3.3 VERTICAL WIND OSCILLATION OBSERVED BY VERTICALLY POINTING W-BAND RADAR

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1. INTRODUCTION

Lhermitte (1988) showed that a vertically pointing W-band radar can measure vertical wind in rainy environment using Doppler spectra of rain. He used the dip of a rain echo spectrum as an index of the specific size of raindrops that corresponds to Mie resonance. The Doppler velocity of the dip in still air condition is obtained from a relationship between the drop-size and the fall velocity. The environment air velocity can be estimated from the discrepancy between observed Doppler shift of the dip and its velocity in still air. For example, in the case of 95 GHz radar, the diameter of the first minimum backscatter for Mie resonance is about 1.7 mm. The falling velocity of rain drop in still air corresponding to this diameter is 5.94m/s. We estimated vertical wind velocities using Lhermitte's method for several rain events observed from December 2002 to January 2003 in Tokyo.

2. CLOUD RADAR

A W-band (95.04GHz) cloud profiling radar called "SPIDER" was operated as a ground-based radar in a special container that has a radio-transparent window on the ceiling. In Dec 2002 and Jan 2003, SPIDER was operated at CRL, Tokyo and Doppler spectral data including a few rain events were obtained. On 3 and 4 January, FFT spectra of 128 points were obtained every 4.5 sec. Its Doppler resolution was 0.18 m/s and height sampling interval was 150 m.

3. RAIN EVENT ON 3 and 4 JAN 2003

A low pressure system with warm and cold fronts passed over Japan on 3 and 4 January 2003 and it brought rain around Tokyo area, which was especially strong at night. Fig. 1 shows the echo intensity and the Doppler velocity observed by SPIDER. Those parameters are derived from the peak intensity and its Doppler velocity. Light rain reached the ground at 10 JST on 3 Jan. The rapid change in the vertical velocity at 1 - 1.5 km is seen in Doppler velocity after 17 JST. This implies stratiform rain structure. A dip of Mie resonance wasn't recognized up to 20 JST because of the weak intensity of rain echo. The top height of the echoes reached from 4 to 8 km, but it dropped from 22 to 0 JST since upper cloud echoes were attenuated by rain at lower layer.

Fig. 2 shows time variance of Doppler spectra observed from 2040 to 2055 JST at a height of 450 m. Doppler spectra are drawn every one minute. All spectra have dips on rain echoes and their positions varied with time. The vertical line in the figure denotes the dip position in still air inferred from the theory. The dips shifted in the negative direction from the line at 2046-2047 and 2052-2053 means that downward vertical winds encouraged falling velocity of rain at these times. The dips shifted toward the positive direction at 2049-2051 implies significant upward wind.

Fig. 3 shows Doppler spectra change between 2300–2320JST. The spectral intensity of each Doppler velocity is shown by shades of color. You can find that not only the dip position but also all rain echo oscillated up and down, which means the oscillations were caused by the environmental vertical velocity. Oscillation of 2-3 minute period is dominant in Fig. 3.

Vertical winds were estimated using Lhermitte's methods from 20 JST on 3 Jan to 1 JST on 4 Jan. Fig. 4 shows the time series of vertical winds at every 150 m up to 1.5 km. Vertical winds were averaged every one minute. Below 1 km, vertical winds were measured almost continuously. Clear vertically coherent oscillations are seen in this figure, and their periods are in the 2-6 minute range. The height of the maximum amplitude was around 0.5 km and its amplitude reached 1 m/s. Since the oscillation was clear and periodic, it seems to be related to gravity waves. The vertical temperature profile that observed at the closest radiosonde station (TATENO) shows strong stable layer exist below 1 km, which support the existence of the gravity waves. We infer from the weather station and wind profiler observations, that there were cold air pool near the ground and the warm air intruded from the south overlaid cold air when the low pressure system passed Tokyo area.

In Fig. 3, the peak intensity seems to be stronger at the timing when the vertical wind changes from the downward to the upward. We will carefully investigate this relation using statistical methods.

4. CONCLUSION

Clear oscillations of vertical winds were observed when a low pressure system passed over the W-band radar on 3rd January 2003. These oscillations seem to be related to the gravity wave, which generated by the intrusion of warm air above cold air pool. We will validate this oscillation and understand its mechanism using other meteorological data.

Information of vertical wind is important for measuring accurate rain drop-size distributions from the vertically pointing radar. By comparing these data with data from a distrometer as well as a vertically pointing L-band radar, we will investigate the change in drop-size distribution affected by vertical air motions.

5. REFERENCES

R. M. Lhermitte, 1988: Observation of rain at vertical incidence with 94 GHz Doppler radar: an insight on Mie scattering, Geophys. Res. Lett., **15**, 1125-1128.

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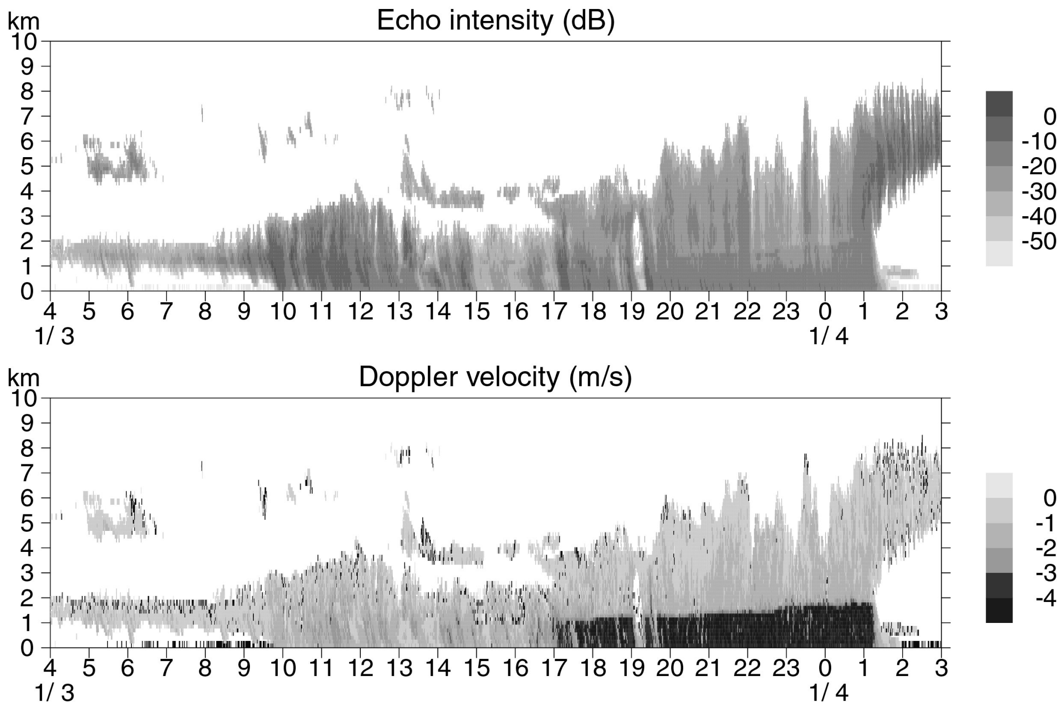

Fig.1 Time-height sections of echo intensity and Doppler velocity observed by SPIDER.

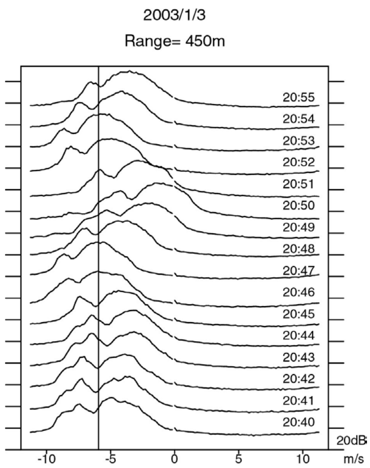

Fig.2 Doppler spectra at 450m height between 2040-2055

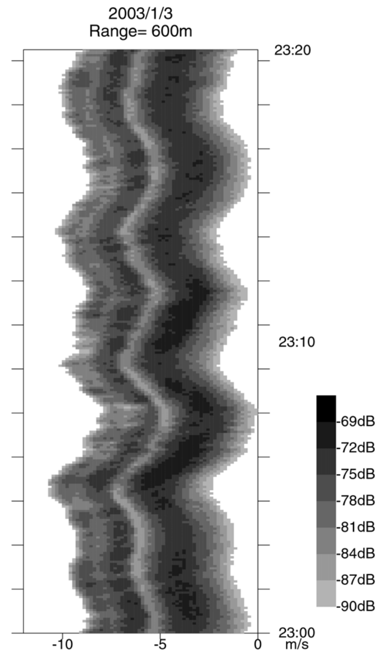

Fig.3 Time change of rain Doppler spectra at 600 m between 2300-2320 obtained by W-band radar

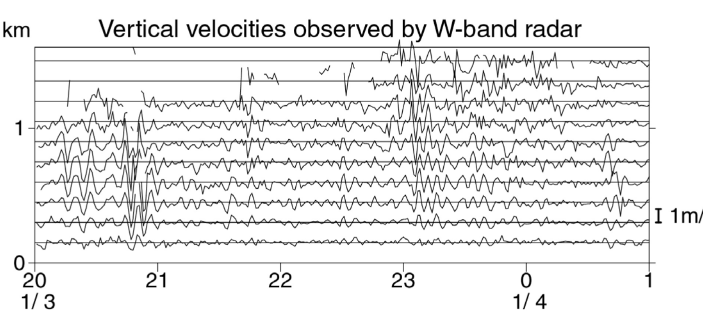

Fig.4 Time series of vertical wind estimated by W-band radar