Z-R RELATION FOR SNOWFALL USING TWO SMALL DOPPLER RADARS AND SNOW PARTICLE IMAGES

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1. INTRODUCTION

Radar measurements of precipitation are based on the relation between the radar reflectivity factor Z and precipitation rate R [1]. Z-R relationships for snowfall are complex compared to that of raindrops. In order to determine the Z-R relationship, Z and R have to be measured independently with high accuracy at short time intervals.

In this paper, a new system to measure physical snowfall parameters using two Doppler radars and image processing techniques is proposed. Snowfall rate was directly calculated by weighting the amount of snowfall, exploiting two high sensitive snow gages. Additionally, snow particle size distribution was obtained by image data and each particle was classified into snowflake or graupel. During this observation, the received power was measured using small bistatic X-band radar and monostatic K-band radar. The relationships between two band wave attenuations and snowfall rate were investigated and compared to the characteristics of snow particles.

2. MEASURMENT METHODS

2.1. Doppler radars

To measure the scattered power from snow particles having different velocity, two Doppler radars were used as shown in Fig. 1. The POSS (Andrew, Precipitation Occurrence and Sensor system) radar is a small solid state 10.525 GHz, 43 mW Doppler radar set developed by the Canadian Atmospheric Environment Service. The transmitter and receiver are separated by only 31 cm and tilted so that each antenna axis is 70 degrees from horizontal. The intersection of the two antenna beams is the sensing volume. A Doppler shifted frequency of 71

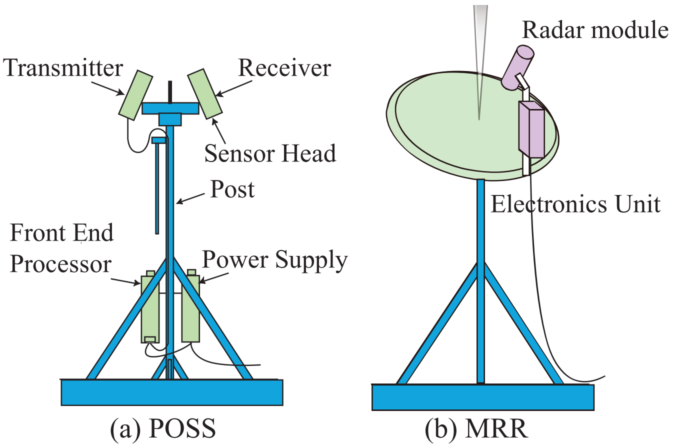

Fig. 1 Two Doppler radars.

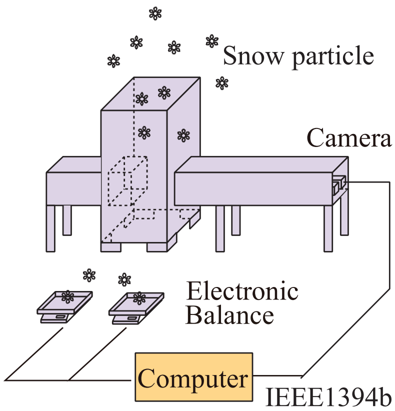

Fig. 2 Electric balances and image system.

Hz corresponds to a velocity component of 100 cm/sec. The power spectrum of the received power is recorded by a computer by an RS-232C serial connection. The MRR (METEK, Micro Rain Radar) is a compact 24GHz, FM-CW radar which uses an offset paraboloid antenna with a vertical beam orientation. Characteristic falling velocity divided into 30 range gates is derived from the backscatter intensity in each Doppler frequency. A Doppler shifted frequency of 160 Hz corresponds to a velocity component of 100 cm/sec.

2.2. Electric balances and image system

The snowfall rate is expressed as the equivalent water intensity resulting from melting of the snow particles. Using two high sensitive electronic balances, it is possible to measure the snowfall rate with high accuracy at short time intervals. The snowfall rate was directly calculated by weighting the amount of snowfall exploiting two high sensitive snow gages and taking the average of data per minute.

The imaging system is outlined in Fig. 2. In order to protect falling snow particles from wind and sunlight, a tower was constructed [2]. Images of snow particles were photographed using a CCD camera (1280 x 960 pixel) with 1/10000 s shutter speed. Measurement of size and classification of snow particles were obtained by image processing. The particle size was determined by an area equivalent diameter. The data was recorded in every minute.

3. MEASUREMENT RESULTS

3.1. Radar reflectivity Z

The analyzed data was observed in Kanazawa during January and February, 2009. In this paper, the presented case was on February 16th from a total of 9 days of snowfall. Kanazawa was covered with snow on February 16, 2009, due to a wintry atmospheric pressure pattern.

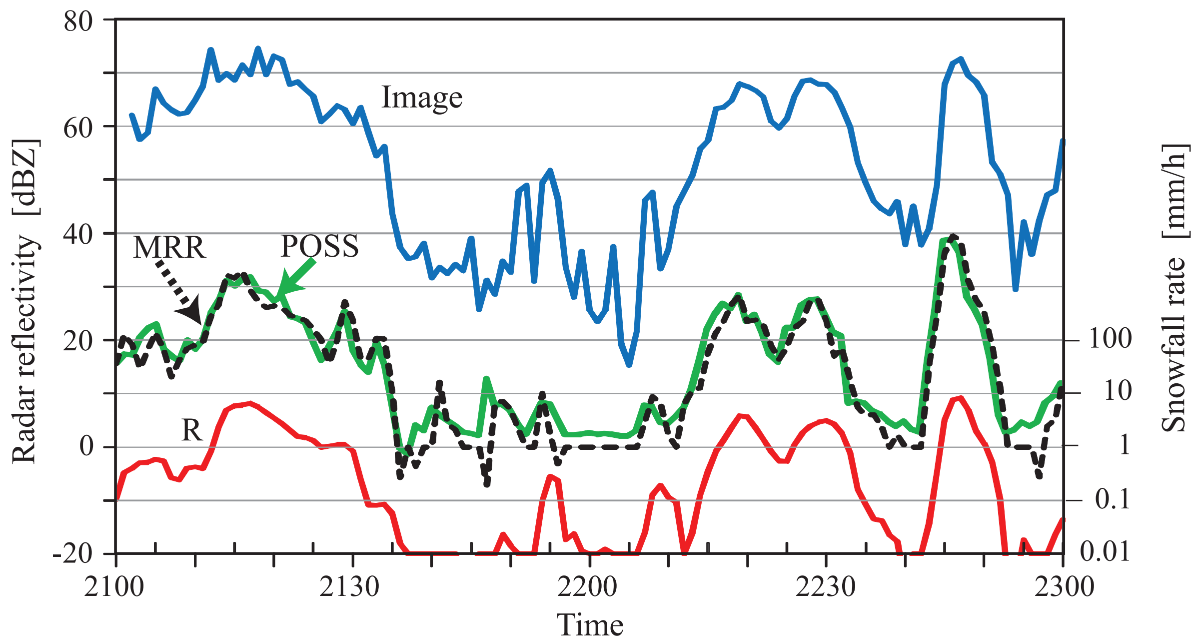

Fig. 3 Time series of radar reflectivity Z and snowfall rate R.

Time series of POSS and MRR radar reflectivity are shown in Fig. 3. The MRR reflectivity is the average of the 2 lowest cells, 35m and 70m in height. Although two radars operated in a different wave length, the average data of MRR fairly corresponds with the radar reflectivity of POSS. The correlation between the POSS and MRR is 0.95 in Fig. 3. Therefore, it seemed to be useful for POSS and MRR to assume Rayleigh approximation.

Using image data, it is possible to calculate the radar reflectivity Z, assuming Rayleigh scattering and discrete data [3]. It is given by

$$Z = \sum_i N_i D_i^6 \qquad (1)$$

where N_i is the number of particles having equivalent spherical diameter D_i. The radar reflectivity for image data is shown in Fig. 3. In this equation, there is a problem with the diameter D_i. In the case of rain, the diameter of a rain drop is unique. Although a snow particle has the cross-section diameter D_i, which is measured by image processing and the melted diameter. Since the D_i is larger than the melted diameter, Z of image data is much larger than those of POSS and MRR.

Fig. 4 shows the relation for radar reflectivity Z between POSS and image data. Exploiting the image processing, all particles for each snowfall event were classified into snowflake or graupel. If either snowflake or graupel was dominant over 80%, we identified the period as the snowflake or graupel event. In Fig. 4, graupel event was observed from 22:43 to 22:47 and snowflake events were in 21:00 – 22:42 and 22:48 – 23:00. It can be observed that the distribution pattern for a graupel event was different from that of snowflake events. It was shown that the density of a graupel is smaller than that of a snowflake.

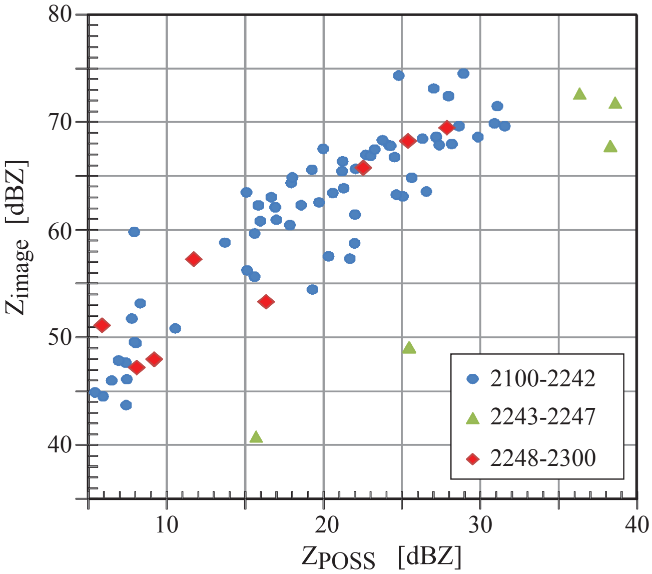

Fig. 4 Radar reflectivity using POSS and image data.

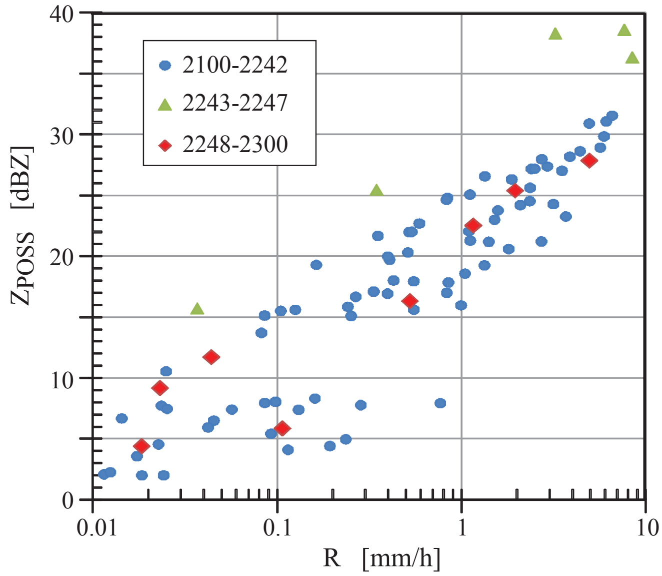

Fig. 5 Z-R relation.

3.2. Z-R relation

Fig. 5 shows Z-R relation in the same period as Fig. 3 and 4. It was known that the distribution pattern for a graupel event was different from that of snowflake events. The coefficients of B and β for the Z-R relation, that is $Z=BR^{\beta}$, were calculated in Fig. 5. There were $Z=1000R^{0.95}$ for a graupel event and $Z=158R^{1.10}$ for snowflake event.

4. CONCLUSION

A new system for the simultaneous measurement of snowfall rate using two electric balances and radar reflectivity of two radars was developed for a long time. To distinguish the Z-R relation for graupel and snowflake, there were also analyzed snow particle images using image processing and automatically classified into graupel or snowflake event. Characteristic falling velocity was measured from the backscatter intensity of POSS in each Doppler frequency. Moreover, the vertical profile of radar reflectivity was obtained by MRR. Using our method, it was useful to understand the Z-R relation of individual snowfall event.

5. REFERENCES

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