Application and analysis of the radar precipitation estimation over the South Korea

Mi-Kyung Suk*, Jeong-Hee Kim, Kyung-Yeub Nam, Ki-Ho Chang

National Institute of Meteorological Research/KMA

1. Introduction

Rainfall estimation based on meteorological radar data is one of the intensely studied topics. Challenge is to obtain an accuracy, high-resolution, extended rainfall-intensity and accumulation maps by the radar data. These maps provide the essential information for a variety of hydrological applications, such as estimating and forecasting floods, stream-flow, and water budget (Morin *et al*., 2003).

Korea Meteorological Administration (KMA) had applied the stratiform Z-R relationship of $Z=200R^{1.6}$ for all cases of precipitation until 2005. However, such as the fixed Z-R relationship is not suitable particularly in case of the convective type rainfall events in summer in Korea. Therefore, the KMA has developed a system estimating the quantitative precipitation by adjusting the weather radar data by the ground rain gage data from 2006. This system was named the Radar-AWS Rainrate (hereafter "RAR"). The RAR system determines the Z-R relationship using Z-R pairs applied Window Probability Matching Method (WPMM; Rosenfeld et al. 1994; Morin et al. 2003) theory about rain rates(R) of rain gauges within radar coverage and reflectivity (Z) of operated 11-radars at KMA, and then estimates the quantitative precipitation in radar and merges the composited rainfall field over the South Korea.

In this study, the application of the bias correction in real-time for the improvement of RAR accuracy is examined the radar and the raingauge precipitation and analyzed for the accuracy of these radar precipitation estimations.

2. Study area

The location of the rain gauges and radars is represented in Fig. 1. The total number of rain gauges is 642 and that of radars is 11 over the South Korea. The spatial distribution of raingauges is not even between the rural areas and cities in the South Korea. The number of rain gauges at radars located in inland such as Gwanaksan, Gwangdeoksan and Myeonbongsan is over 300, whereas those located in cosatal area such as Backryngdo, Gosan and Sungsanpo is under 200.

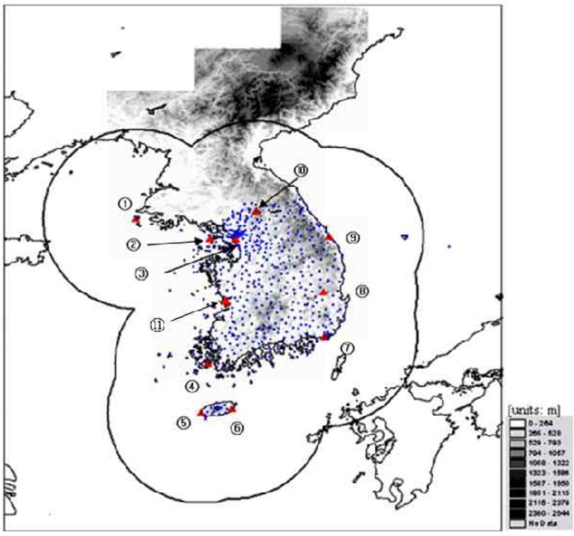

Fig.1 Locations of the rain gauges (small circle) and radars (triangle).The solid line denotes the coverage composite of radars. ((1) Backryungdo, (2) Incheon, (3) Gwanaksan, (4) Jindo, (5) Gosan, (6) Sungsanpo, (7) Busan, (8) Myeonbongsan, (9) Donghae, (10) Gwangdeoksan, (11) Osungsan)

3. Algorithm of the RAR system

The RAR system in real-time consists of the following four steps: 1) the quality control of the volumetric reflectivity and the production of its 1.5-km CAPPI (Constant Altitude Plan Position Indicator) of each radar, 2) the 10-min average of the pixel-based rainrate of rain gauges within the radar observation area, 3) the hourly Z-R computation by the minimization the difference between the 10-min CAPPI and raingage rainrate during one latest hour and the rainfall estimation updated at each 10 minutes, and 4) the composition of the 11-radars estimated rainfall data (Fig. 2).

Corresponding author address: Mi-Kyung Suk, National Institute of Meteorological Research /KMA, Seoul 156-720, South Korea. E-mail: mksuk@kma.go.kr

3.1. The processing of the radar data

The radar reflectivity of the RAR system uses the operated and measured data in KMA. The radar data have been obtained in 11 sites of Backryungdo, Incheon, Gwanaksan, Jindo, Gosan, Sungsanpo, Busan, Myeonbongsan, Donghae, Gwangdeoksan. The measurement range is 130 km in Incheon site, 200 km in Myeonbongsan, 240 ~ 256 km in the others sites. The processing of the radar reflectivity data is summarized as follows: 1) The radar data is recorded in the volume data every 10-min., 2) The radar volume data goes through the processing of the quality control (QC) to remove the non-meteorological echo (Zhang, 2004). The QC algorithm removes non-meteorological echo like that spot echo, line echo, sun strobe, second trip echo, ground clutter, sea clutter(Collier, 1996), Anomalous Propagation (AP; Battan, 1973), and 3) The reflectivity is calculated as the CAPPI (Constant Altitude Plan Position Indicator) of 1 km × 1 km grid resolution at 1.5 km altitude by Mohr's interpolation method (Mohr, 1979).

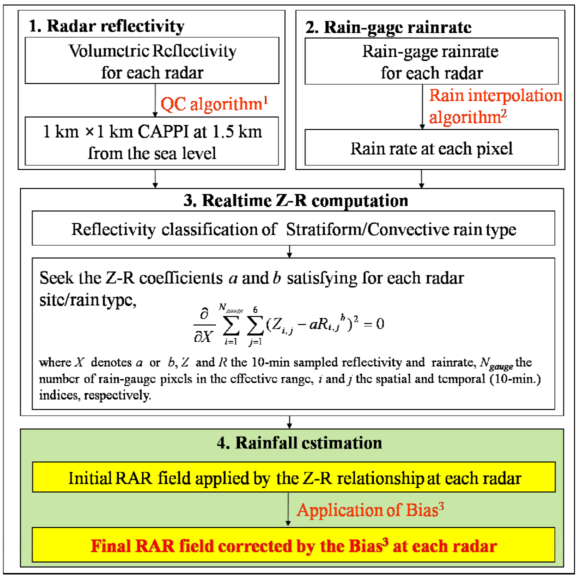

Fig. 2 Steps for the RAR (Radar-AWS-Rainrate) system.

3.2. The processing of the rain gauge data

The rainfall is obtained from the 642 Automatic Weather Stations (AWS) including the 0.5 mm tipping-bucket raingage over Korea area. The tipping bucket rain gauges save the measurement data accumulated rainfall every 1 minutes. The rain interpolation algorithm generates the hourly rain rates from discrete tipping bucket rain gauge data by applying an interpolation algorithm (NASA, 2003).

3.3. Z-R relationship computation

This system needs the Z-R relationship to estimate the real-time (updated by the hourly radar reflectivity at each 10 min.) radar rainrate. To reduce the spatial and temporal sampling error of radar reflectivity, we adopt the window probability matching method (WPMM) matching the Z to the R (Rosenfeld *et al.* 1994, Morin *et al.* 2003). For each rain gauge in each radar, one value of Z is selected among 9 reflectivities around the rain gauge (3×3 grids) to have the minimum difference between them and the rain-gauge value (Fulton, 1999). Temporally, the corresponding Z value is determined as one satisfying to minimize the Z-R difference among the 6 spatially selected Z values during the latest one hour. These Z-R pairs computed are aggregated within 100 km range of each radar for efficiency. Finally, the coefficients of Z-R relationship are computed for each radar at each 10 minutes from the WPMM-sampled Z-R pairs. We derive the Z-R coefficients by the best-fit power law curve using the least square fitting method (Rosenfeld *et al*. 1994; Rosenfeld *et al*. 1998; Morin *et al*. 2003).

3.4. Bias correction

The bias between the rain-gauge and radar estimated rainfall is corrected for a radar in real time. The real-time bias correction of RAR is conducted at each 10 minutes for each radar by making the bias (B), where G is the sum of the 10-min accumulated rain-gauge rainfalls and R is the sum of the radar estimated rainfall over the corresponding radar within the effective range, to unity.

3.5. Merging of estimated rainrates

The 11 single-radar estimated rainrates obtained from the Z-R computation is merged over the South Korea region. The averaged merging method is adopted for the radar overlapped region to produce the radar rainfall field.

4. Analysis results

4.1. Case study

We examine to improve the accuracy of radar rainfall for heavy rainfall case in 18 Jun., 2008. Fig. 3 shows the distribution of radar rainrates by no bias-correction and bias-correction against raingauge rainrates for KSN site located in the central area of South Korea on 0250 LST 18 Jun., 2008. Comparing with the no bias-corrected and bias-corrected results, bias-corrected result close to the raingauge rainrates and reduce the overestimation of no bias-corrected results. Fig. 4 shows the accumulated rainfall of raingauge and KSN radar by no bias-correction (EXP0) and bias-correction (EXP1) over the South Korea during 18 Jun. 2008. For the flash rainfall increasing from 0000 LST to 0400 LST, the radar rainfall by no bias-correction causes the overestimation. But the radar rainfall by the bias-correction reduces the overestimation and underestimation against the raingauge rainfall during 18 Jun. 2008.

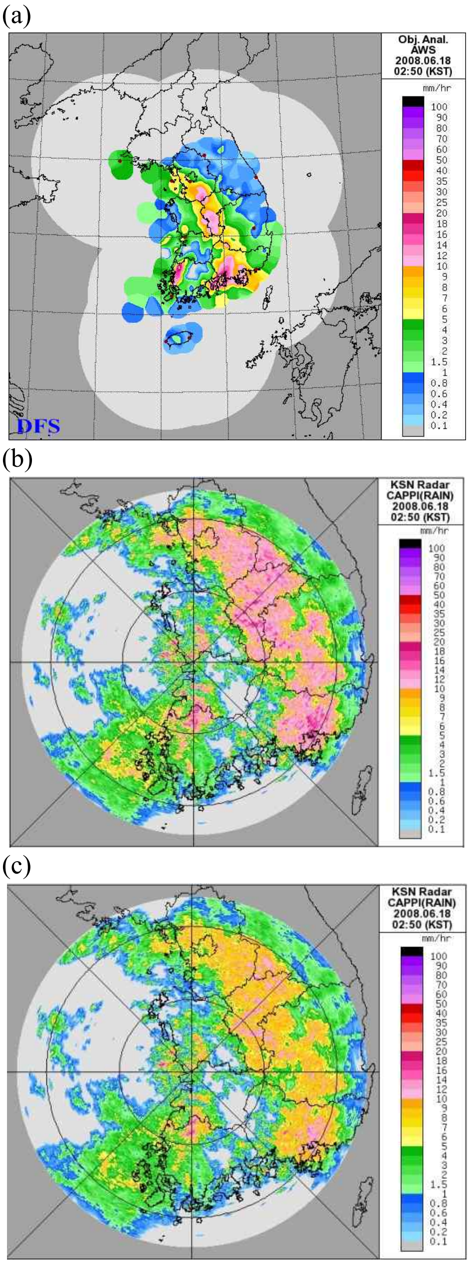

Fig. 3. Rainrates of (a) raingauge, the estimated KSN radar site applied by (b) no-bias correction and (c) bias correction for KSN radar site on 0250 LST 18 Jun., 2008.

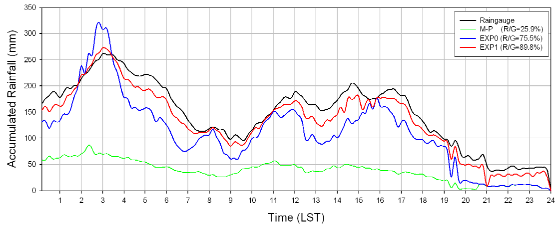

Fig. 4. Accumulated rainfall (mm) of raingauge and KSN radar by M-P Relationship ($Z=200R^{1.6}$), no-bias correction (EXP0), bias-correction (EXP1) during 18 Jun., 2008.

4.2. Verification and assessments

It is calculated for the verification and the assessment of the RAR system and the improvement ability of accuracy of the bias-correction algorithm during summer (Jun. – Aug.) 2008. The verification result of RAR system for KMA radars located in inland shows the improvements of the performance for the application of the bias-correction algorithm (Table 2). And the accuracy of the composited radar rainrates field against raingauge rainrates is verified in Table 3. Radar rainrates applied by the bias-correction algorithm improve the R/G (=Radar/RainGauge) of 8 % and the mean error of 0.44 mm/h about the underestimation of the no bias-correction. Threshold

*Table 2. Verification results of every 10-min. between raingauge rainrates and the sites radar rainrates by no bias-correction and bias-correction during Jun. − Aug. 2008 (**unit =mm/h).*

Site name	No Bias-correction					Bias-correction				
	AWS Mean**	Radar Mean**	Mean Error**	RMSE**	R/G (%)	AWS Mean**	Radar Mean**	Mean Error**	RMSE**	R/G (%)
JNI	5.28	4.32	-0.96	6.95	82	4.95	4.28	-0.66	6.25	86
KSN	4.73	3.64	-1.09	5.85	77	4.77	4.01	-0.76	6.08	84
PSN	4.93	3.89	-1.04	6.04	79	4.91	4.02	-0.88	5.95	81
KWK	4.40	3.56	-0.48	5.24	81	4.53	3.53	-0.99	4.96	78
GDK	4.97	3.97	-1.0	5.80	80	4.51	3.80	-0.71	5.52	84
MYN	4.89	3.66	-1.23	5.97	75	4.86	3.71	-1.15	5.41	76
IIA	4.64	3.66	0.98	4.31	79	4.67	4.08	-0.59	4.70	87

Table. 3. The verification results of every 10-minute between the raingauge rainrates and the composited radar rainrates by no bias-correction and bias-correction during Jun. – Aug. 2008.

	No Bias-correction	Bias-correction
AWS Mean(mm/h)	4.49	4.49
Radar Mean(mm/h)	3.59	4.04
Mean Error(mm/h)	-0.9	-0.46
RMSE(mm/h)	5.38	5.75
R/G(%)	80	88

for the verification is 0.1 mm/h about the raingauge rainrates.

5. Summary

Radar-AWS Rainrate (RAR) system is operated using radar and raingauge (AWS) to estimate the quantitative precipitation by NIMR/KMA over the South Korea from 2006. This study examines the application of the bias correction algorithm to the estimation of radar rainrates in real-time for from Jun. to Aug., 2008 about each radar site and composited radar field of KMA 11-radars. The results of the bias-correction algorithm compared with no bias-correction improve the accuracy and reduce the overestimation and underestimation of precipitation against raingage rainrate.

Acknowledgment

This work was supported by the "Meteorological Observation Technology and its Application" of National Institute of Meteorological Research (NIMR), funded by the Korea Meteorological Administration (KMA).

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