred about 8 minutes later the first gusts. The maximum wind speed was recorded 14 m/s (first gust) and 15 m/s (second gust), respectively. First gust was observed about 2 km behind the gustfront leading edge. Second gust occurred about 5 km behind the first gust and maximum wind speed of the second gust was larger than that of the first gust.

The pressure increased before the passage of GF for 1.6 hPa and oscillated after GF. The pressure rises were corresponded with the time of gusts, which indicates the vertical circulation in the cold air of GF. The temperature and mixing ratio dropped after the passage of GF for 4.6 ℃ and 4.4 g/kg, respectively. These results suggest the existence of vertical circulations behind GF.

3.5 AIR MOTION NEAR SURFACE

Upper wind up to 500 m AGL was observed by a Doppler sodar at the radar site. Figure 6 shows time-height cross sections of horizontal and vertical current before and after the occurrence of the second gust. Strong wind cores (> 25 m/s) existed between 30 m and 500 m in height and descended. The gusts, which were observed at the surface, were well corresponded with the strong wind core near the surface (an arrow in Fig.6).

Both updraft and downdraft exceeding 5 ms^{-1} observed in the vertical circulation. The vertical circulation of the rear region, which is an overturning internal rotation of the gustfront “head”, had about 5 km in horizontal scale and 500 m in vertical and made the arc cloud. Surface gust and strong wind core were corresponded with the head of the circulation. Two successive gusts were well corresponded with two circulations.

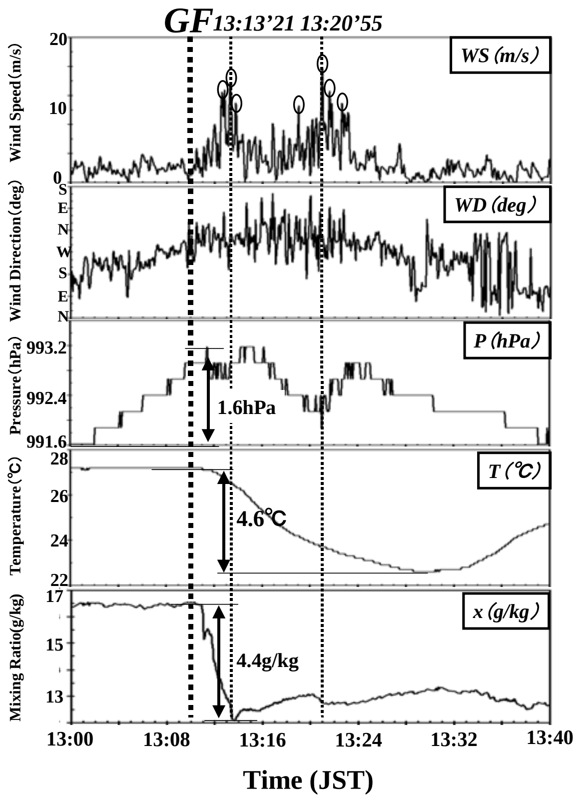

Fig.5 Temporal changes in the meteorological elements of pressure, temperature, wind direction, wind speed, and mixing ratio measured at 10-second intervals at the radar site from 13:00 to 13:40 JST on July 11, 2004.

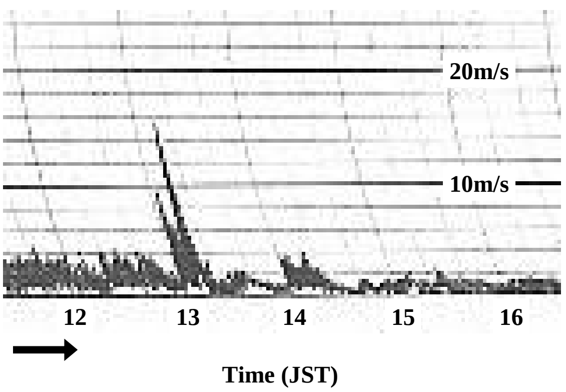

Fig.4 Temporal changes of wind speed at the radar site on July 11, 2004.

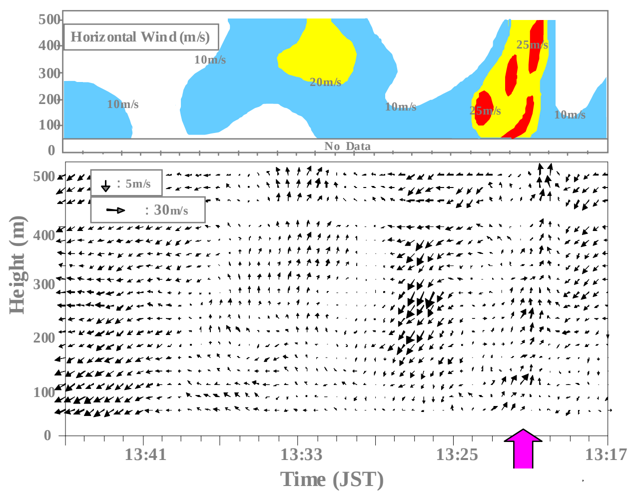

Fig.6 Time-height cross-section of horizontal wind speed (top) and horizontal/vertical current of propagation direction (bottom). An arrow denotes the time of the second gust.

4. SUMMARY

A thunderstorm developed around Yokohama near Tokyo at noon on July 11, 2004. A line-shaped radar echo system formed and bow echo developed at the south edge of the line echo system. After the descending of an echo core, the propagation of a gustfront was detected by Doppler radar and photographic / video visual observations. The detailed structure of the gustfront was revealed at the passage of Yokosuka observation site using Doppler radar, Doppler sodar, weather station and video cameras.

The gustfront propagated to the southeast at the speed of 12 ms^{-1} and a lifetime of the gustfront was about 50 minutes. Arc cloud generated at the head of gustfront and changed its shape remarkably. The cloud top and cloud base of the arc cloud were about 600 m and 300 m ASL, respectively. The evolution of arc cloud was observed below the gustfront using cameras and a video camera. Updraft was observed at the leading edge of the gustfront and new cloud was continued to generate at the frontal surface. Downdraft was observed at the rear of the cumulus line.

Remarkable changes of surface meteorological elements, pressure drop, pressure perturbations, temperature and humidity drop, were observed at the passage of the gustfront. Two successive gusts occurred after the passage of the gustfront. First gust was observed about 2 km behind the gustfront leading edge. Second gust occurred about 5 km behind the first gust and maximum wind speed of the second gust was larger than that of the first gust. The vertical circulation of the gustfront "head", which is an overturning internal circulation, had about 5 km in horizontal scale and 500 m in vertical. Both updraft and downdraft exceeding 5 ms^{-1} observed in the vertical circulation. Two gusts were well corresponded with two successive circulations. Strong wind cores (> 25 m/s) existed between 30 m and 500 m in height at the front of the head circulation. Two gust winds, which were observed at the surface, were corresponded with the strong wind core near the surface and the front of head circulations.

5. REFERENCES

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