# Analysis of Radar Rainfall Estimation Accuracy using Hybrid Surface Rainfall (HSR) Technique

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(Dated: 18 July 2014)

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## 1 Introduction

The role of weather radar with high spatial and temporal resolution is increased to observe and forecast the meteorological disaster. High resolution radar data contributes to the short-range forecast by monitoring and tracing the torrential rain, hailstone and typhoon, etc.  KMA (Korea Meteorological Administration) operates 11 single and dual-pol. radars to cover the Korean Peninsula. However, due to the nature of weather radar, limited observation area is occurred by the ground clutter beam-blockage. Especially, most radars in Korea experience significant blockage of radar beam even at the lowest antenna level due to our nation's geographical features whose territory consists of more than 70% of mountainous areas

Therefore, KMA has been applied the HSR (Hybrid Surface Rainfall; Maddox et al., 2002, Chang et al., 2009) systems for quantitative rainfall estimation to minimize the effect of radar beam-blockage. HSR technique is widely used to utilize reflectivity measurements from as close to 1km altitude as possible while minimizing the likelihood of ground clutter and data loss due to terrain blockages (Fulton et al., 1998).  This study accounts for the HSR technique of KMA, and shows its performance by analyzing 3 rainfall cases for 3 radar sites in Korea.

## 2 Data and Method

### 2.1 Data

For this study, it is used the Gwanaksan (KWK), Gwangdeoksan (GDK), Osungsan (KSN) single polarization radar sites for HSR analysis. Table 1 represents the information of elevations, antenna heights, observing ranges of those 3 radar sites. To evaluate the accuracy of HSR technique for radar rainfall estimation, 3 substantial rainfall cases caused by Changma front, local heavy rainfall and typhoon are selected such as Table 2. Figure 1 represents the locations and ranges of the 3 radar sites and the accumulated rainfall distributions for each rainfall case during the analyzed period which were observed by about 640 Automatic Weather Station (AWS) over Korean Peninsula. Heavy rainfall regions above 200 mm are found during the rainfall events.

*Table 1 Elevations, antenna heights and ranges of radar sites of KMA.*

| Site name | Elevations (°) | Antenna Heights (km)/Ranges(km) |
|---|---|---|
| Gwanaksan (KWK) | 0.0, 0.4, 0.8, 1.2, 1.6, 2.0, 3.0, 4.2, 5.7, 7.5, 9.8, 12.5, 15.8 | 0.641 / 240 |
| Gwangdeoksan (GDK) | 0.0, 0.1, 0.2, 0.3, 0.6, 1.0, 1.7, 2.8, 4.6, 7.6, 12.3, 20.0 | 1.064 / 250 |
| Osungsan (KSN) | 0.5, 0.69, 0.89, 1.09, 1.5, 2.0, 2.59, 3.5, 4.59, 6.0, 7.89, 10.5, 13.8, 18.19, 24.0 | 0.232 / 240 |

*Table 2 Selected dates and rain systems.*

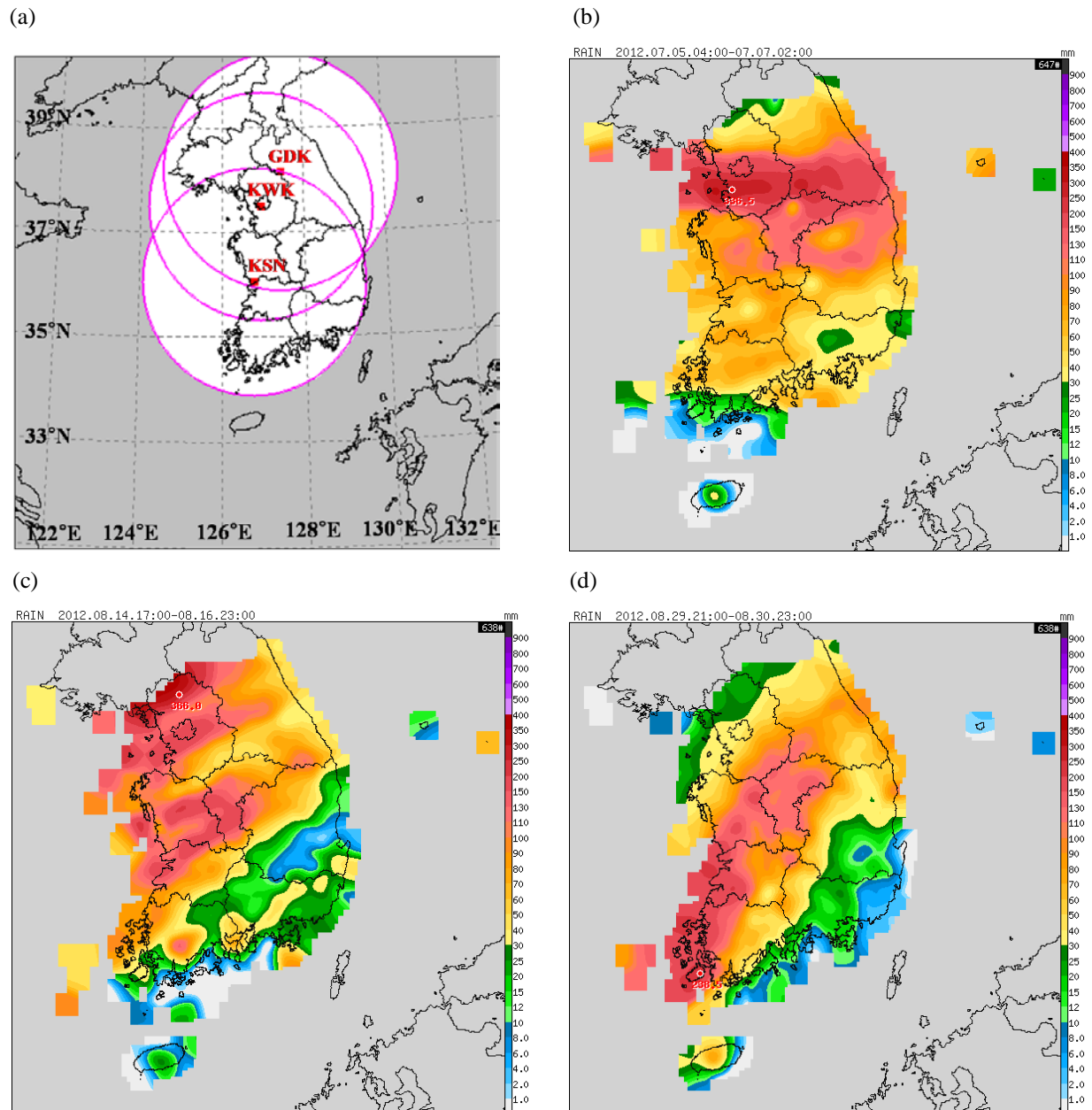| CASE | Dates of cases | Rain systems |
|---|---|---|
| CASE I | From 0400 LST July 5 to 0200 LST July 7 | Changma front |
| CASE II | From 1700 LST Aug. 14 to 2300 Aug. 16 | Locally heavy rainfall |
| CASE III | From 2100 LST Aug. 29 to 2300 LST Aug. 30 | Typhoon |

*Figure 1: (a) observation coverages of GDK, KWK, KSN radar sites("■" symbols represent the location of radar site),and the accumulated rainfall distribution over the Koean Peninsula for(b) CASE I, (c) CASE II, (c) CASE III .*

## 2.2    Method

The procedure to apply the HSR technique for the estimation of rainfall is composed of 5 steps; First, generate the HSR (beam-blockage) mask (beam-blockage ratio ≥ 90 %, ground clutter ratio ≥ 20 dBZ) using the radar variables. Second, alter a radar elevation using a Fuzzy QF (Quality Factor) (QF ≤ 0.5). Third, rearrange bin and ray values of the HSR mask to match with data format of all weather radar. Forth, generate the HSR reflectivity map using a HSR mask. Finally, estimate the rainfall ($Z=200R^{1.6}$) using the HSR reflectivity map.

Figure 2 represents the HSR masks which show the measurable lowest elevation angles for KWK, GDK, KSN radar site. From Figure 2(a), KWK radar site is able to measure the lowest elevation in the west part of radar center but, there are beam-blockages of lowest elevation in the east part due to ground clutter. From Figure 2(b), GDK radar site are many beam-blockage region and it is high the measurable lowest elevations due to high mountain area. Compared to the other 2 sites, the blockage area of radar beam at the KSN radar site (Figure 2c) are relatively narrow because the KSN radar site is located in shore and the mountain areas are little near the KSN radar site as compared with GDK radar site. These HSR masks are used for the estimation of radar rainfall.
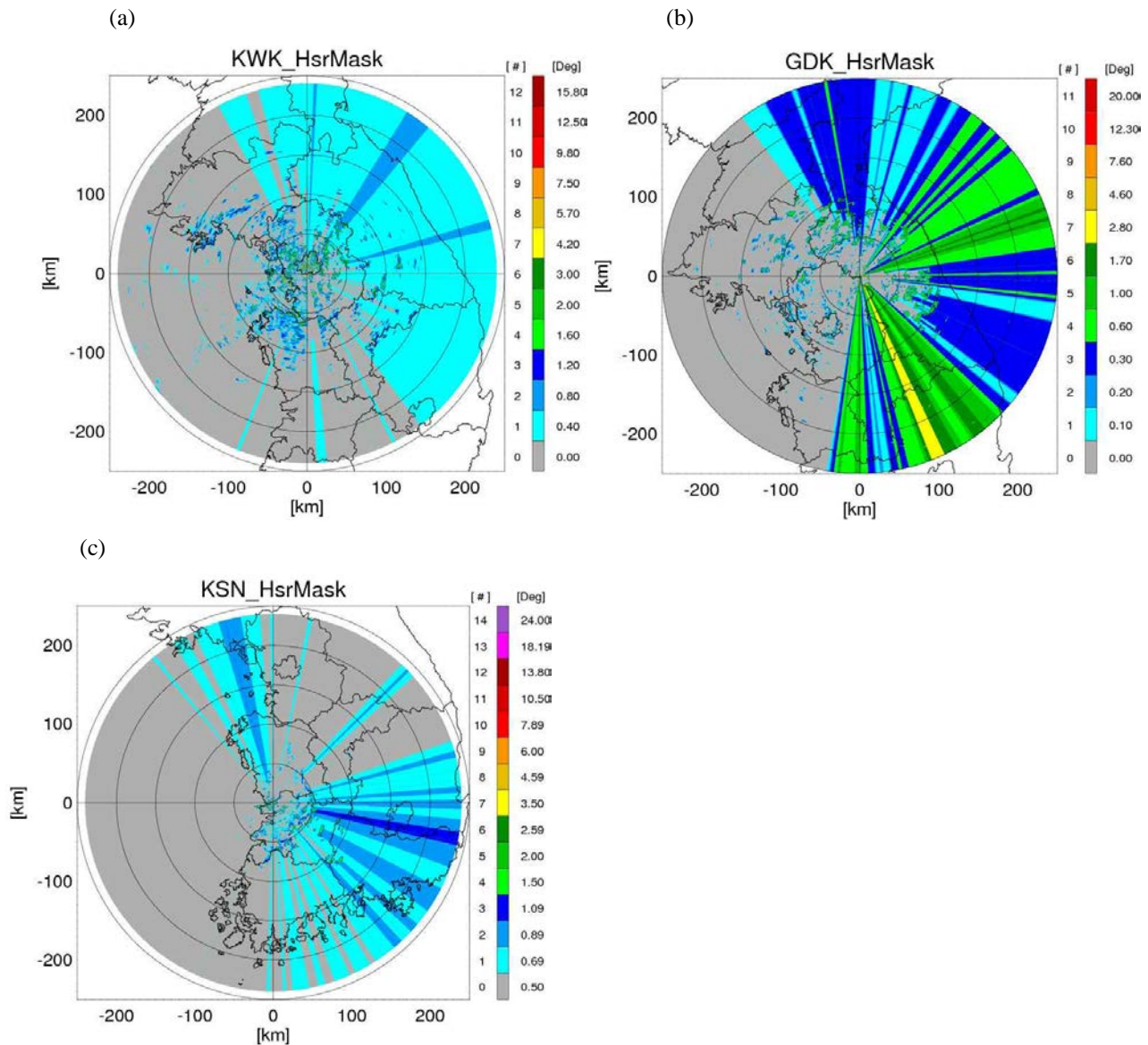
(a)



(b)



(c)



*Figure 2:The HSR Masks computed using (a) KWK, (b) GDK and (c) KSN radar data ( courtesy by WRC 2013)*

## 3  Study Results

The accuracy of HSR rainrate is analyzed for CASE I, CASE II, CASE III at KWK, GDK, KSN radar site. And it is analyzed the effect of improvement the rainfall estimation at the beam-blockage region. Table 3 indicates the numbers of the rain-gauges inside 100 km ranges of GDK, KWK, KSN radar site for the verification of HSR rainfall. The rate of rain-gauge number at the beam-blockage region is highest at the GDK radar site and lowest at the KSN radar site in Table 3.

*Table 3. Numbers(rate) of the rain-gauges inside100 km ranges of GDK, KWK, KSN radar site used for verification analysis.*

| Category | GDK | KWK | KSN |
|---|---|---|---|
| Total numbers of rain-gauges (T) | 91 | 203 | 171 |
| Numbers of rain-gauges at non-beam-blockage region (NB) | 37(41%) | 93(46%) | 107(63%) |
| Numbers of rain-gauges at beam-blockage region(B) | 54(59%) | 110(54%) | 64(37%) |

(a)  Rainrates at 0deg elevation level at GDK

(b) HSR rainrates at GDK

(c) Rainrates at 0deg elevation level at KWK

(d) HSR rainrates at KWK

(e) Rainrates at 0.5deg elevation level at KSN
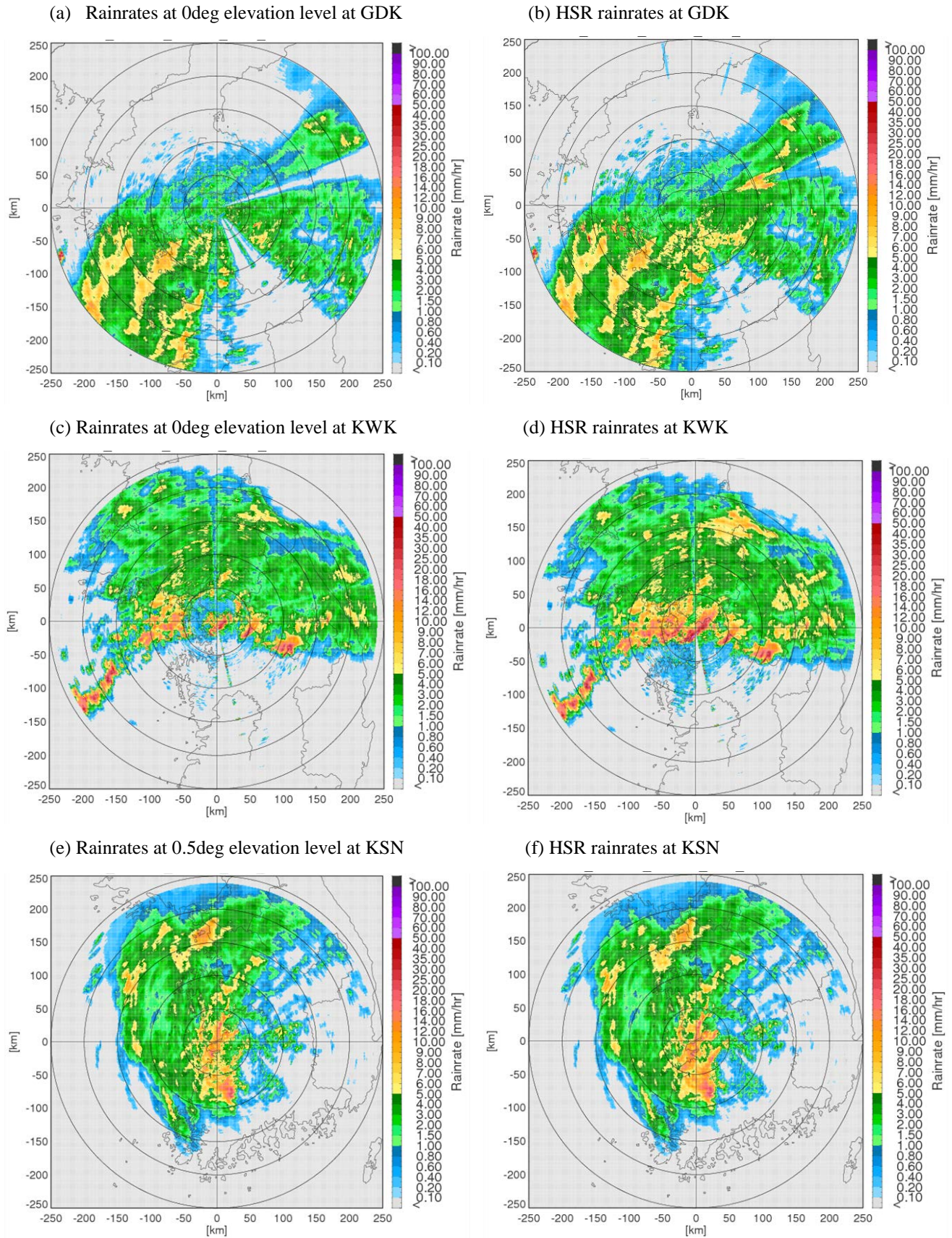
(f) HSR rainrates at KSN



*Figure 3: Rainrates(mm/hr) distribution at the lowest elevation level (left panel) and at the HSR mask (right panel). $Z=200R^{1.6}$ is applied for both level. (a)& (b) are for GDK radar on 1200 LST Aug. 30, (c) & (d) are fort KWK radar on 0210 LST July 6, and (e) & (f) are for KSN radar on 1200 LST Aug. 30, 2012.*

Figure 3 shows the rain-rate distributions obtained at the lowest elevation and at the HSR mask at GDK, KWK, KSN radar site. Qualitatively it is found that the intensity and coverage of rainrates obtained by HSR technique is improved for each sites compared to those at the lowest elevations. Especially, the improvement at the GDK radar site is obvious because large beam-blockages by the mountain area are corrected by the higher elevation values by HSR mask.

To verify this improvement quantitatively, the accuracies of the HSR rainrate at total region, non-beam-blockage region and beam-blockage region are analyzed and then compared to the CAPPI rainrate at the 1.5km height using the rain-gauges. The results are shown in Table 3 for each CASEs. Here, FRMSE means the normalized RMSE (mm/h) and CSI means the Critical Success Index. The perfect score of FRMSE is 0 and CSI is 1. The verification scores of FRMSE and CSI in Table 3 indicate the HSR is more accurate than the CAPPI. Particularly, the verification scores at the beam-blockage region (B) are better than that at the total region (T) and the non-beam-blockage region (NB).

*Table 3. The verification results of GDK, KWK, KSN radar site for CASE I, CASE II, CASE III. (Here, T, NB, B mean results verified using computed radar rainrates(CAPPI or HSR) and observed rainrates at Total rain-gauges, Non-beam-blockage, Beam-blockage inside 100 km range of each radar site. CAPPI means the radar rain-rate estimated from reflectivities of CAPPI (Constant Altitude Plan Position Indicator) and HSR means the radar rain-rate estimated from reflectivities of HSR field.)*

| Categories | | CASE I | | | | | | CASE II | | | | | | CASE III | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FRMSE | | | CSI | | | FRMSE | | | CSI | | | FRMSE | | | CSI | | |
| | | T | NB | B | T | NB | B | T | NB | B | T | NB | B | T | NB | T | T | NB | B |
| GDK | CAPPI | 1.54 | 1.54 | 1.55 | 0.66 | 0.72 | 0.57 | 1.33 | 1.27 | 1.48 | 0.74 | 0.86 | 0.60 | 1.28 | 1.27 | 1.22 | 0.89 | 0.94 | 0.81 |
| | HSR | 1.46 | 1.46 | 1.47 | 0.87 | 0.89 | 0.84 | 1.27 | 1.25 | 1.35 | 0.88 | 0.92 | 0.82 | 1.00 | 0.88 | 1.00 | 0.98 | 0.97 | 0.98 |
| KWK | CAPPI | 1.64 | 1.63 | 1.65 | 0.70 | 0.72 | 0.69 | 1.33 | 1.42 | 1.27 | 0.82 | 0.78 | 0.85 | 1.07 | 1.05 | 1.09 | 0.91 | 0.90 | 0.92 |
| | HSR | 1.55 | 1.56 | 1.53 | 0.91 | 0.90 | 0.92 | 1.28 | 1.37 | 1.23 | 0.94 | 0.93 | 0.95 | 1.03 | 0.98 | 1.07 | 0.95 | 0.94 | 0.95 |
| KSN | CAPPI | 1.55 | 1.58 | 1.53 | 0.65 | 0.70 | 0.62 | 1.56 | 1.58 | 1.58 | 0.71 | 0.72 | 0.71 | 1.05 | 0.95 | 1.15 | 0.89 | 0.95 | 0.85 |
| | HSR | 1.54 | 1.58 | 1.50 | 0.82 | 0.84 | 0.81 | 1.48 | 1.50 | 1.49 | 0.88 | 0.90 | 0.87 | 1.09 | 0.99 | 1.11 | 0.95 | 0.98 | 0.93 |

## 4 Summary

KMA (Korea Meteorological Administration) has applied the HSR (Hybrid Surface Rainfall; Maddox et al., 2002) systems for radar rainfall estimation to overcome the radar beam-blockage due to ground clutters and terrain. This study analyzed the accuracy of HSR rainrate for CASE I, CASE II, CASE III at KWK, GDK, KSN radar site. After applied the HSR technique, the blockage of the rain distribution is improved for each radar sites and the verification results also indicate the accuracies of rainrate are improved quantitatively. This improvement by HSR technique is obvious over the beam-blockage region compared to those over the total region and the non-beam-blockage region

## Acknowledgement

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