P14.5 Correction of bright band effects in radar observations from plain areas

Jian Zhang[1] and Youcun Qi*[2,3]

[1]NOAA/OAR National Severe Storms Laboratory, Norman, Oklahoma

[2]Nanjing University of Information Science & Technology, Nanjing, China

[3]Cooperative Institute for Mesoscale Meteorological Studies, The University of Oklahoma, Norman, OK

1 Introduction

The bright band is a layer of enhanced reflectivity due to melting of aggregated snow. The phenomenon has been recognized near the beginning of radar meteorology (e.g., Ryde 1946.). The locally high reflectivity causes significant overestimation in radar precipitation estimates if appropriate correction is not applied. To mitigate radar precipitation errors associated with the bright band and other factors related to non-uniform vertical profiles of reflectivity (VPR), many methods have been proposed (e.g., Koistinen 1991; Kitchen et al. 1994.). Advantages and disadvantages associated with each type of VPRs were discussed by previous investigators (e.g., Germann and Joss 2002).

The main objective of the current study is to develop a method that automatically corrects for large errors due to bright band effects in the real-time NMQ radar-derived QPE product. Therefore, both product accuracy and computational efficiency are important. An approach that combines the mean volume scan VPR and the idealized VPR techniques were adapted based on the following considerations:

1) The mean volume scan VPR approach is used because of its computational simplicity and efficiency. *
2) The mean volume VPR in this study is computed from single volume scan instead of averaging several volume scans over a time period. This further simplifies computations by eliminating the need for time associations
3) An idealized VPR model is used to handle the situations when the bright band is near the ground.
4) Parameters in the idealized VPR model are dynamically adjusted using real-time radar observations as well as environmental data.

Detailed descriptions of the correction method and the correction procedure are provided in the next section. Case study results for three events representing different seasons/different precipitation types in the United States are presented in section 3. A summary is provided in section 4.

2, Methodology

Since the current VPR correction scheme is for bright band correction, it assumes that the 0°C height (or freezing level) is above the ground. In other words, the scheme is designed for liquid precipitation at this point, not for snow. If the 0°C height (usually obtained from a radio sounding or from a model temperature profile) is at or below the ground, then no VPR correction would be applied. The correction procedure includes four major steps as presented below.

1) Convective and stratiform segregation and bright band area delineation

Because of large differences between the vertical structure of convective and stratiform precipitation (e.g., Zhang et al. 2008), it is important to segregate the two types of precipitation before a VPR correction is applied. In the current study, convective and stratiform precipitation is segregated using a simple method based on the vertically integrated liquid water. If VIL is greater than a threshold (default = 6.5 kg/km^2) at a given gate; then the gate is classified as convective. Otherwise, it is classified as being stratiform.

The stratiform area is further divided into two parts: one is the BB affected area (BBA), and another is not. The BBA is delineated as areas a) within a pre-defined

* Corresponding author address: 120 David L. Boren Blvd., Suite 2100 Norman, OK 73072-7304;
e-mail:youcun.qi@noaa.gov

BB top (default = 0°C height + D1,[1]) and bottom (default = 5 km below the BB top) boundaries; and b) with composite reflectivity greater than a pre-defined threshold, ZBB. Figure 1 shows an example of the convective and stratiform segregation and the BBA delineation for a squall line event observed by the KFWS radar.

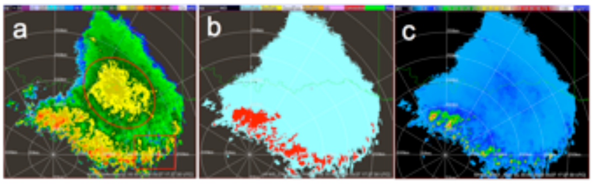

Fig. 1 (a) Base reflectivity on 0.5° tilt, (b) precipitation type, and (c) VIL fields from KFWS at 17:27Z on May 27, 2008. The red circle in (a) indicates the area being affected by bright band. The colors in (b) represent convective (red) and stratiform (blue) precipitation regions.

2) *Parameterized BB VPRs*

For each tilt, a mean observed VPR is computed by taking azimuth average of reflectivities in the BBA. After a valid mean VPR is obtained, a linear VPR model with five parameters is fitted to the mean observed VPR (Fig.2). The five parameters are:

i. Height of the BB top (h_t)
ii. Height of the BB bottom (h_b)
iii. Height of the BB peak (h_p)
iv. Slope above the BB peak (a)
v. Slope below the BB peak (b)

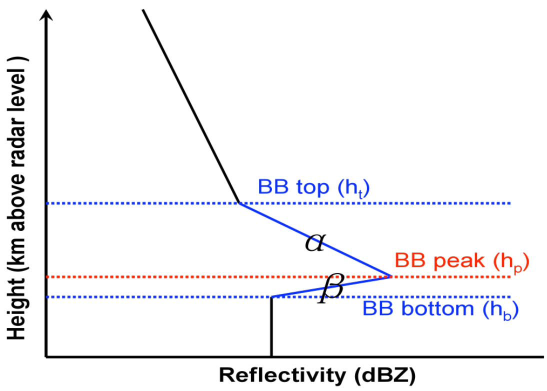

Fig. 2 Idealized VPR and the idealized bright band VPR parameters (see text) have been labeled on.

As mentioned above, the BB top (h_t) was determined by the background 0°C height and radar beam width on the lowest tilt. The BB peak (h_p) is defined as the height of the first maximum reflectivity below the BB top. Then the slope (a) of the upper part of the idealized VPR is obtained by a least-square linear fitting to the mean observed VPR between the BB top and peak (Fig.2). BB bottom (h_b) is found by searching for the minimum reflectivity in the VPR below the BB peak. If the minimum reflectivity is lower than a threshold (default = 28 dBZ), then the height associated with the threshold is defined as h_b. The minimum reflectivity threshold is used to avoid excessive corrections. Once the BB bottom is found, the slope (b) of the idealized VPR below the BB peak is found by a least-square linear fitting to the mean observed VPR between the BB peak and bottom (Fig.2).

3) *Apply VPR correction*

Once the idealized BB VPR is obtained, a reflectivity correction factor, *DZ*, is computed from the VPR according to the following:

$$\Delta Z(r) = \begin{cases} \alpha \bullet [h(r) - h_p] + \beta \bullet [h_p - h_b] & ; \quad h(r) > h_p \\ \beta \bullet [h(r) - h_b] & ; \quad h(r) \le h_p \end{cases} \quad (1)$$

$$Z_c(r)\big|_{r \in BBA} = Z_o(r)\big|_{r \in BBA} - \Delta Z(r) \quad (2)$$

Here, r is the range from the radar to any given gate and $h(r)$ is the height of the beam axis at the gate; $Z_o(r)$ and $Z_c(r)$ represent the observed and VPR corrected reflectivities at any given gate within a BBA, respectively. For a bright band situation, $\Delta Z(r)$ is usually positive, thus the correction would only reduce the observed reflectivities after the correction. $\Delta Z(r)$ can become negative when $h(r) - h_p$ is so high that $\alpha \bullet [h(r) - h_p] > \beta \bullet [h_p - h_b]$, and equation (1) may be potentially used to correct for underestimations in radar-derived QPE when the radar beam is sampling upper part of precipitation clouds (i.e, the snow/ice region). However, this correction may not be very accurate if only one slope is considered

[1] $D1 = Height_{Range\_0°c\_beam\_center} - Height_{Range\_0°c\_beam\_bottom}$

above the BB peak.

3 Case study results

In the current study, multiple VPRs are derived and then applied for correction, one for each tilt. These mean observed VPRs accurately account for the beam spreading effects because the reflectivity were averaged at the same range on a single tilt, instead of over multiple tilts at a certain height as shown in Figure 3.

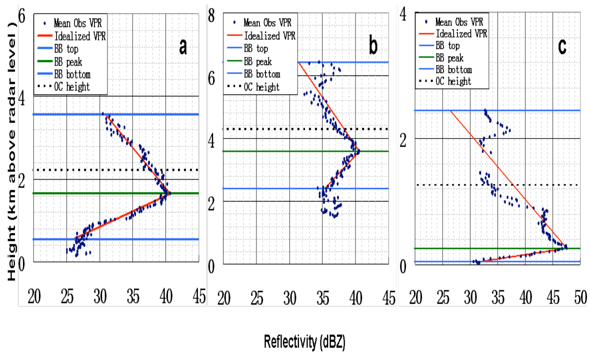

Fig. 3 Mean observed VPRs (blue dots) and idealized BB VPR parameters (see text) fitted to the mean observed VPRs for (a) KCLE at 10Z Nov. 15, 2008, (b) KFWS at 18Z May 27, 2008, and (c) KUDX at 05Z May 27, 2008.

When applying the correction back to observed reflectivity, the beam spreading effects are automatically accounted for. This approach was found to be superior to the single-VPR approach, where one mean VPR is computed from observations of multiple elevations angles at closer ranges and then applied to the far ranges. Experiments with the single-VPR approach resulted in some circular discontinuities (not shown) because the VPRs could not accurately account for the beam spreading at different ranges. Using the VPRs for each tilt, the correction is adaptive to the range variation of the beam width and the BB distribution, and discontinuities in the corrected fields are minimized. Figure 4 shows example reflectivity fields before and after the VPR correction. The inflated reflectivity in bright band area was corrected. The corrected fields showed physically consistent distributions and were free of circular discontinuities that were usually caused by non-representative BB top/bottom heights in single-VPR approaches.

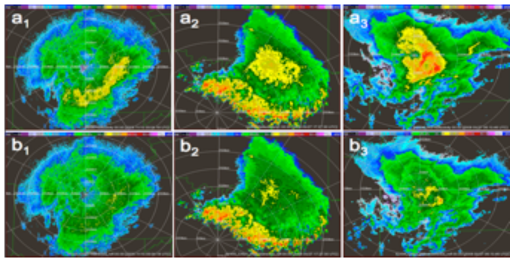

Fig. 4 Base level reflectivities on the lowest tilt before (row *a*) and after (row *b*) the VPR correction. The three columns are images from (*column 1*) KCLE at 10Z Nov. 15, 2008, (*column 2*) KFWS at 18Z May 27, 2008, and (*column 3*) KUDX at 05Z May 27, 2008.

The hybrid scan reflectivity field is converted into rain rate using two Z-R relationships, one for convective area ($Z=300R^{1.4}$) and another for stratiform area ($Z=200R^{1.6}$). The rain rates are aggregated into hourly rainfalls and compared to the surface gauge observations. Figure 5 shows a comparison of hourly radar rainfall estimates before and after the BB VPR correction against gauge observations for the five events shown in Fig.4. The significant overestimations in radar-derived QPE of the KCLE (Fig.5a), KFWS (Fig.5b), and KUDX (Fig.5c), were successfully reduced by the VPR correction. Radar estimates after the correction agreed much better with the gauge observations than those before, especially for the amounts less than 5 mm.

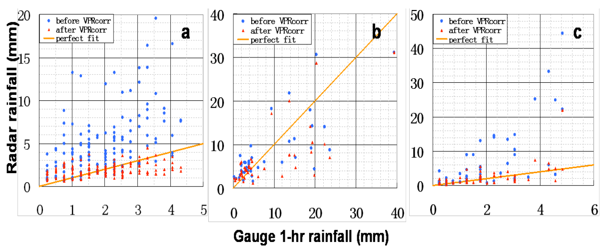

Fig. 5 Scatter plots of one-hour radar precipitation estimates before (blue dots) and after (red triangles) the VPR correction versus gauge observations. The data are from (a) KCLE 05-10Z Nov. 15, 2008 (b) KFWS 13-20Z May 27,

2008, and (c) KUDX 00-09Z May 27, 2008.

4, Summary

An algorithm was developed for the correction of bright band (BB) in radar precipitation estimation in flat lands. The correction was based on mean observed vertical profiles of reflectivity (VPRs) from volumetric radar data. The VPR was computed from each single tilt in BB area, and the BB area was delineated according to radar reflectivity distributions and atmospheric environmental data. A linear model was fitted to the mean observed VPR and then the linear BB VPR was used to correct for BB effects in the observed reflectivity field.

The linear BB VPR model was found to be representative and stable for various BB structure. High reflectivities associated with BB were correctly reduced in most of the cases and the corrected reflectivity field showed physically continuous distributions. The overestimation errors in radar-derived QPE were largely reduced after the VPR correction, and the VPR corrected radar-derived QPE agreed well with rain gauge observations. The VPR correction is most effective and robust for radars in flat lands because of relative uniform spatial distributions of BB. The current convective and stratiform segregation still needs further refinement.

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Reference

Germann, U., and J. Joss, 2002: Mesobeta profiles to extrapolate radar precipitation measurements above the Alps to the ground level. *J. Appl. Meteor.*, **41**, 542-557.

Kitchen, M., R. Brown, and A. G. Davies, 1994: Real-time correction of weather radar data for the effects of bright band, range and orographic growth in widespread precipitation. Quart. J. Roy. Meteor. Soc., 120, 1231–1254.

Koistinen, J. 1991: Operational correction of radar rainfall errors due to the vertical reflectivity profile. Preprints, 25th Int. Conf. On Radar Meteor, Paris, France, Amer. Meteor. Soc., 91–94.

Ryde, J. W., 1946: The attenuation and radar echoes produced at centimeter wavelengths by various meteorological phenomena. Meteorological Factors in radio Wave Propagation, Phys. Soc., 169–188.

Zhang, J., C. Langston, and K. Howard, 2008: Bright Band Identification Based On Vertical Profiles of Reflectivity from the WSR-88D. J. Atmos. Ocean. Tech. 25, 1859-1872.