The Shimodate Downbursts on July 15, 1996

by

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ABSTRACT

On July 15, 1996 strong gust winds accompanied with a severe thunderstorm hit Shimodate city, northwest of Ibaraki Prefecture, resulting in one people dead, 19 injured and 425 houses collapsed. A field survey revealed that the strong winds were caused by at least two downbursts. The intensity of the first one was estimated as F2 by Fujita scale (corresponding to wind speed of 50 - 69 m/s), which was one of the severest downbursts reported before in Japan.
Doppler weather radar at Narita International Airport caught parent thunderstorm of the downbursts. Echo reflection intensity and Doppler velocity showed precursor events of the downbursts in the thunderstorm cloud such as descent of precipitation core and divergence of winds in the lower level above the surface.

Key Words:

downburst, gust wind, Doppler weather radar, precursor, warning

1. Introduction

In the afternoon of July 15, 1996 a thunderstorm developed in the northern part of the Kanto Plains and moved southeastward passing through Tsukuba. Strong gust winds with hail hit Shimodate city, Ibaraki Prefecture, northwest of Tsukuba, resulting in one people dead, 19 injured, 425 houses collapsed, 2 trains canceled, electric power cut of 8 thousand houses and 3,500 million yen loss to the agriculture etc. Meteorological Research Institute (MRI) performed a field survey of the damages produced by strong winds with Mito Local Meteorological Observatory. It was identified that at least two downbursts occurred successively in 10 minutes, first one being one of the strongest downbursts in Japan reported in the past.

A downburst is a strong descending airflow in cumulus or cumulonimbus clouds which causes a damaging horizontal outflow near the ground surface (Figure 1). Strong downward motion of the airmass in a cloud is accelerated by evaporative cooling of the waterdrops or loading of heavy raindrops or hails onto the air. The speed of outflows of downbursts sometimes reaches 70 m/s but their horizontal scales are almost less than 10 kilometers and their lifetimes are less than 10 minutes. Downbursts with horizontal scale of less than 4 km is especially hazardous to airplane and called microburst. In the United States, during the period 1974 to 1985, microbursts have caused at least 11 civil aviation accidents involving over 500 fatalities and injuries (Proctor, 1988). In Japan 25 events of downbursts have occurred during the period 1981 to 1994 (Ohno et al. 1996).

Japan Meteorological Agency (JMA) have installed 3 Doppler weather radars at Narita, Haneda and Kansai airports and started operation to detect dangerous windshear for aviation which are caused by downbursts and other atmospheric disturbances. These Doppler radars have higher time resolution and greater number of scanning angles than the conventional radars of JMA. Some precursors

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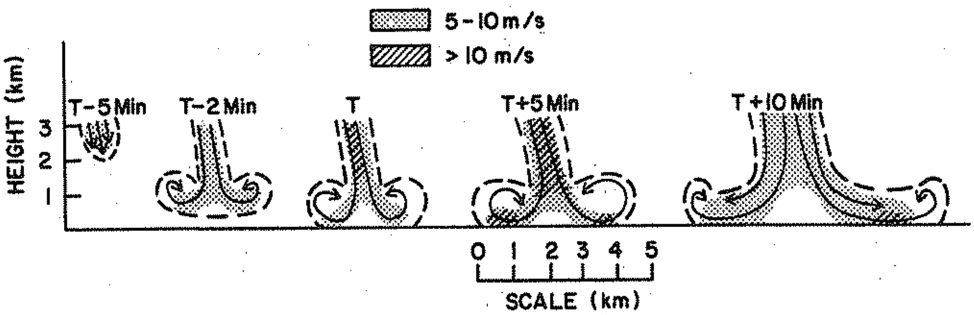

Figure 1 A schematic representation of the evolution and flow within an average downburst obtained by Doppler weather radar from the Joint Airport Weather Studies (JAWS) near Denver (after Wilson et al., 1984). T is the time of initial divergence at the surface. The shading denotes the vector wind speeds.

of the downbursts at Shimodate were observed by Narita Doppler weather radar. The case presented here is the first time in Japan that parent clouds of downbursts and/or the precursors are observed by an operational Doppler weather radar.

This paper will present the results of the field survey, meteorological conditions of the environment air around the thunderstorm, and the precursors of the downbursts identified by Narita Doppler weather radar.

2. Damage characteristics

We investigated mainly the following 3 items in the field survey;
1) degrees of damages to specify strength (speed) of winds,
2) directions in which damaged objects such as trees and constructions fell down or were blown down to determine wind directions, and
3) horizontal extent of damaged area to determine area of the damage-induced wind.
We also made interviews to the residents to get specific features of the event and to specify the time when strong winds occurred.

It was found that there were two areas where damaging winds blew, each 6 km apart. Figures 2 and 3 show the horizontal area and wind directions of the two damage areas. These figures clearly indicate that
1) shapes of damage areas are ellipse,
2) wind directions distribute radially,
and we also get by interviews the information that
3) hail storm started almost simultaneously with the damage winds.
Therefore, we concluded that the damages

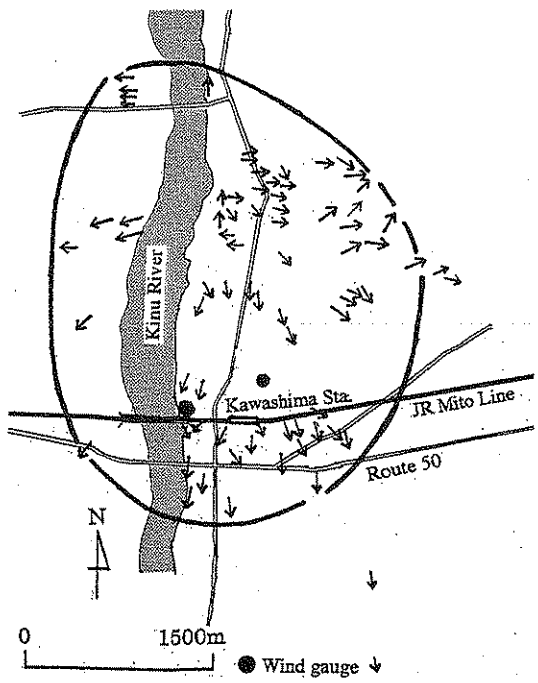

Figure 2 Distribution of damages and directions of winds of the first downburst occurred north of JR Kawashima station, western part of Shimodate City. Dots indicate positions of wind gauges.

were caused by two downbursts.

The first downburst occurred at around 14:51, in the area north of JR Kawashima Station, western part of Shimodate City (Figure 2). The intensity was estimated as F2 by Fujita scale (corresponding to wind speed from 50 to 69 m/s). This is one of the severest downbursts in Japan reported in the past. The damage area was 4 km long and 3 km wide. A wind gauge located in the southern portion of the damaged area recorded 46 m/s maximum instantaneous wind velocity at 14:53:30 and another wind gage located north of JR Kawashima Station observed 47.5 m/s northerly wind.

The second downburst occurred at around 14:59 in the southern part of Shimodate City. The estimated intensity was F1 (wind speed from 33 to 49 m/s) and the area was 2.5 km

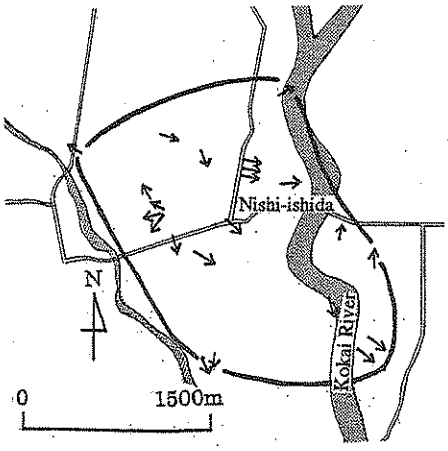

Figure 3 Distribution of damages and directions of winds of the second downburst occurred at southern part of Shimodate City.

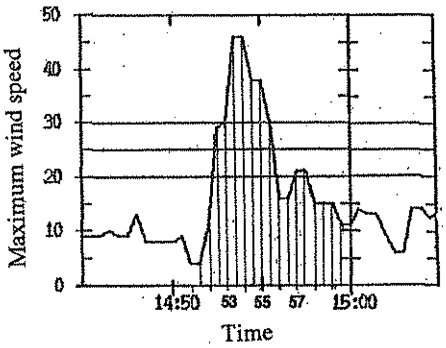

Figure 4 Wind speed record at Kinugawa railroad bridge of JR Mito line.

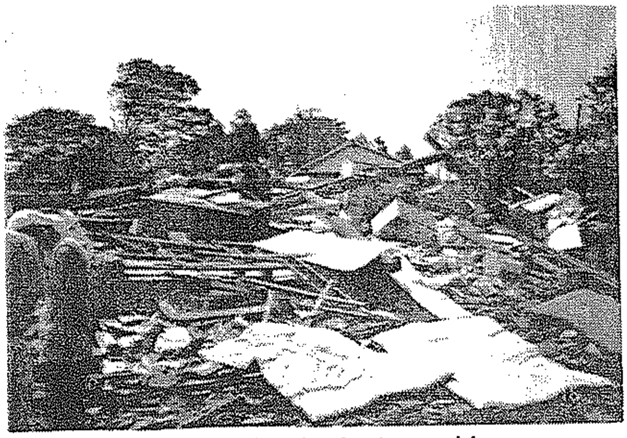

Photo 1 A completely destroyed house. Intensity of the downburst was estimated from the degree of damage.

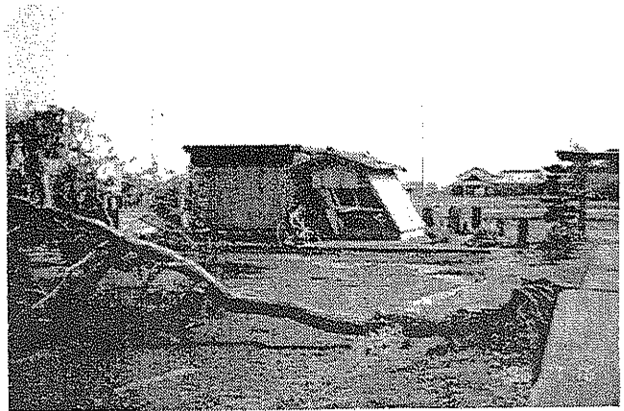

Photo 2 Wind directions were estimated from trees blown down and constructions inclined.

Photo 3 Holes made by hails on a pumpkin. Hails as large as a ping-pong ball fell.

long and 1.5 km wide.

Photos 1 to 3 show some examples of the damages.

3. Meteorological Conditions

On July 15, 1996, the Baiu front stayed over northern part of the Japan Island from Niigata to Fukushima Prefecture and the Kanto Plains was covered by the subtropical high pressure extending from the northwest Pacific Ocean. Over the northern part of the Kanto Plains, i.e. Tochigi and Ibaraki Prefectures, weak easterly winds flew in the morning and temperature has risen to over 30℃ at noon. Cumulus clouds were started to form in the center of Tochigi Prefecture in the afternoon and developed to a thunderstorm moving southeastward towards Shimodate city and then Tsukuba city.

Figure 5 shows the distribution of radar echo reflection intensity by the JMA weather radar when the downbursts occurred. A line-shaped echo was extending along the border between Tochigi and Ibaraki Prefectures. There observed the echo reflection intensity over 64 mm/hr and the echo top height as high as 12 km. The downbursts at Shimodate occurred near the southwestern end of the echo.

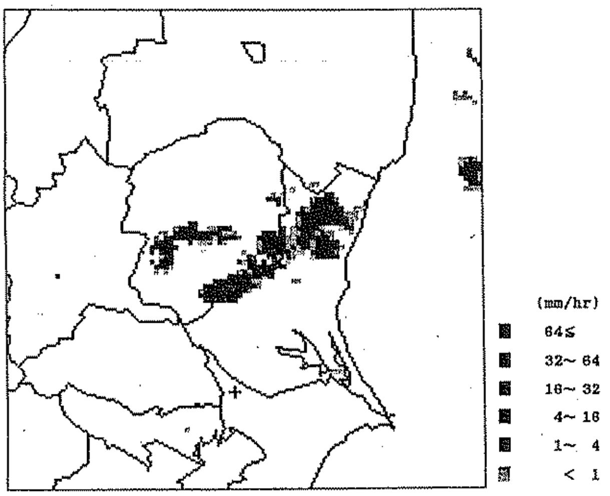

Figure 5 Radar echo reflection intensity at 14:52, July 15, 1966 observed by Tokyo weather radar, JMA.

Pattern of surface winds and temperatures (Figure 6) indicates that cold northerly outflow from the thunderstorm intruded into the warm south-southwesterly air in the western part of the Kanto area and slightly colder easterly flow in Ibaraki Prefecture. The line-shaped echo lay along the border between the cold northerly outflow and the easterly flow. At Shimozuma south of Shimodate temperature decreased from 29℃ to 23℃ and wind direction changed from E to NNE after passage of the thunderstorm.

In order to investigate whether atmospheric vertical stability of the environmental air around the thunderstorm was favorable for formation of cumulus clouds and initiation of downbursts, we calculated the convective available potential energy (CAPE) and $\Delta\theta e$, the difference of the equivalent potential

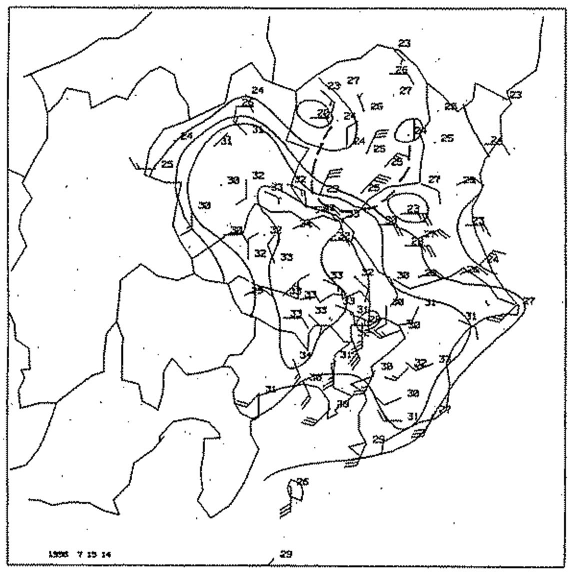

Figure 6 Surface winds and temperature at 14:50, July 15, 1966 obtained by automated weather stations AMEDAS, JMA. Solid lines denote temperature with contour interval of 3 degree and a dashed line denotes boundary of northerly wind.

temperature between its maximum value at the lower level (typically 950 hPa) and its minimum at the middle level (typically 600 hPa) from upper air soundings twice a day at Tateno in Tsukuba city.

Figure 7 indicates that in the afternoon of July 15, CAPE was larger than 1,000 m^2/s^2 which is said to be the threshold value for cumulus clouds to form. $\Delta\theta e$ in the morning of July 15 was 21K. Atkins and Wakimoto (1991) suggested that a wet downburst in the United States often occurs when the criterion $\Delta\theta e >$ 20K is satisfied. Therefore, the conditions of storm environment on July 15 were favorable to cumulus convections and downbursts. However, in many other days in Figure 8, conditions of CAPE and $\Delta\theta e$ were satisfied but there were no reports about thunderstorms and downbursts for most of those days. Thus, it seems to be difficult to forecast thunderstorms and downbursts using only these parameters. One of the reasons is that soundings do not represent conditions of environmental air of a thunderstorm since the storm is of small scale and sounding position is in general far apart from the storm.

4. Precursors observed by Narita Doppler weather radar

Narita Doppler weather radar in operation since April 1996 has a range of 100 km radius and the increment are 150 m in radial direction and 0.7 degree in tangential direction. It takes about 6 minutes to perform one scan mode during which the radar scans 17 elevation angles. Since Shimodate city is about 75 km north of Narita Airport, resolution of the radar near Shimodate is about 900 m in tangential direction and also about 900 m in the vertical. Narita Doppler weather radar has time resolution higher than conventional weather radars and succeeded to catch the details of precursors in the parent thunderstorms of the downbursts presented here.

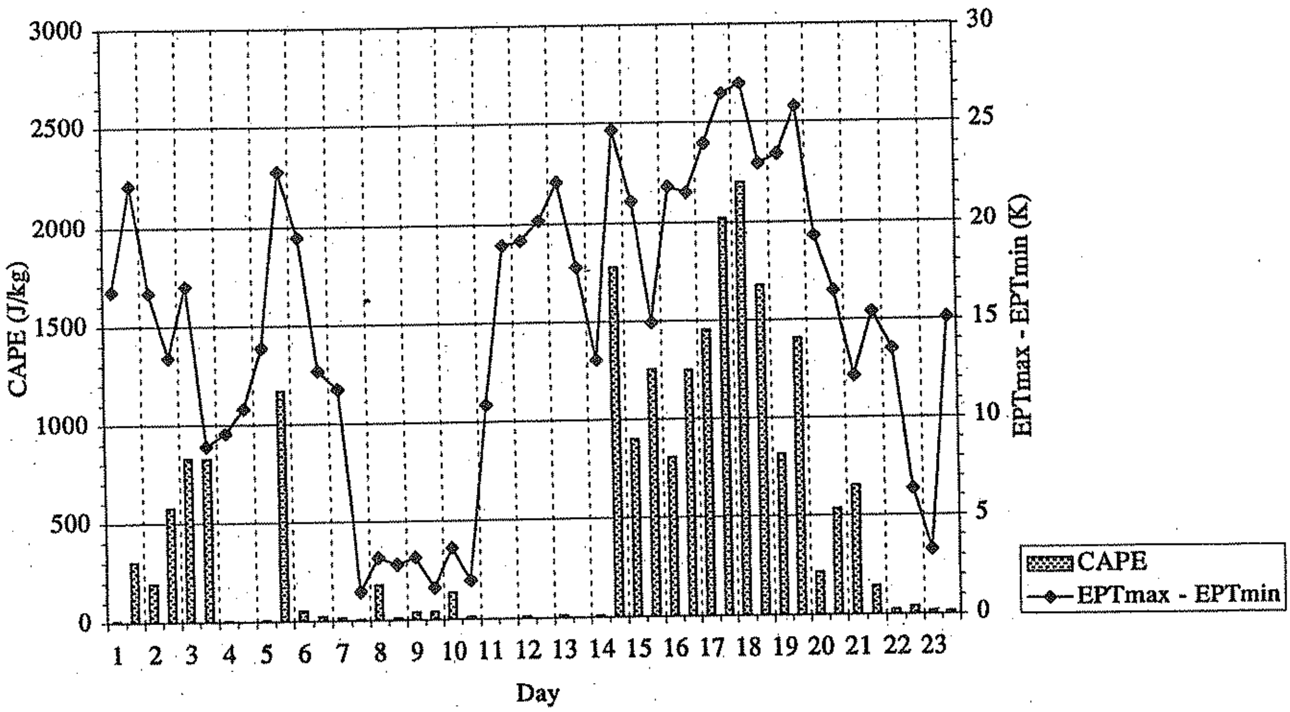

Figure 7 CAPE (convective available potential energy) and $\Delta\theta e$, the difference of the equivalent potential temperature between its maximum in the lower level and its minimum in the middle level in the period from 1 to 23, July 1996 computed from upper air soundings at Tateno.

Figure 8 shows patterns of echo reflection intensity and Doppler wind velocity at the level of about 1 km high, 1.5 minutes before the first downburst. A strong echo reflection intensity is observed above the first downburst area (top figure) and there is a pair of wind towards the radar southeast of the first downburst area (thick hatch) and wind away from the radar northwest of the downburst. The high echo reflection intensity suggests existence of precipitation core or hails and wind pair with opposite direction means divergent wind flows.

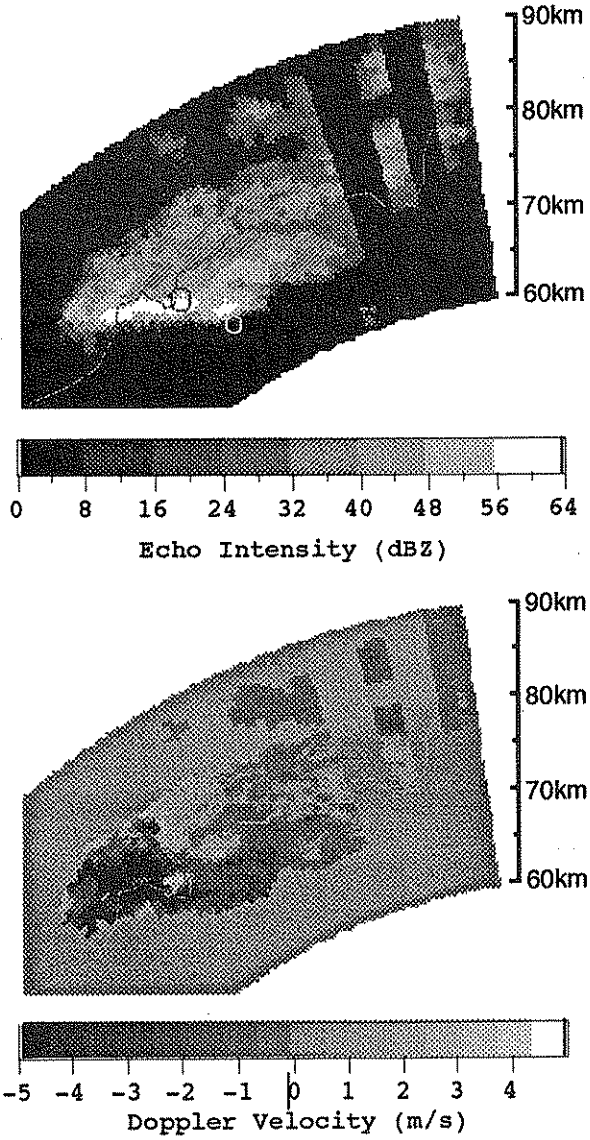

Figure 8 Echo reflection intensity (top) and Doppler velocity (lower) by Narita Doppler weather radar at 14:49:32, July 15,1996. Elevation angle of radar scan is 0.7 degree. Solid line indicates the border between Tochigi and Ibaraki Prefectures and two ellipse damage areas by the downbursts.

Since downbursts are quite dangerous to aviation as well as public, using Doppler radar some attempt have already been performed to detect precursors of downbursts several

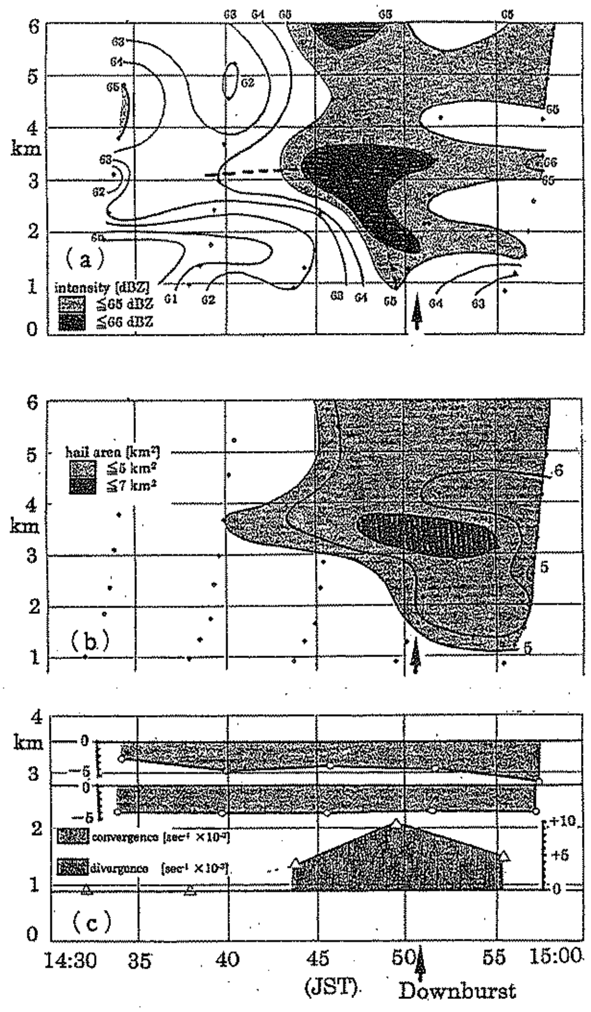

Figure 9 Time-height cross sections composed from Narita Doppler weather radar data (Kusunoki et al., 1996). Top: Echo reflection intensity; middle: hail area, and bottom: convergence in the middle level and divergence near the surface.

minutes before the occurrence of downbursts. As precursors which can be caught by Doppler radar, the followings are for example noted (e.g., wheeler and Roeder, 1995):

(1) divergence in the lower level near the surface
(2) convergence in the middle level
(3) rotation in the middle level
(4) descending precipitation core
(5) notch pattern
(6) extension of hail area

Kusunoki et al. (1996) investigated the precursors of the downbursts using Narita Doppler weather radar. Figure 9 shows time-height cross sections composed from radar beams with different elevation angles which pass through the parent thunderstorm of the first downburst. Figure 9 (top) indicates that the area of high reflectivity at 3 km height level started to descend about 6 minutes before the downburst at the surface and reached 1 km above surface 1 minute before the downburst. Figure 9 (middle) shows that hail area was formed around 3 to 4 km level about 3 minutes before the downburst. Figure 9 (bottom) depicts that divergence area in the lower level existed already 5 to 7 minutes before the downburst.

If we can detect these precursors on real time base by the operational Doppler radar, it will be possible to issue downburst warning to aviation and/or public.

5. Conclusion

We performed a field survey to identify the source of severe winds that brought damages at Shimodate City on July 15, 1996. It was found that the strong winds were caused by at least two downbursts. The intensity of the first one was estimated as F2 by Fujita scale and the second one F1. The meteorological condition of the environment of the parent thunderstorm was examined with upper air soundings at Tateno. A vertical stability index CAPE satisfied the criteria for development of cumulus convection. On of the downburst indices , $\Delta\theta e$, the difference of the equivalent potential temperature was over the criteria for occurrence of downbursts obtained from case studies in the United States. The Doppler weather radar at Narita International Airport caught the precursors of the downbursts such as descending motion of precipitation core, enlargement of hail area in the middle level and divergence in the lower level. It will be expected a rapid progress in developing tools to detect the precursors of downbursts by Doppler radar and we hope that downburst warnings will be issued as operational base in the near future.

Acknowledgments

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