MULTI-WAVELENGTH RADAR OBSERVATION OF WINTERTIME THUNDER CLOUDS RELATED TO THE POLARITY OF THE LIGHTNING DISCHARGES

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ABSTRACT: Time, location, and polarity of lightning discharges in wintertime thunderstorms are discussed in light of horizontal and height distribution of radar echoes observed by C-band and millimeter-wave radars. The core of the radar echoes that produced a number of positive-current cloud-to-ground discharges in a few minutes tends to be found near a comparatively lower cloud top of 2-3 km heights, suggesting that the lightning strokes directly come from the cloud top to the ground. The amount of these positive-currents is less than 50 kA and not so much as those coming from higher cloud tops that occurred more intermittently.

1. INTRODUCTION

Along the coast of the Sea of Japan, thunders peculiar to wintertime frequently occur as strong northerly or westerly seasonal winds approach the coast. The wintertime thunder clouds are characterized by a relatively low cloud top and frequent occurrence of positive-current cloud-to-ground strokes. Compared with the summertime thunder clouds, however, very little is yet known about the wintertime thunder clouds. In this study, a C-band (5.27 GHz) weather radar of the Kansai Electric Power Company and a millimeter-wave (34.75 GHz) radar of Kyoto University were both used to observe the wintertime thunder clouds at Mikuni in Fukui Prefecture, Japan. The millimeter-wave radar was recently developed especially to observe fine spatial structure and distribution of cloud droplets. From December 2001 to February 2002, the millimeter-wave radar was located at Mikuni, and it observed several thunderstorm events simultaneously with the C-band Kusuya radar. This paper presents horizontal and height distribution of radar echoes observed by both C-band and millimeter-wave radars, and primarily discusses the feature of thunder clouds that produced a large number of positive-current lightning discharges.

2. OBSERVATIONAL RESULTS

2.1 Horizontal distribution of radar echoes

In the event on December 30, 2001, more than 100 cloud-to-ground lightning strokes were detected. Both positive- and negative-current strokes occurred successively almost every minute at the developing and matured stages of the thunder clouds. The time, location, and polarity of each cloud-to-ground lightning stoke are obtained from the LLP system of the Kansai Electric Power Company. Figure 1 show the horizontal distribution of radar echoes on the 2 km height CAPPI display observed by the C-band Kusuya radar on December 30, 2001. The abscissa and the ordinate represent the distance from the Kusuya radar. The thick line is the coast line and to the north-west of the line is the Sea of Japan. The cross indicates the location of the millimeter-wave radar at Mikuni. The contour lines show the C-band Kusuya radar echoes at every 10 dB interval. The numbers in the figure mean a degree of disturbances or turbulent velocities, and "3" is equivalent to the velocity of more than 6 m/s. The asterisks and the triangles are the locations of positive- and negative-current lightning discharges to the ground or the sea, respectively, which occurred during the observational time of each panel. In this event, lightning activities were so high that positive or negative discharges were observed almost every minute. Echo intensities and turbulent velocities are available at 2 km x 2 km grid points.

In general, we can see two or three cores of the thunder clouds in each panel. It should be noted that almost all lightning discharges, whether they are positive or negative, occurred around these cores where the echo intensity exceeds 40 dBZ [*Maekawa et al.*,1993]. Also, there seems to be a tendency that the larger cores may produce a larger number of lightning discharges. The areas of large turbulent velocities as noted by the number "3" are widely distributed around the cores with the lightning discharges. The observational period of Fig.1 is characterized by very frequent occurrence of positive-current strokes. Especially in panels #4 and #5, positive-current strokes occurred successively at about 10 km distance in the north-west direction from the millimeter-wave radar site (x). Positive-current strokes may be one of the unique features of wintertime thunderstorm, but it is still a very rare phenomenon that the positive-current discharges continue to happen so many times in such a short time span.

2.2 Height distribution of radar echoes

The millimeter-wave radar has a wavelength by one order shorter than the C-band Kusuya radar, and this realizes a much higher resolution for the observations of spatial structure or distribution of cloud droplets and hydrometeors. In this observation, the millimeter-wave radar used seven elevation angles of 7.0, 8.5, 10.2, 12.2, 14.7 17.8, 90 (zenith) deg. The antenna was scanned in the azimuth direction once a minute (1 rpm), with the elevation angle switched every minute among these seven values. The maximum range is 30 km for the echo intensity observation, Using these echo data, we can depict the CAPPI display with horizontal resolution of 250 m x 250 m at any height from 1 to 5 km.

Fig.2 shows the height distribution of the CAPPI displays obtained from the millimeter-wave radar observations of the same thunderstorm event on December 30, 2001. The observational time is much the same as the panel #4 of Fig.1. Four height levels are depicted from 1.8 to 2.4 km at 200 m intervals. Contour levels of echo intensities are 0-25 dBZ. At 1.8 km height, a core of the intense radar echoes appears at 10 km distance from the radar in the north-west direction. This core corresponds to the one that produced a number of positive-current discharges in the panel #4 of Fig.1. This core, however, gradually disappears above the height of 2 km, and another core of the thunder clouds is found in the nearer range from the radar.

Fig.3 depicts height distribution of radar echoes around the lightning locations of those positive-current discharges. The height section of the echo intensities is shown in the north-south direction at 12 and 10 km west from the radar, respectively. The observational time also coincides with the panel #4 of Fig.1. Contour levels are same as in Fig.2. In this case, the core at 10 km distance from the radar is found in a comparatively low cloud top of 2-3 km heights at the moment, and seems to have produced frequent positive lightning strokes directly from the cloud top to the ground (sea). An estimated amount of their currents is less than 50 kA, being not so much as positive-currents from higher cloud tops, which have occurred more intermittently, and sometimes reach more than 100 kA in other cases.

3. CONCLUSIONS

This paper has presented several cases of the echo intensities and the distribution of the core observed by the C-band and millimeter-wave radars in a very active thunderstorm event on December 30, 2001, at Mikuni, Fukui. A number of positive-current strokes, which are one of the unique features of wintertime thunder clouds, have been observed. The time and location of the occurrence of those positive-current discharges seem to be closely related to lower heights of the core near the echo top of the thunder clouds. In future, more comprehensive discussion on the statistical nature of wintertime lightning strokes will be, of course, needed in addition to the case studies of the thunderstorm events presented this time.

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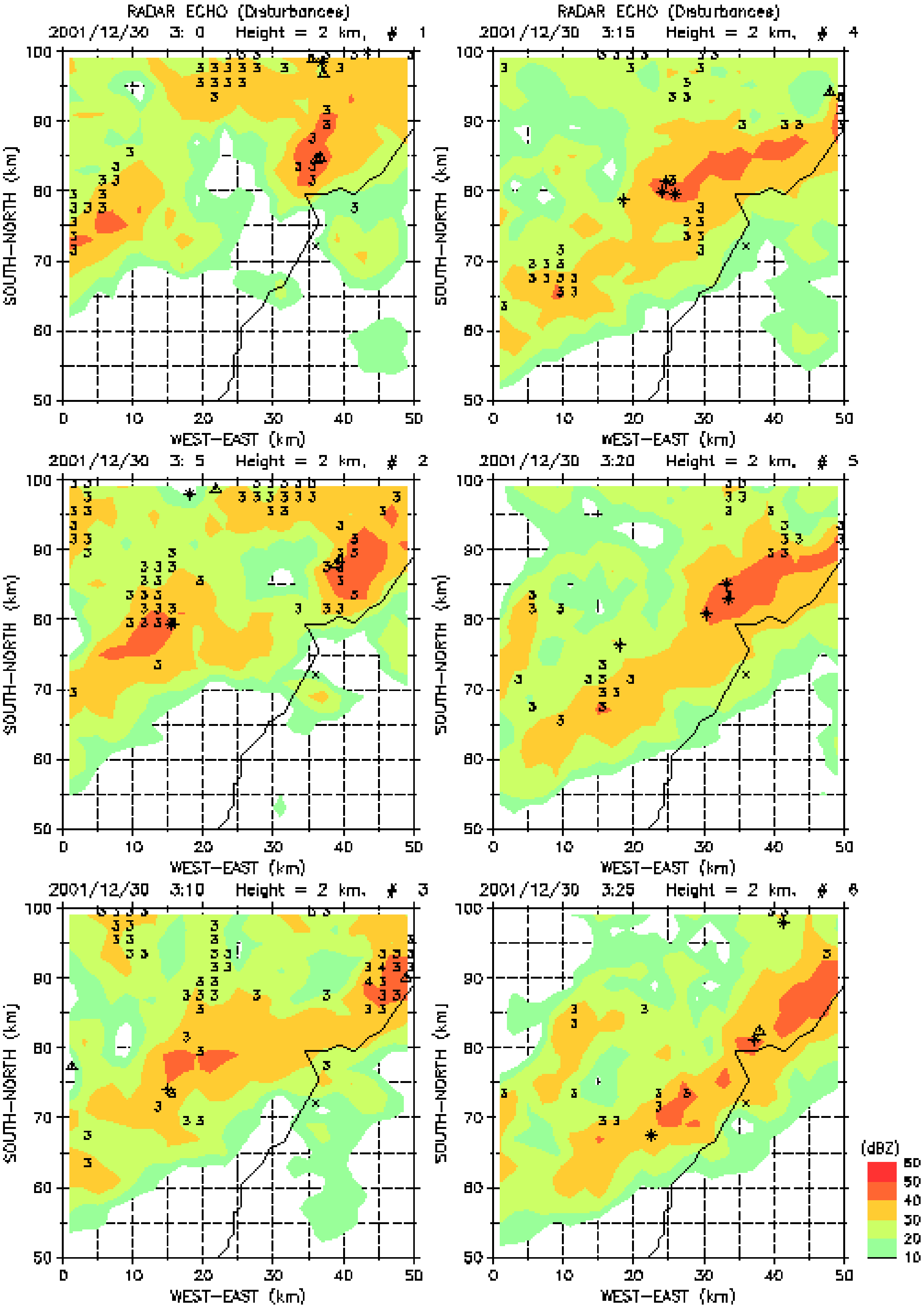

Figure 1. CAPPI displays observed by the C-band Kusuya Radar. The asterisks and the triangles are the locations of positive and negative lightning discharges, respectively. The numbers (x2) mean a degree of disturbances (turbulent velocities in m/s),

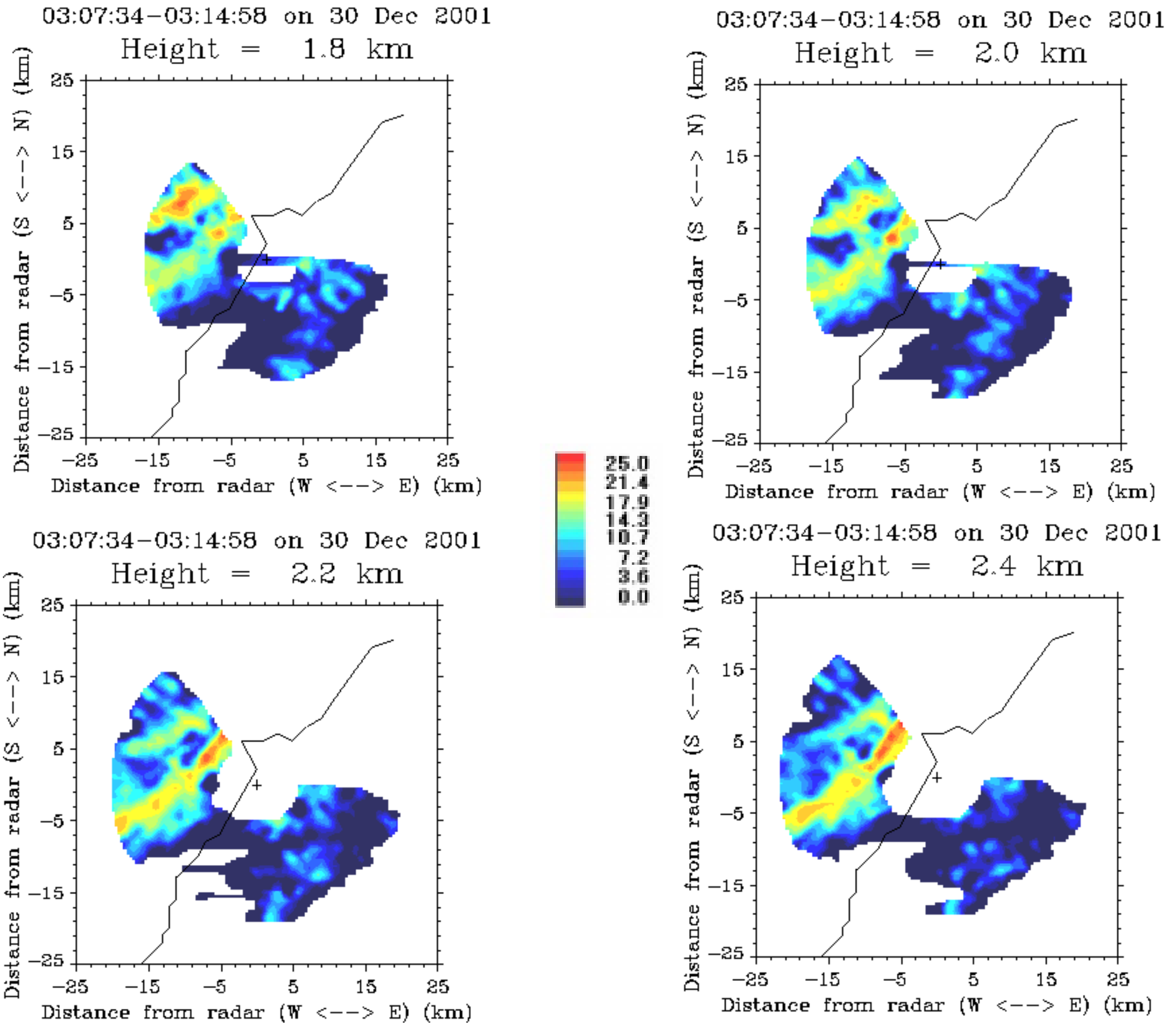

Figure 2. Height distribution of CAPPI displays observed by the millimeter-wave radar. The observational time is much the same as the panel #4 of Fig.1. Contour levels of echo intensities are 0-25 dBZ.

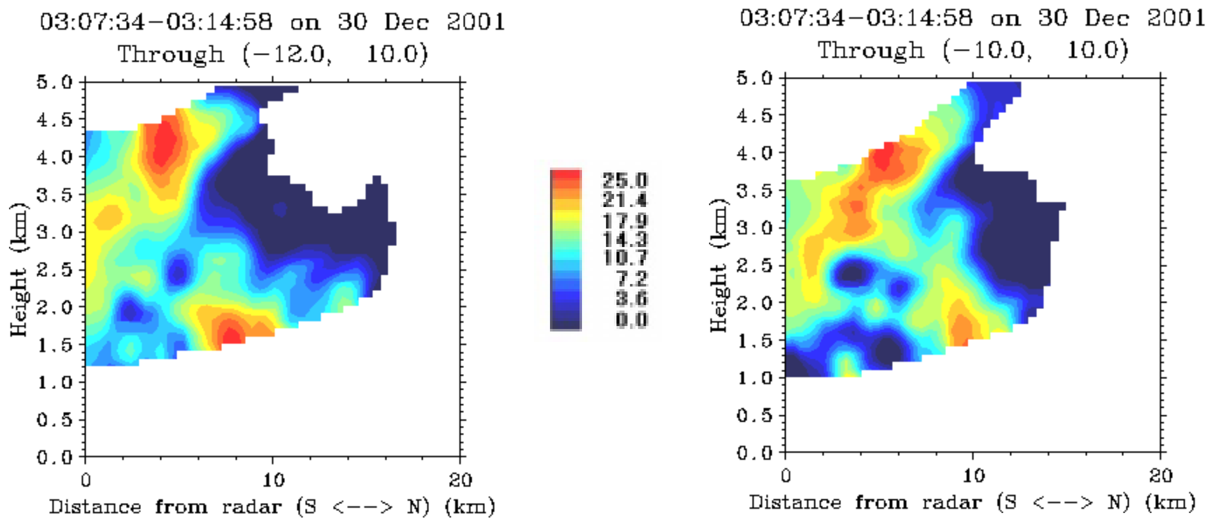

Figure 3. Height distribution of radar echoes observed by the millimeter-wave radar. The observational time and contour levels are same as in Fig.2.