P11B.6 DIFFERENTIAL REFLECTIVITY CALIBRATION WITHOUT USING VERTICAL INCIDENCE OBSERVATIONS

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1. INTRODUCTION

Calibration of the differential reflectivity, Z_{dr}, measurements is important for correct interpretation of dual polarization radar measurements. There are several approaches that are used for achieving an accurate estimation of system induced Z_{dr} biases. Hubbert et al (2003) have proposed to use imbalances in cross–polar channels for estimation of the differential reflectivity biases. This approach provides excellent means for calibration of the differential reflectivity measurements in cases of alternating polarization measurements. It was shown (Bringi and Chandrasekar, 2001) that the receiver calibration can be achieved by carrying out sun radiometric measurements. In this case transmitter characterization can be carried out either by observing an external target, with a known scattering matrix, or by using approach of Hubbert et al (2003).

A more direct way of measuring Z_{dr} biases is light rain observations at vertical incidence (Gorgucci et al 1999). In this approach the Z_{dr} bias is calculated as an average Z_{dr} observed over all azimuth angles. However, this method implies an ability of carrying out vertical incidence measurements.

In this paper we present a new Z_{dr} calibration approach that can be employed by the radars whose antenna systems are not capable of vertical incidence observations. Moisseev and Chandrasekar (2006, 2007) have shown that by using rain observations taken at elevation angles between 30 and 60 degrees one can discriminate between signals coming from drops of different diameters. Furthermore, it was shown that for moderate widths of the spectral broadening kernel, i.e. moderate values of wind shear and turbulence, one can directly observe scattered signal coming from smaller raindrops. Since, drops smaller than 1 mm can be considered to be spherical, one can use those measurements for estimation of the Z_{dr} bias. This approach employs spectral decompositions of dual-polarization observations and can be carried out by most dual-polarization radars capable of time-series collection.

2. DUAL POLARIZATION SPECTRAL DECOMPOSITIONS

2.1 Co-polar coherency spectrum

The co-polar coherency spectrum is defined as:

$$\rho_{hv}(v) = \frac{C_{hv}(v)}{\sqrt{P_{hh}(v)P_{vv}(v)}}, \tag{1}$$

where $C_{hv}(v)$ is the co-polar cross spectrum and $P_{hh}(v), P_{vv}(v)$ are *hh* and *vv* power spectra respectively. The co-polar coherency physical meaning is similar to the co-polar correlation coefficient and can be defined as a spectral decomposition of the co-polar correlation coefficient.

The co-polar coherency is an efficient tool to discriminate between noise and signal. In this study we use it to define parts of the spectrum that are dominated by noise.

2.2 Spectral decomposition of differential reflectivity

The spectral decomposition of the differential reflectivity is defined as the ratio of *hh* and *vv* power spectra, $P_{hh}(v)/P_{vv}(v)$. Similar to the differential phase the precipitation signal is characterized by the constant spectral differential reflectivity over all Doppler frequencies. The clutter spectral differential reflectivity, however, varies with the Doppler frequency and range.

In Fig. 1 and Fig.2 examples of dual-polarization spectral observations in light rain are shown. These measurements were taken by the CSU-CHILL on July 25, 2006. The elevation angle for these measurements is 45 degrees. One can observe that the spectral differential reflectivity exhibits a clear trend where smaller values correspond to smaller velocities. In Fig. 2 it is more apparent.

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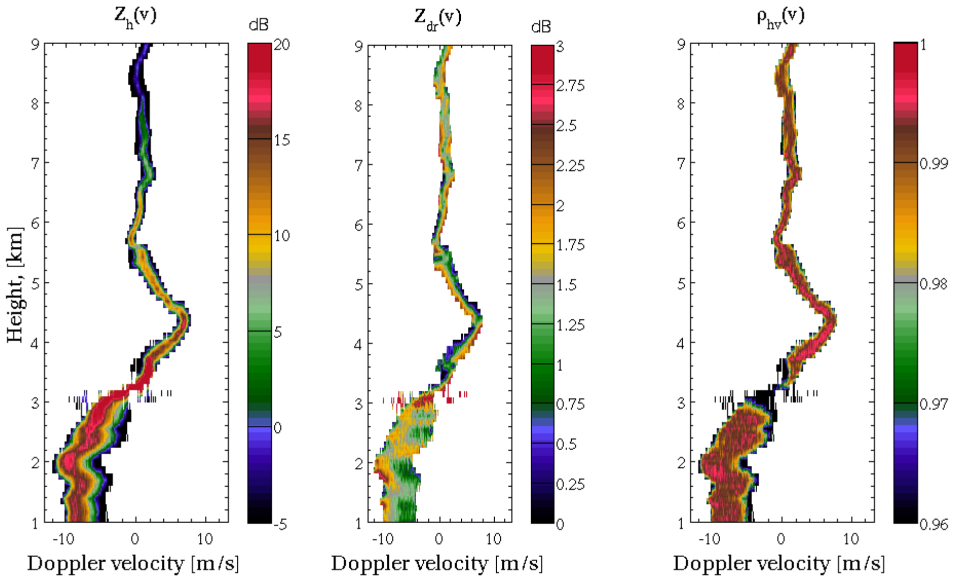

FIG. 1 Spectrographs of dual-polarization rain observations. The measurements are taken at 45 degree elevation in a light rain event on July 26, 2006.

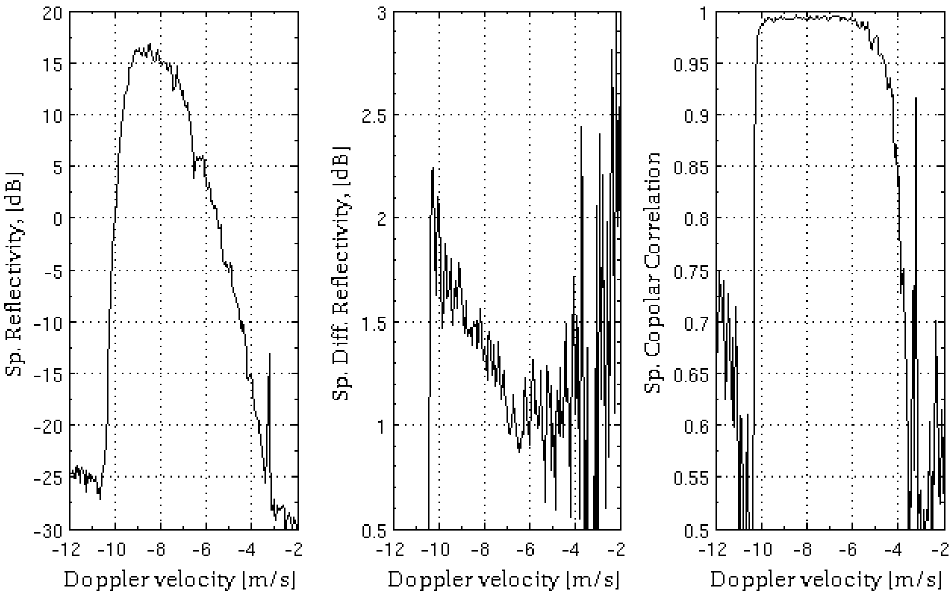

FIG. 2. Plots of spectral reflectivity, differential reflectivity and co-polar correlation coefficient corresponding to the measurements shown in Fig. 1. at height of 1.16 km.

3. CALIBRATION METHODOLOGY

The calibration of the CSU-CHILL is usually carried in several steps (Bringi and Chandrasekar, 2001), where the differential reflectivity bias is split into three parts.

$$Z_{dr}^{bias}(dB) = Z_{dr}^{cal}\_base(dB) + 10\log(\frac{P_t^v}{P_t^h}) + G_r^v(dB) - G_r^h(dB) \qquad (2)$$

The $Z_{dr}^{cal}\_base(dB)$ is considered to be a more stable part of the bias and corresponds to the bias due to difference in waveguide paths and difference in antenna radiation patterns. This part of the bias is usually obtained from the vertically pointing measurements in light rain. The transmit power for both channels is measured every two seconds and used for on fly bias correction. The difference in the receiver gains is estimated several times during the day.

For this study we use 45 degree elevation angle measurements collected in a light rain event on July 25, 2006. Fig. 3 demonstrates the principle, if there is a bias in the differential reflectivity measurements then spectral differential reflectivity values for small velocities would be different from zero. Therefore, spectral differential reflectivity values in this part of the spectrum would provide us the Z_{dr} bias value.

It is important to use spectral decomposition of the correlation coefficient for censoring the data. In our case we only consider spectral lines with spectral co-polar correlation coefficient values larger than 0.95. Furthermore, a change in wind direction and magnitude can influence the spectral measurements, therefore only measurements from those range gates should be considered where changes in radial velocity are minimal.

4. APPLICATION TO CSU CHILL OBSERVATIONS

To test the new calibration methodology slant and vertically pointing time-series data in light rain was collected by the CSU-CHILL radar on July 25, 2006. The vertically pointing measurements were collected for different azimuth angles to apply the procedure proposed in (Gorgucci et al, 1999).

For estimation of the differential reflectivity bias only data obtained from heights 1.1 to 1.2 km and 1.9 to 2.1 km were considered. This was done to minimize influence of the wind shear that is apparent in measurements shown in Fig. 1. Furthermore, all spectral data was censored by using spectral co-polar correlation coefficient as discussed in the previous section.

Since, the transmit power difference and difference in the receiver gains are observed independently the purpose of our study was to estimate $Z_{dr}^{cal}\_base(dB)$ value. In Fig 4.the resulting calibration base value is shown.

In order to validate the proposed methodology the retrieved $Z_{dr}^{cal}\_base(dB)$ is compared to the one obtained from the vertical incidence measurement. This comparison is shown in Fig. 5. One can see that they are in a good agreement.

The change of the differential reflectivity bias values with the azimuth is not well understood. Gorgucci et al, 1999 speculated that this variability can be attributed to ground clutter. However, we have applied a ground clutter filter to our measurements. It was also observed that rotary joints contribution to this variability is negligible. Therefore, one possible explanation of this effect can be non uniform radom wetting. That can also explain small difference in $Z_{dr}^{cal}\_base(dB)$ values obtained using slant and vertical measurements.

5. CONCLUSIONS

In this study a new methodology for the differential reflectivity calibration was proposed. It was demonstrated that accurate Z_{dr} bias values can be retrieved from slant profile measurements. This study further demonstrates value of dual-polarization spectral observations that can be used not only for precipitation microphysics studies, but also for a radar system characterization.

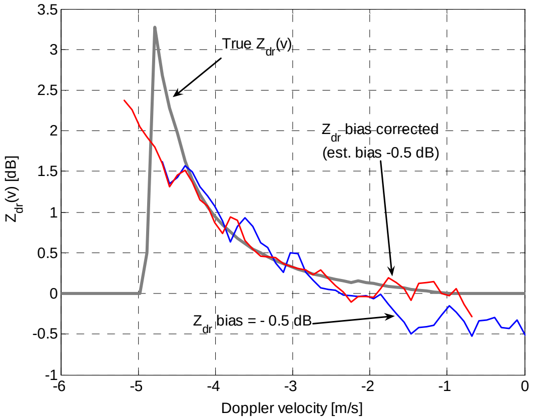

FIG. 3 Illustration of the differential reflectivity calibration approach.

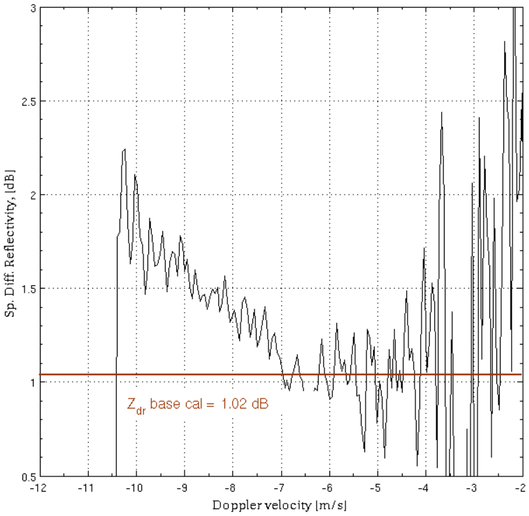

FIG. 4 Estimation of the Zdr calibration base value from the observations.

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REFERENCES

Bringi, V. and V. Chandrasekar, 2001: Polarimetric Doppler Weather Radar. Cambridge Univ. Press, Cambridge, UK.

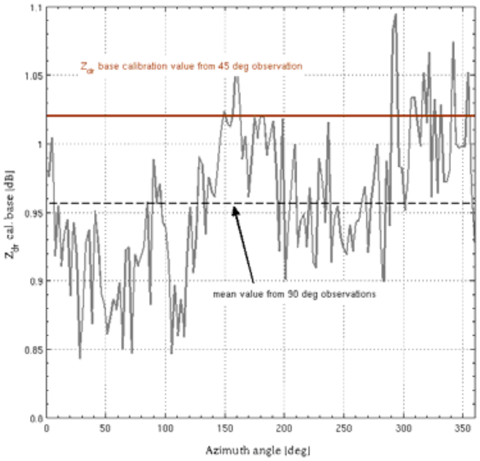

FIG. 5 Comparison of vertical and slant profile calibration results.

Gorgucci, E., G. Scarchilli, and V. Chandrasekar, 1999: A procedure to calibrate multiparameter weather radar using properties of the rain medium. *IEEE Trans. Geosci. Remote Sens.*, **17**, 269-276.

Hubbert, J.C., V.N. Bringi and D. Brunkow, 2003: Studies of the polarimetric covariance matrix: Part I: Calibration methodology. J. *Atmos. and Oceanic Technol.*, **20**, 696-706.

Moisseev, D. N and V. Chandrasekar, 2006: Raindrop shapes as seen by a polarimetric Doppler radar. Proceedings of 12th Conference on Cloud Physics, Madison, WI Amer. Meteor. Soc.

Moisseev, D. N, and V. Chandrasekar, 2007: Nonparametric estimation of raindrop-size distributions from dual-polarization radar spectral observations. *J. Atmos. Oceanic Technol.*, **24**, 1008-1018.