FIELD EXPERIMENT FOR GPM GROUND VALIDATION USING THE DUAL KA-RADAR SYSTEM

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1. INTRODUCTION

Global Precipitation Measurement (GPM) started as an international mission and follow-on mission of the Tropical Rainfall Measuring Mission (TRMM) project to obtain more accurate and frequent observations of precipitation. Japan Aerospace Exploration Agency (JAXA) is in charge of developing GPM/Dual-frequency Precipitation Radar (DPR) algorithms as the sensor provider and producing and delivering hourly global precipitation map to make useful for various research and application areas. In order to secure the quality of precipitation estimates, ground validation (GV) of satellite data and retrieval algorithms is essential.

End-to-end comparisons between instantaneous precipitation data observed by satellite and ground-based instruments are not enough to develop and improve the algorithms. In order to estimate the error of various physical parameters in the precipitation retrieval algorithms of DPR, we have started to conduct intensive observations using several instruments for measuring precipitation. DPR algorithm estimates particle size distribution (DSD) parameters of precipitation using the difference of scattering and attenuation feature. The equivalent reflectivity factors (Ze) and attenuation factors (k) are independently calculated in the algorithm. The characteristics of the Mie scattering effect and attenuation of the actual precipitation particles for radar beams are essential for construction of the DPR algorithm, especially for Ka-band. The folding observation of two ground-based Ka-band radars can directly measure Ze and k regardless of solid and liquid phase.

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2. KA-RADAR SYSTEM

The simultaneous observations using the two Ka-radars and precipitation particle observation systems will provide the combination of the information of the precipitation particles and scatter and attenuation. This idea has been proposed by Li et al. (2001), Srivastava and Tian (1996), and Tian and Srivastava (1997).These information are very useful for the development of DPR and GMI algorithms as scattering tables. Ka-radar observation with C/X-band radar can verify the dual-frequency algorithm of GPM/DPR.

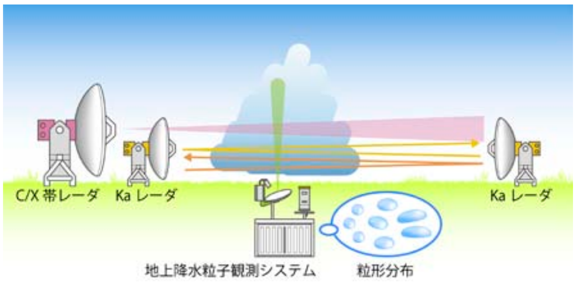


Fig. 1 The concept of the simultaneous observations using the two folding Ka-radars, X/C-band radar and precipitation particle observation system

JAXA has developed a dual Ka-band radar system for the GPM/DPR algorithm development to detect the scattering characteristics of Ka-band by precipitation particles and validate and evaluate DPR algorithm. This system consists of two identical FMCW type Ka-band radars. In order to achieve the folding observation, the radars need to satisfy the following conditions:

(1) to observe the precipitation echo between the long distance,
(2) to detect the weak echo with the attenuation by precipitation particles, and
(3) to avoid the radio wave interference each other and the ground clutter.

The volume scanning capability is not the primary requirement, and the radar has only a limited capability for steering the antenna. For the elimination of the ground clutter, sharp beam width and low sidelobe level are needed. Two off-set parabolic antennas for transmission and reception are applied. At the folding observation of two radars, a main lobe beam is directly encountered to each other, so the transmitting power for transmission should be low enough to avoid the damage of the receiver in the other radar. High range resolution is needed for comparison between radar reflectivity and in situ observation. For these purposes we adopted the Frequency-Modulated Continuous Wave (FMCW) type radar system with travelling-wave tube amplifier (TWTA). As the result, the basic requirements of the radar are:

- observation range: more than 15 km,
- minimum detectable reflectivity: -20 dBZ at 10 km from the radar,
- sidelobe level: less than -22 dBZ
- Nyquist velocity: 10 m/s
- beam width: 0.58 degree
- different transmission time between the two radars using GPS

Table 1. Major specifications of the Ka-band radar

Radar type	FMCW type
Frequency	35.25 GHz
Antenna	Two 1.2 mϕ offset parabolic antennas
Beam width	0.6 degrees
Transmitter	TWTA
Transmitting power	100W
Sensitivity	-20 dBZ at 10 km
Minimum range resolution	12.5 m
Minimum observable range	< 500 m
Maximum observable range	15 km/30 km
Doppler velocity range	< 10 m/s
Data	Averaged Z, Doppler velocity and width, raw I, Q, etc

Fig. 2. Outlook of the Ka-radar with the beam 45 degree elevation

The performance is shown in Table 1 and the outlook of the radar is shown in Fig. 2. This radar has four observation modes (normal, fine resolution, long range and high sensitivity) with several pulse repetition intervals and numbers of sweep for averaging, observation ranges and range resolutions as shown in Table 2. High sensitivity mode is prepared for the achievement of requirement to minimum detectable reflectivity: -20 dBZ at 10 km from the radar

Table 2 Observation modes

Mode	Pulse repetition interval [μsec]	Number of sweep	Observation range [km]	Range resolution [m]
Normal	200	256	15	50
		512		
	400	256		
Fine resolution	200	256	15	12.5
		512		
	400	256		
Long range	300	256	30	50
		512		
	400	256		
High sensitivity	300	256	15	250

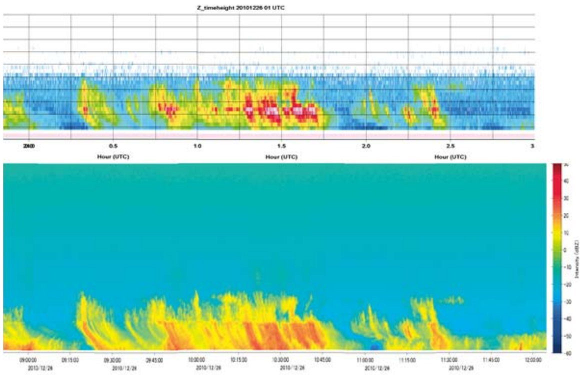


Fig.2. Time-height cross sections of a C-band radar (upper) and the Ka-radar (lower)

3. SYSTEM EVALUATION

The system evaluation was performed by comparing with other radar or ground-based rain measuring instruments. Figure 3 shows time-height cross sections of vertical profiles of C-band radar and Ka-band radar reflectivity for an example of a comparison with a C-band precipitation radar. In this case, a Ka-radar was at the C-band radar site. Except near range where the C-band radar has poor sensitivity, the cross sections are similar. Figure 4 shows the scatter diagram of the radar reflectivity of both radars at a range of 2 km. The correlation is good and the dynamic range of more than 60 dB is attained. Figure 5 is another comparison result with a ground-based disdrometer. Again, the correlation is reasonable showing the good performance of the Ka-radar.

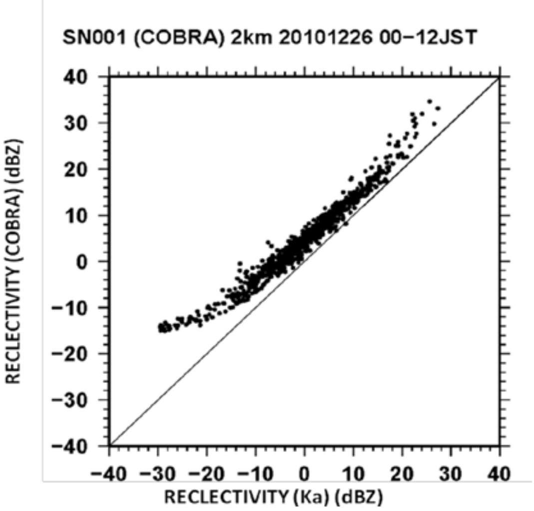


Fig. 4. Scatter diagram of radar reflectivity by a Ka-radar and C-band radar.

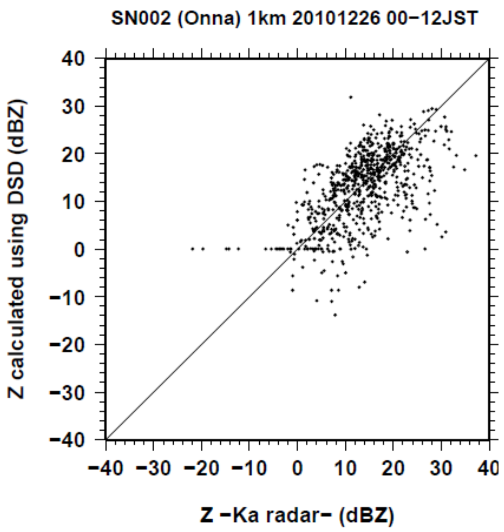
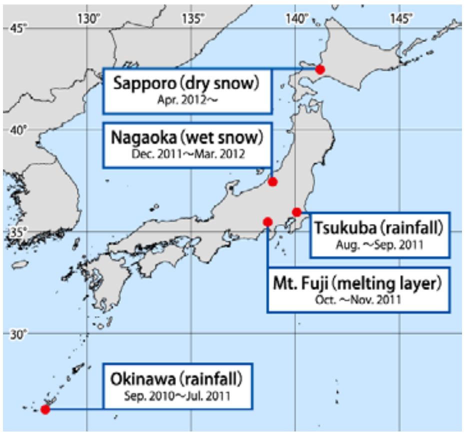


Fig. 5. Scatter diagram of radar reflectivity by a Ka-radar and a disdrometer.

4. Experiments using dual Ka-radar

Figure 6 shows the observation sites for validation of GPM/DPR in Japan. Five observation sites are prepared for the DPR algorithm validation targeted to several types of the precipitation (rain, dry snow, wet snow and melting layer) using the Ka-radars in Okinawa, Tsukuba, Mt. Fuji, Nagaoka and Sapporo before the launch of the GPM-core satellite in 2013.



We started to conduct the intensive observation in Okinawa Island using the Ka-band radars and a mobile precipitation particle observation system for system evaluation and rain observation. We confirmed that the both Ka-radars satisfied the established specifications for the algorithm validation activity. The comparison reflectivity value of the Ka-band radars with that of the C-band radar of National Institute of Information and Communications Technology (NICT) and disdrometer indicated good correlation.

5. Summary

A dual Ka-radar system has been developed for the GPM DPR algorithm development. The performance of the system was confirmed by the system check, comparisons with a C-band radar, and ground-based rain observation instruments, such as, a disdrometer. The observation is dual-observation mode and also a different direction mode. The data analysis is ongoing. After the observation in Okinawa Island, rain observation in extratropical region was conducted in Tsukuba and then melting layer observation at the slope of Mt. Fuji is scheduled. This observation at Mt. Fuji is very unique but challenging. The data on the melting layer which has complicated precipitation particles will be invaluable.

Acknowledgments

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