P1R.2 WIND OBSERVATION IN BOUNDARY LAYER BY W-BAND RADAR USING NON-HYDROMETEOR ECHO

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1. INTRODUCTION

A W-band cloud radar has high sensitivity enough to observe non-precipitating clouds. It normally aims to observe various clouds, rain or snow, but it frequently receive non-hydrometer echoes near the surface. It is thought that non-hydrometeor echoes are caused by small insects or bits of vegetation. They are removed from data set to use meteorological study. However, if those insects are floating in the air and blowing with wind, they can be used as wind tracers.

In this paper, statistical appearances of the non-hydrometer echoes are studied using several month data of a W-band cloud profiling radar. We also show availability of their Doppler speeds for the atmospheric boundary layer study.

2. CLOUD RADAR OBSERVATION

The National Institute of Information and Communications Technology (NICT) is operating a W-band (95.04GHz) cloud profiling radar called "SPIDER" (Horie et al., 2000). Although the SPIDER is originally designed as an airborne cloud radar, it can also be operated as a ground-based radar in a special container that has a radio-transparent window on the ceiling. The SPIDER has dual receiver channels for the linear polarization measurement. The Doppler velocity of the echo can be measured by the pulse-pair method or the FFT method. From July 2003 to January 2004 and from September 2004 to December 2004, SPIDER was continuously operated at NICT, Tokyo. Its antenna beam had been directed to the zenith. Cloud echo profiles were obtained every 0.6 second and the height sampling interval was 82.5 m.

3. IDENTIFICATION OF NON-HYDROMETEOR ECHO

Non-hydrometer echoes were frequently observed near the surface. Fig. 1 shows time-height section of the reflectivity factor of the SPIDER from 1 to 10 October 2003. Black dots in this figure are the ceilings of cloud measured by a ceilometer. It is installed close to the SPIDER. The strong echoes more than –20 dBZ on 4 and 6 Oct are caused by rain, but other continuous echoes below the ceilings are not caused by either cloud or rain. Several previous studies pointed out that those non-hydrometeor echoes with higher frequency radar are caused by small insects or bits of vegetation rather than by the atmospheric turbulence (Mueller and Larkin 1985, Wilson et al. 1994, Martner and Moran, 2001, Geerts and Miao, 2005). Kusunoki (2002) also analyzed insect echoes around Tokyo area using C-band radar. We also think that these non-hydrometeor echoes are caused by small insects or bits of vegetation. In order to distinguish the non-hydrometeor echoes, we used liner depolarization ratio (LDR) following Martner and Moran (2001). Fig. 2 is time-height sections of LDR observed by the SPIDER. Comparing with the cloud echoes above 1 km and the rain echoes, non-hydrometeor echoes have larger LDR. We can roughly distinguish the non-hydrometeor echo using LDR more than –15dB, although some hydrometeor echoes may be still remained in these echoes. Fig. 3 shows the time-height section of the reflectivity factor of the non-hydrometeor echoes, after removing the small LDR echoes. The magnitude of these echoes are from –60 to –40 dBZ. Their height ranges are roughly below 1.2 km. This figure clearly shows the diurnal variation of the appearance height. The maximum echo height rises up to 0.8 –1.2 km around the noon and falls in night. This diurnal change is seen in all month data and it is similar to the previous studies (Kusunoki 2002).

4. APPEARANCE RATE OF NON-HYDROMETEOR ECHO

The appearance rates of hydrometeor and non-hydrometeor echoes of the SPIDER are calculated at each month in 2003 and 2004. The hydrometeor and non-hydrometeor echoes are classified using the LDR. However, in order to avoid contamination of the melting layer or the snow/ice echoes in upper height to the non-hydrometeor category, we added conditions of height range of non-hydrometeor echoes below 2 km in Jul-Oct, below 1.5 km in Nov, and below 1 km in Dec and Jan. Fig. 4 shows the appearance rate profiles of hydrometeor and non-hydrometeor echoes in 2003 and 2004. The appearance rates of non-hydrometeor echo exceed 50 % near the surface, but they suddenly decrease with height around 800 m in summer and around 300 m in winter. Comparing 2003 and 2004, similar seasonal changes are seen in the appearance rate profiles. We also checked differences of the appearance rates between day (7-19LT) and night (19-7LT) in Fig. 5. The appearance rates of the non-hydrometeor echoes are clearly larger in daytime than in nighttime. The appearance rates of the hydrometeor echoes have a tendency to be larger in nighttime than in daytime. However, the appearance rates of the cloud echoes in boundary layer are considerably underestimated comparing with the ceilometer analysis. This is because the sensitivity of the SPIDER is not enough to detect all the boundary layer clouds.

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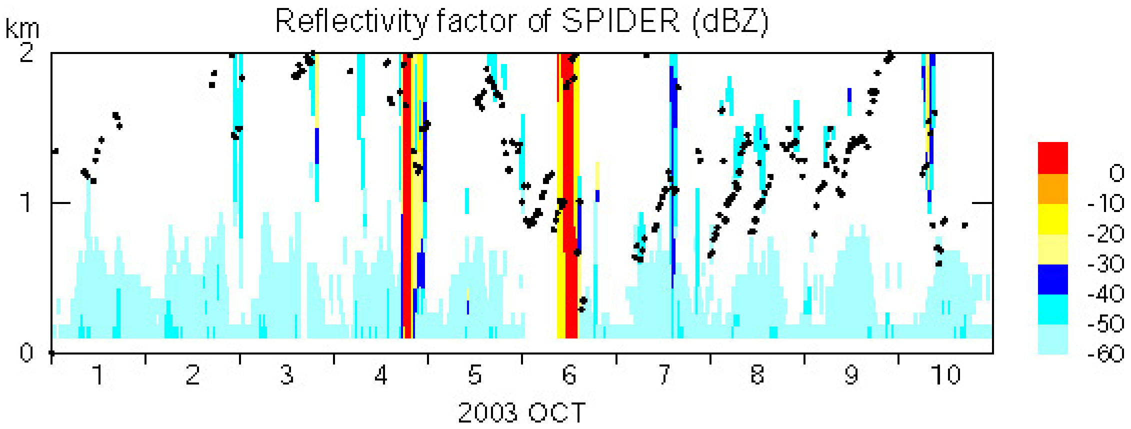

Fig.1: Time-height section of reflectivity factor of SPIDER. Black dots denote the ceilings measured by ceilometer.

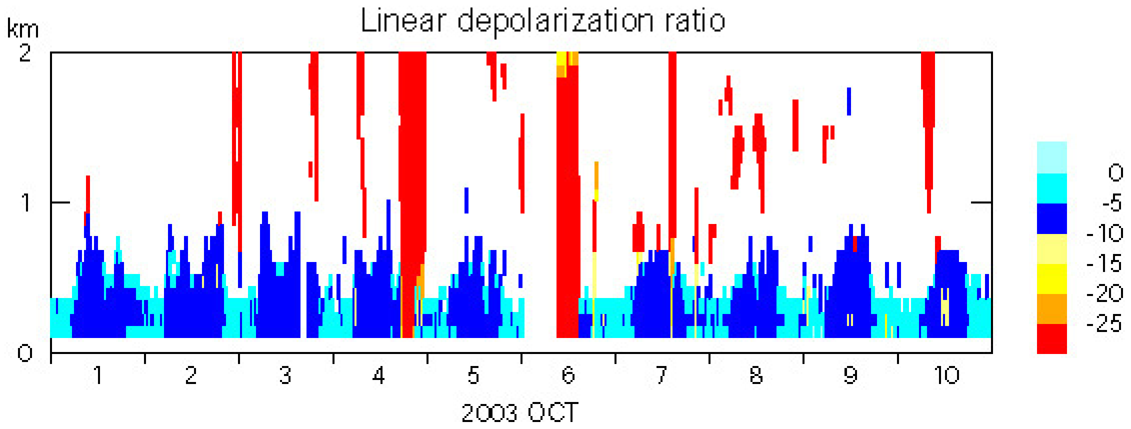

Fig.2: Time-height section of linear depolarization ratio of SPIDER

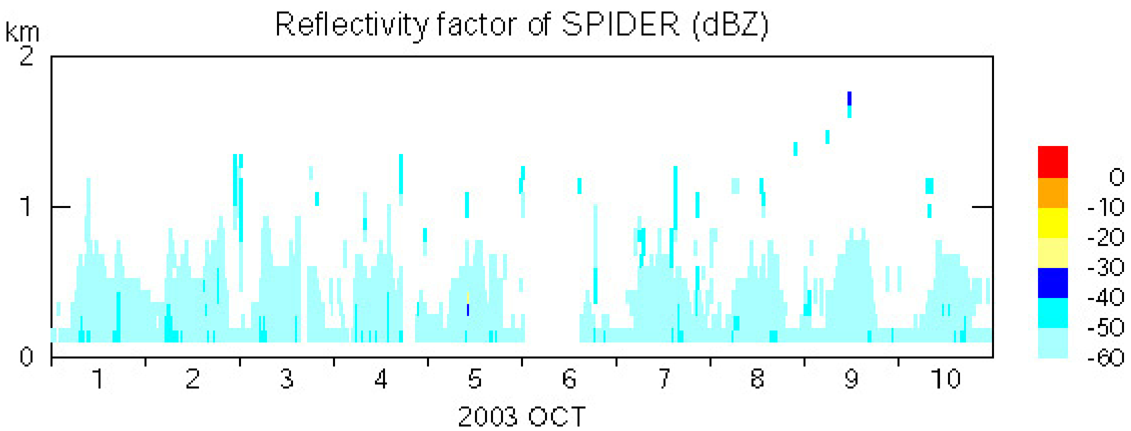

Fig.3: Same as Fig. 1, but hydrometer echoes of small LDR are removed.

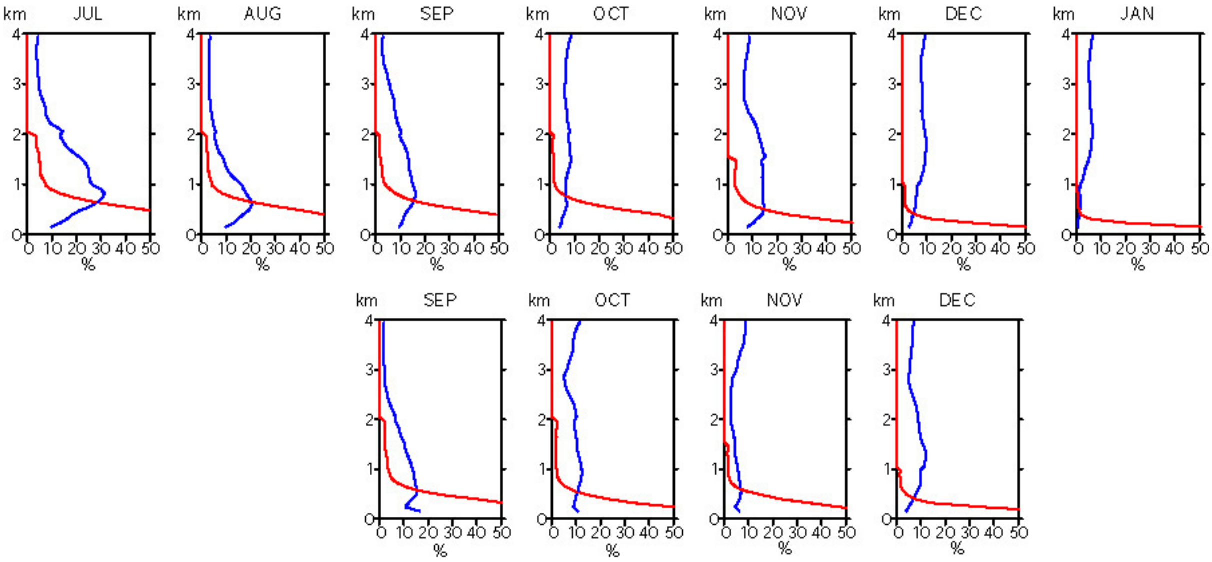

Fig.4: Appearance rates of hydrometer (blue) and non-hydrometeor (red) echoes in each month in 2003 (top) and 2004 (bottom)

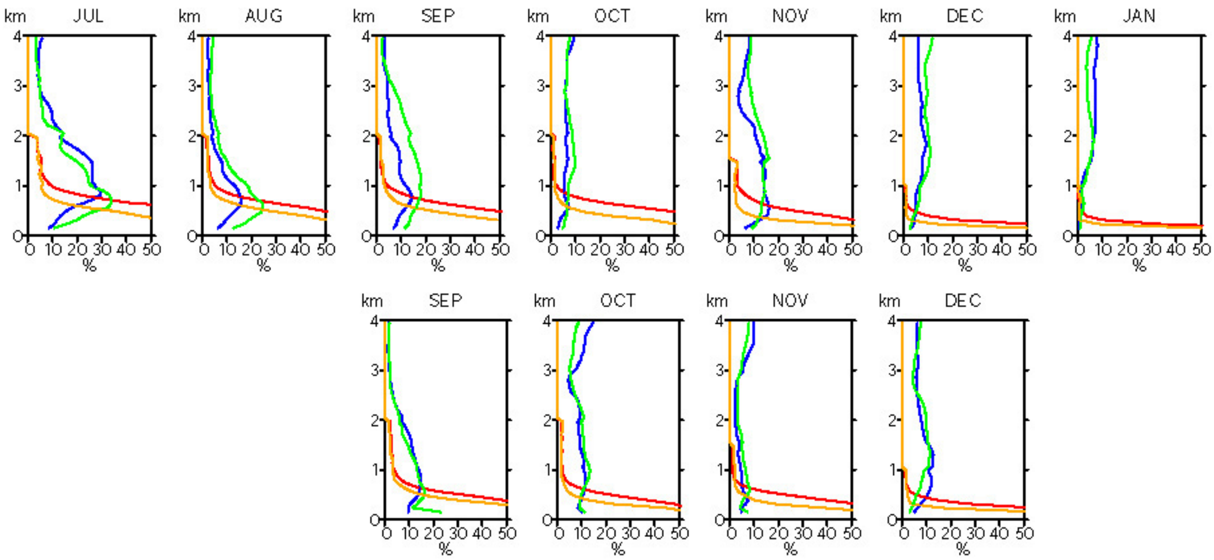

Fig.5: Same as Fig. 4, but Appearance rates of hydrometer echo in daytime (blue) in nighttime (green) and non-hydrometeor echo in daytime (red) in nighttime (orange) in 2003 (top) and 2004 (bottom)

5. AVAILABILITY OF DOPPLER VELOCITY OF NON-HYDROMETEOR ECHO

Fig. 6 shows the time-height sections of the radar reflectivity factor and the vertical Doppler velocity on 6 Oct 2003. The non-hydrometeor echo is seen from the surface up to 800 m. The top height of the echo rose around 5 LT and fell around 19 LT. The Doppler velocities show vertically coherent structure. Upward and downward motions were replaced in a period of a few tens minutes. Its Doppler speed shows large variability in daytime and small variability in night. These features seem to indicate convective motions in the boundary layer, which are similar to the convective boundary layer structure observed by airborne cloud radar in Oklahoma (Geerts and Miao 2005). Fig. 7 shows the same as Fig. 6, but on 9 Oct. From 6 to 18 LT, a non-hydrometeor echo appeared below 1 km. Its vertical velocities show similar upward-downward replacement. In the bottom, a time sequence of the vertical velocity at 400 m height is shown. Oscillations between upward and downward motions are clearly seen and their amplitudes increased from morning to noon and decreased from noon to evening. Around noon, upward and downward velocities exceeded 1 m/s.

If the velocities of the non-hydrometeor can be used as actual wind, the fine resolution of the W-band radar are very attractive for the boundary layer research. It seems that W-band radars can measure the lower boundary layer winds in daytime more stable than sodars or wind profilers, which have the noise problem and contamination of the ground clutter. Geerts and Miao (2005) pointed out that the vertical Doppler velocities of the non-hydrometeor echoes have some downward bias. A L-band wind profiler had been operated 400 m apart from the SPIDER site in the NICT. Comparing vertical velocities observed by the wind profiler, we will check the accuracy of the vertical speed obtained from non-hydrometeor echoes and show availability of those data.

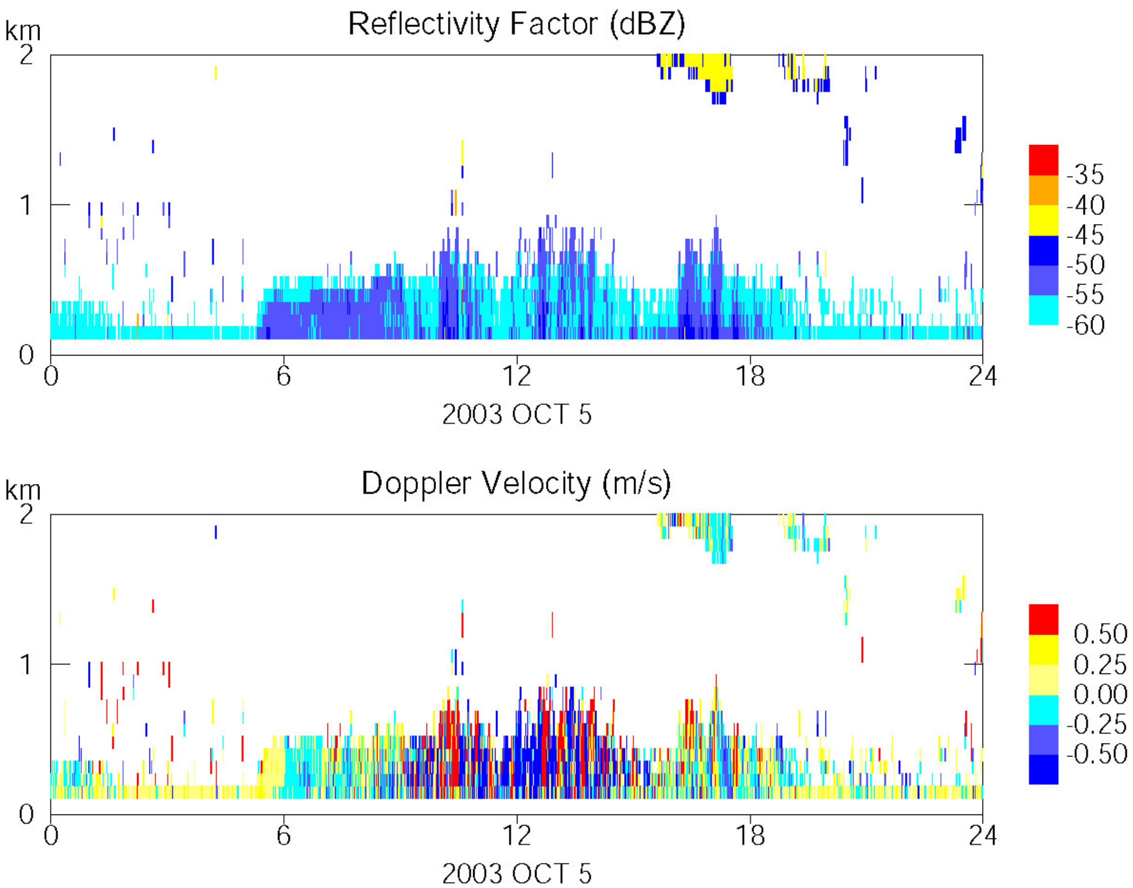

Fig.6: Time-height section of reflectivity factor (top) and vertical Doppler speed (bottom) observed by SPIDER on 5 October 2003.

6. REFERENCES

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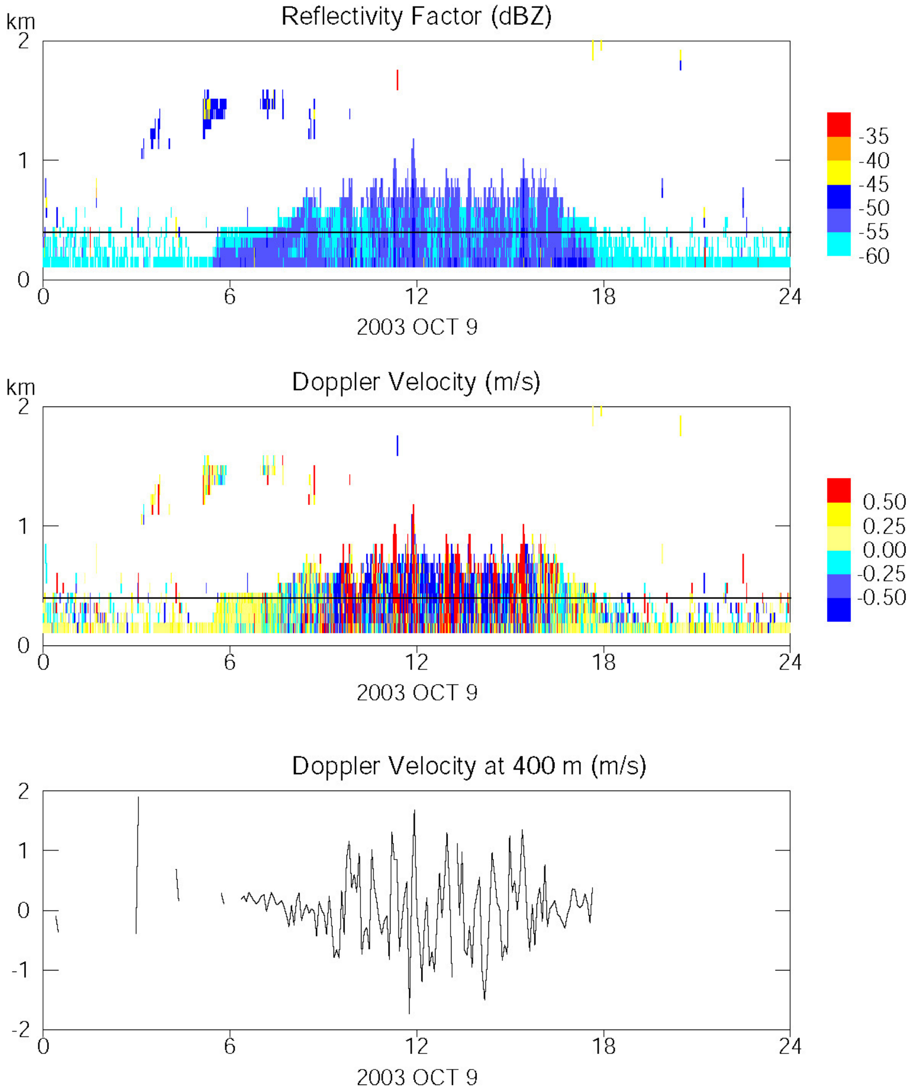

Fig.7: Time-height section of reflectivity factor (top) and vertical Doppler speed (middle) and time sequence of Doppler velocity at 400m (bottom) on 9 October 2003.