The Error Structure of the CAPPI and the Correction of the Range Dependent Error

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1. Introduction

Characterization and quantification of the error inherent in the radar rainfall is important for enhancing the applicability of the radar rainfall. The radar reflectivity - rain rate (Z-R) conversion error (Battan, 1973; Austin, 1987; Rosenfeld et al., 1993), the error from the beam blockage (Andrieu et al., 1997; Gabella and Perona, 1998), the error from the anomalous propagation (Battan, 1973) and the range dependent error (Andrieu and Creutin, 1995; Fabry and Zawadzki, 1995; Vignal et al., 1999) are typical errors in the radar rainfall. Among these, the range dependent error is occurred by the earth curvature and nonuniform vertical profile of reflectivity and causes the bias. If the radar rainfall without removing the range dependent error was corrected by using gauge rainfall, another error could be introduced to the radar rainfall (Borga and Tonelli, 2000).

This study focus on the range dependent error among various of the radar error. So, identification of the error structure of the volume radar reflectivity is first aim in this study. And the specification of the error inherent in the CAPPI displayed by the volume radar reflectivity to have the error structure is the second aim. Finally, the correction of the range dependent error of the CAPPI using the VPR model is included in the research objectives.

2. Error Structure of the Volume Radar Reflectivity and the Range Dependent Error of the CAPPI

2.1 Error Structure of the Volume Radar Reflectivity and VPR Model

If the reflectivity at ground z_0 is assumed the reference reflectivity, the error of the radar reflectivity can be defined as Eq. (1) (Koistinen et al., 2003). The error is a function of the location x determined by the range r and the azimuth θ and the height h.

$$\varepsilon(x,h) = 10\log\frac{Z(x,h)}{Z_0(x,h)} = z(x,h) - z_0(x,h) \tag{1}$$

Where, $\varepsilon(x,h)$ [dBZ] represents the error at the location x and the height h. And $Z(x,h)$ [mm^6/m^3] and $z(x,h)$ [dBZ] are the reflectivities in different units.

The reference reflectivity assumed is needed for identifying the error structure and in this study the ground reflectivity estimated by the VPR (Vertical Profile of Reflectivity) model was assumed to be the reference reflectivity.

As the VPR model Eq. (2) was adapted. The reflectivity decreases exponentially as the height increases.

$$z(h) = c(1 - e^{-a(b-h)}) \tag{2}$$

Where, a, c are constants and b is the zero-reflectivity height. The reflectivity at the ground, z_0 estimated by this model becomes $c(1-\exp(-ab))$. Now, the error of the radar reflectivity can be calculated as in the following equation.

$$\varepsilon(h) = c(1 - e^{-a(b-h)}) - c(1 - e^{-a(b-0)}) = ce^{-ab}(1 - e^{ah}) \tag{3}$$

The error of the radar reflectivity becomes exponentially increased represent by the negative value as the height increases

2.2 Range Dependent Error Structure of the CAPPI

CAPPI displays the reflectivity on two dimension plane and is frequently used to the horizontal analysis of the rainfall field. The CAPPI data were displayed by the Bilinear method by Mohr and Vaughn (1979). The dot-and-dash line in Fig. 1 represents the beam height and the bold line is the observation height of the CAPPI. And the dotted line indicates the 1.5km height. The height of the CAPPI retain 1.5km but higher over the certain range. Fig. 2 shows the reflectivity and the error structure with respect to the distance when parameters a=0.4, b=10, c=35 are used for the VPR model.

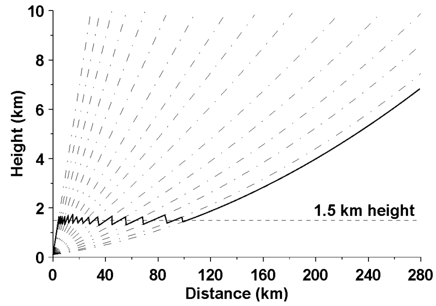
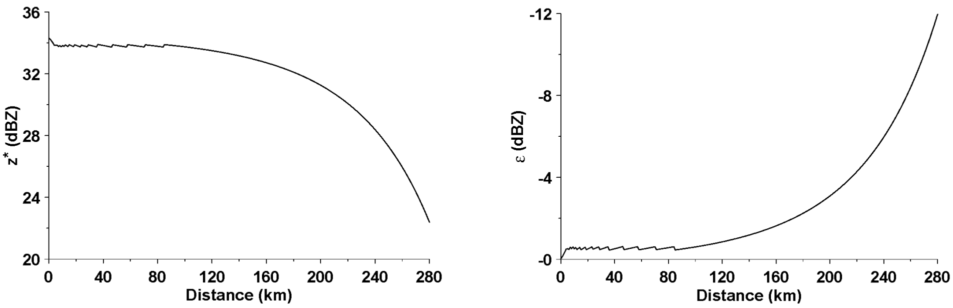


Fig. 1. Observation height of the CAPPI vs. the distance from the radar



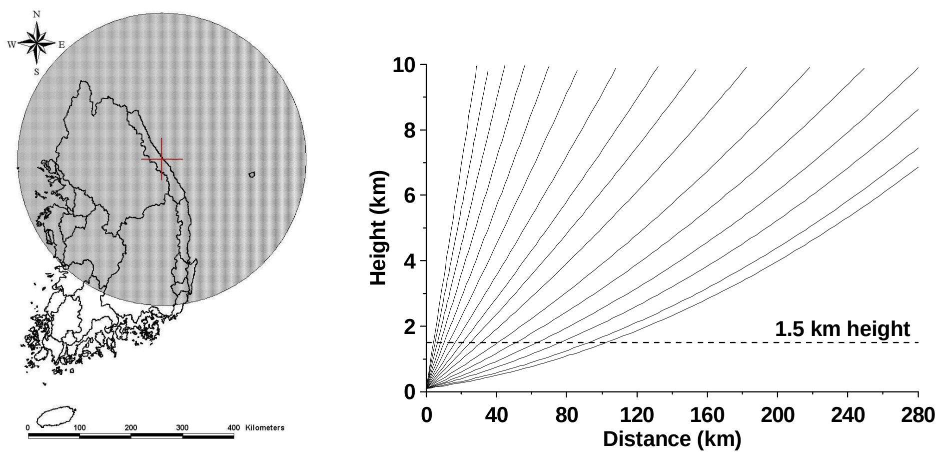
(a) Reflectivity vs. distance *(b) Error vs. distance*

Fig. 2. The reflectivity and error structure of the CAPPI with respect to the distance from the radar

3. Application

3.1 Data

This study analyzed the data of the Gangneung weather radar near the shore. The S-band radar has the 280 km observed range and a total of 16 altitudes (0.44°, 0.56°, 0.80°, 1.06°, 1.41°, 1.84°, 2.47°, 3.12, 3.83, 4.83°, 6.20°, 7.86°, 9.97°, 12.61°, 15.91°, 19.91°). Fig. 3 shows the location and the coverage of the Gangneung weather radar, along with the beam height with respect to the distance from the radar site.



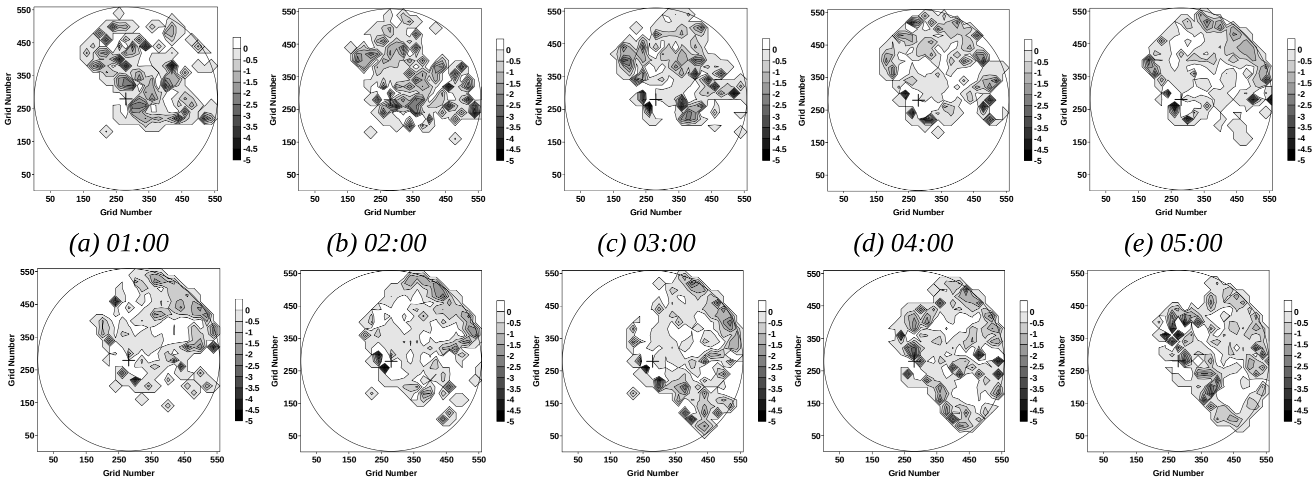
(a) Location and coverage *(b) Beam height*

Fig. 3. Location and beam height of the Gangneung weather radar

3.2 Error Structure of CAPPI and Correction of Range Dependent Error

Fig. 4 represents the error of the CAPPI on 2-dimenstional plane. The error uniformly appears as far as 100 km, but becomes larger over 100 km. The local error appears from 01:00 to 03:00 but the error at a long distance becomes obviously large after

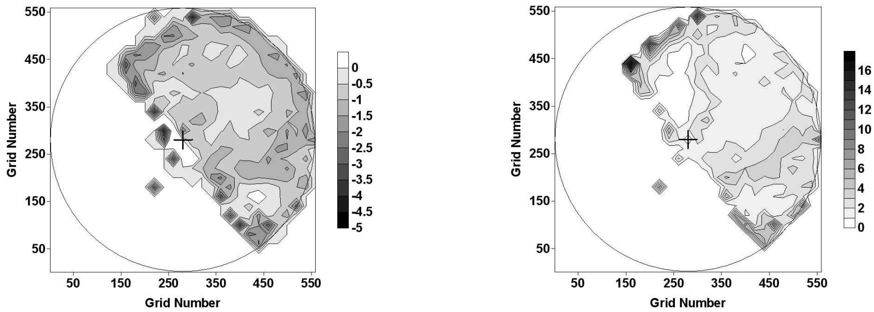
04:00. This characteristic feature appears on plot of average error (Fig. 5).



(a) 01:00 *(b) 02:00* *(c) 03:00* *(d) 04:00* *(e) 05:00*

(f) 06:00 *(g) 07:00* *(h) 08:00* *(i) 09:00* *(j) 10:00*

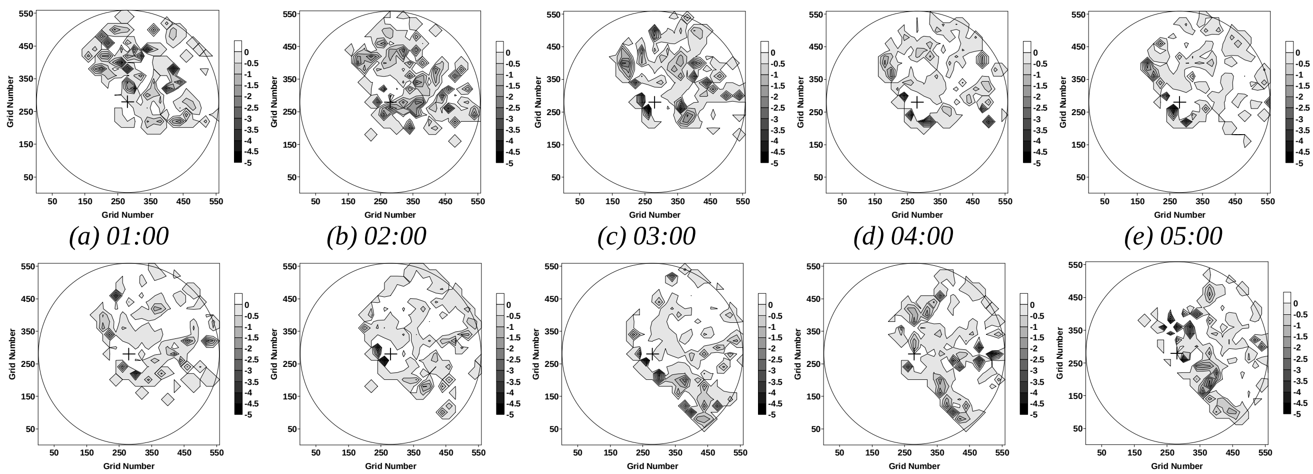
Fig. 4. Spatial error structure of 1.5km CAPPI estimated hourly within the radar umbrella



(a) Mean *(b) Standard deviation*

Fig. 5. Mean and standard deviation of the error of 1.5km CAPPI estimated over the rainfall event within the radar umbrella

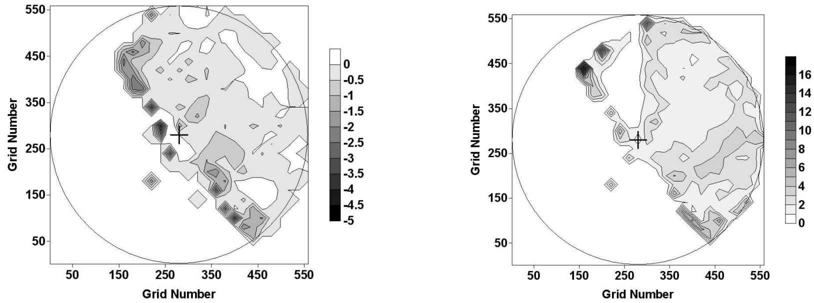
The range dependent error of the CAPPI was corrected by applying the VPR model. As can be seen in Fig. 6 the error at a long distance appeared to be removed effectivly. Fig. 7 shows the overal mean and the standard deviation of the errors estimated every hour.



(a) 01:00 *(b) 02:00* *(c) 03:00* *(d) 04:00* *(e) 05:00*

(f) 06:00 *(g) 07:00* *(h) 08:00* *(i) 09:00* *(j) 10:00*

Fig. 6. Spatial error structure of 1.5km CAPPI estimated hourly within the radar umbrella after removing the range-dependent error



(a) Mean *(b) Standard deviation*

Fig. 7. Mean and standard deviation of the error of 1.5km CAPPI estimated over the rainfall event within the radar umbrella after removing the range-dependent error

4. Result

It is important to characterize and quantify the error inherent in the radar rainfall for enhancing the applicability of the radar rainfall. This study aimed to identify the error structure of the CAPPI displayed by the volume radar reflectivity. First, the error structure of the CAPPI was derived using the reference reflectivity estimated by applying a VPR model. Similarly, the range dependent error was corrected by applying the VPR model. The effect of removing the range dependent error could also be well identified in the data analysis of the Gangneung wether radar.

Acknowledgment

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References

FamilyName N., FamilyName N., Year: Title. *Journal_name_in_italic*, **volume**, first pagenumber– last pagenumber

Andrieu H., Creutin J.D., 1995: Identification of vertical profiles of radar reflectivity for hydrological applications using an inverse method. Part I: Formulation. *American Meterological Society*, **34**, 225-239.

Andrieu H., Creutin J.D., Delrieu G., Faure D., 1997: Use of a weather radar for the hydrology of a mountainous area. Part 1: Radar measurement interpretation. *Journal of Hydrology*, **193**, 1-25.

Austin P., 1987: Relation between measured radar reflectivity and surface rainfall. *Monthly Weather Review*, **115**, 1053-1070.

Battan L., 1973: *Radar observation of the atmosphere*, University of Chicago Press, 324pp.

Borga M., Tonelli F., 2000: Adjustment of range-dependent bias in radar rainfall estimates. *Physics and Chemistry of the Earth*, **25**, 909-914.

Fabry F., Zawadzki I., 1995: Long-term radar observations of the melting layer of precipitation and their interpretation. *Journal of the Atmospheric Sciences*, **52(7)**, 838-851.

Gabella M., Perona G., 1998: Simulation of the orographic influence on weather radar using a geometric-optics approach. *Journal of Atmospheric and Oceanic Technology*, **15**, 1486–1495.

Koistinen J., Michelson D.B., Hohti H., Peura M., 2003: Operational measurement of precipitation in cold climates. *Weather Radar—Principles and Advanced Applications, P. Meishcner, Ed., Springer*, 78–114.

Rosenfeld D., Wolff D., Atlas D., 1993: General probabilitymatched relations between radar reflectivity and rain rate. *Journal of Applied Meteorology*, **32**, 50-72.

Vignal B., Andrieu H., Creutin J.D., 1999: Identification of vertical profiles of reflectivity from volume scan radar data, *Journal of Applied Meteorology*, **38**, 1214-1228.