# P9.96 POLARIMETRIC ATTENUATION CORRECTION AND RAINFALL ESTIMATION FOR HEAVY RAIN EVENTS AT C BAND

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## 1. INTRODUCTION

To obtain high-quality radar data, reliable radar calibration and efficient attenuation correction are very important. Microwave radiation at shorter wavelength experiences strong attenuation in precipitation and has to be accounted for.

Attenuation correction issues at shorter wavelength radars can be efficiently resolved by using measurements of differential phase ($\Phi_{DP}$) which is immune to attenuation (Bringi and Chandrasekar 2001). The simple version of the polarimetric attenuation correction technique is suggested by Bringi et al. (1990). It assumes a linear relationship between the specific differential phase ($K_{DP}$) and both the specific attenuation ($A_H$) and specific differential attenuation ($A_{DP}$) with fixed coefficients of proportionality. However, the correction factors α and β ($A_H/K_{DP}$ and $A_{DP}/K_{DP}$, respectively) are highly variable in convective strong cells containing large raindrops and hail because of effects of resonance scattering (Carey et al. 2000; Keenan et al. 2001; Bringi et al. 2001; Ryzhkov et al. 2006, 2007; Gourley et al. 2006; Vulpiani et al. 2008; Tabary et al. 2008, 2009; Borowska et al. 2009, 2011).

In order to take into account the variability of α and β, more sophisticated polarimetric techniques for attenuation correction have been considered (Carey et al. 2000; Bringi et al. 2001; Ryzhkov et al. 2007; Vulpiani et al. 2008, Gu et al. 2011).

In this paper, we describe another possible method for attenuation correction at C band. Several attenuation schemes including this new methodology were tested on several strong storms in central Oklahoma and in the Chicago, Illinois, metropolitan area, using the data collected by C band polarimetric radars. One of them belongs to Valparaiso University, in Valparaiso, Indiana, and another one belongs to the University of Oklahoma.

Results of attenuation correction are validated using self-consistency between radar polarimetric variables and comparisons with the measurements from a nearby polarimetric prototype of the WSR-88D (KOUN) in Oklahoma and from a single-polarization WSR-88D (KLOT) in Chicago area that did not experience much attenuation in the storms. For one of cases in Oklahoma rain gage data are utilized to validate the performance of different attenuation correction schemes at C band.

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## 2. POLARIMETRIC ATTENUATION CORRECTION

High variability of correction factors α and β in strong rain cells is the main issue in attenuation correction. Even though many attenuation schemes introduced reliable methods for determining α and β, these values are often assumed to be constant along the propagation path. Carey et al. (2000) suggested assigning different fixed values for the parameters α and β in strong convective cells (hot spots or big drop zones) and the rest of the propagation path. This method was further advanced by Ryzhkov et al. (2006, 2007) and Gu et al. (2011) who proposed a procedure for a more objective estimation of α and β within hot spots assuming that these factors are equal to constant values $\alpha_0$ and $\beta_0$ outside of hot spots. In this study, the modified "Hot Spot" attenuation correction method is introduced which blends together the Bringi et al. (2001) and the Gu et al. (2011) procedures. The Hot-Spot correction algorithm of Gu et al. (2011) implies that

$$\alpha = \alpha_0 + \Delta\alpha \tag{1}$$

$$\beta = \beta_0 + \Delta\beta \tag{2}$$

in the HS and the background values $\alpha_0$ and $\beta_0$ are constant outside hot spots for a given radar sweep. In the suggested modified Hot-Spot method, the background values $\alpha_0$ and $\beta_0$ are determined using the Bringi et al. (2001) algorithm rather than considered constant for a particular radar sweep:

$$\alpha = \alpha^{opt} + \Delta\alpha \tag{3}$$

$$\beta = \beta_{opt} + \Delta\beta \tag{4}$$

## 3. RESULTS OF HEAVY RAIN EVENTS

In this study, the performance of different attenuation / differential attenuation correction schemes at C band is tested on 3 cases. The first case is the heavy rainfall event at 0149 UTC on 08/05/2008 in the Chicago Illinois, metropolitan area. The second case is the strong storm case at 0427 UTC on 03/10/2009 in the central Oklahoma. The last one is the flash flood case at 1202 UTC on 06/14/2010 in the central Oklahoma. Typical composite PPIs of Z, $Z_{DR}$, differential phase $\Phi_{DP}$, and $\rho_{hv}$ measured at C bands are shown in Figs. 1 – 3.

The simple version of polarimetric method for attenuation correction (Bringi et al.1990), self-consistent method (Bringi et al. 2001), Hot-Spot method (Ryzhkov et al. 2006, 2007; Gu et al. 2011), and modified Hot-Spot method are tested in all cases. The self-consistency between radar polarimetric variables and consistency with S band radar data are used for validation. The results of consistency checks are displayed in Figs. 4 – 6. In the Chicago case, the Bringi et al. (2001) self-consistent method underestimates $Z_{DR}$ values at high Z. The median values of corrected $Z_{DR}$ seem to be more realistic if the Hot-spot and modified Hot-spot methods are utilized.

In the Oklahoma cases, the self-consistent, Hot-spot and modified Hot-spot methods show good results. However, in the high Z area, the Hot-spot and the modified Hot-spot methods demonstrate better performance. It means the correction factors α and β have to be considered carefully in strong rain cells. The performances of the Hot-spot and the modified Hot-spot methods are very similar with the modified Hot-spot method yielding somewhat smaller biases.

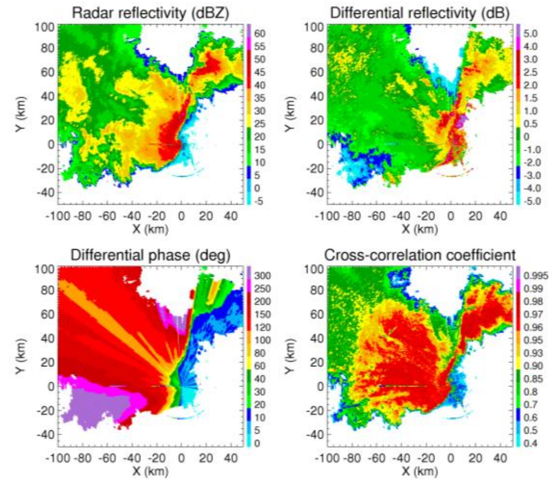


Fig.1. Composite plot of Z, $Z_{DR}$, $\Phi_{DP}$, and $\rho_{hv}$ measured at C band at elevation 0.99° on 08/05/2008, 0149 UTC.

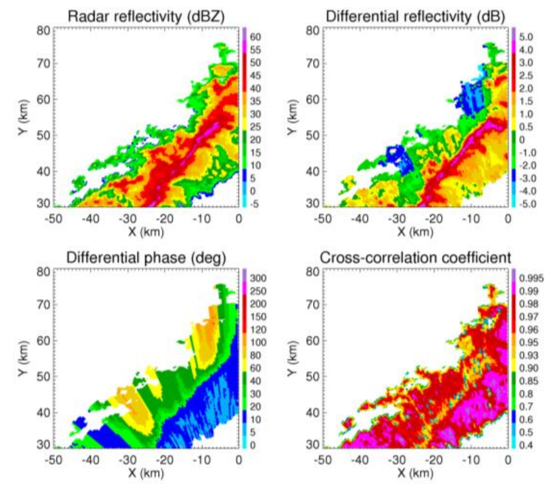


Fig.2. The same as Fig.1 but for 03/10/2009, 0427 UTC at C band at elevation 1.37°.

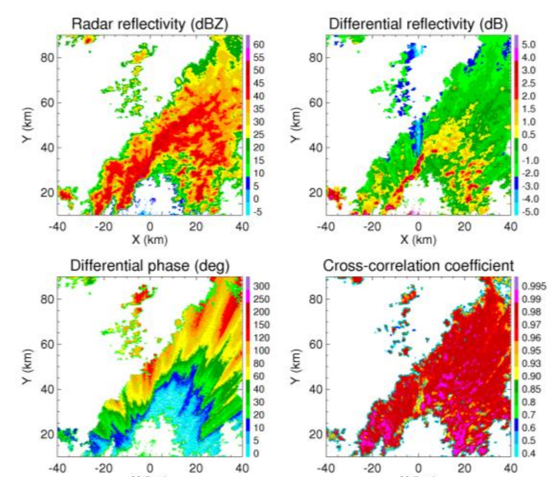


Fig. 3. The same as Fig.1 but for 06/14/2010, 1202 UTC at C band at elevation 1.37°.

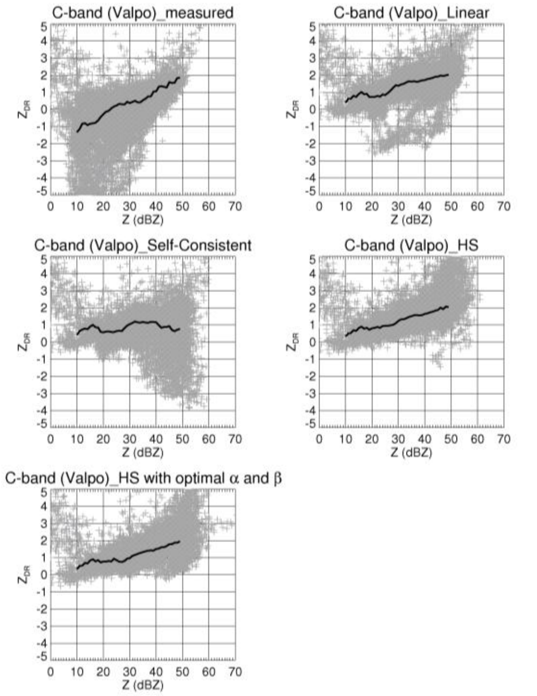


Fig. 4. Scatter plots of Z and $Z_{DR}$ for various attenuation correction schemes on 08/05/2008, 0149 UTC. Black solid line denotes the median values of $Z_{DR}$.

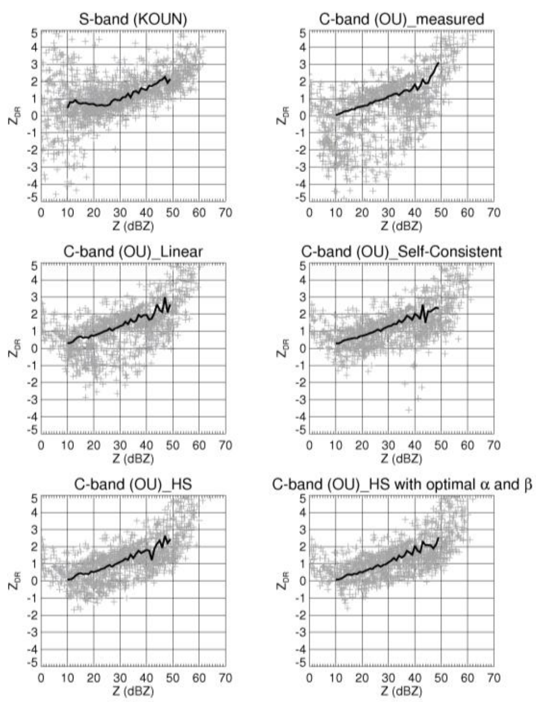


Fig. 5. Scatter plots of Z and $Z_{DR}$ measured at S band and retrieved using various attenuation correction schemes at C band on 03/10/2009, 0427 UTC. Black solid line denotes the median values of $Z_{DR}$.

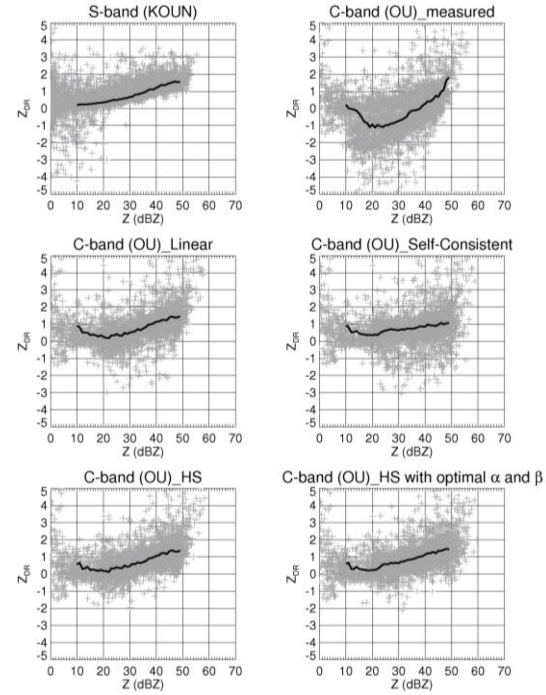


Fig. 6. The same as Fig. 5 but for 06/14/2010, 1202 UTC

One of the possible ways to assess the quality of attenuation correction is to convert corrected values of Z into rain rates and compare these with gage measurements. The Oklahoma Mesonet and Oklahoma City Micronet gage data were utilized as a ground truth for the flash flood rain event on 06/14/2010. Hourly rain totals estimated from gages and radar after reflectivity factor is corrected for attenuation using different schemes are compared in Fig. 7. The following R(Z) relation has been utilized for radar rainfall estimation at C band

$$R(Z) = 1.69^{-2} Z^{0.717} \qquad (5)$$

Apparently, there is not much difference in the scatterplots obtained after linear correction with α = 0.072 dB/deg, self-consistent, and original hot-spot methods. The modified hot-spot method yields smaller negative bias. The problem in interpreting these results is that the R(Z) relation itself may produce underestimation of rain (as the results for S band show) even for perfectly corrected reflectivity. The Hot-spot and the modified Hot-spot methods show small biases. However, in high rainfall region, the modified Hot-spot method shows good performance.

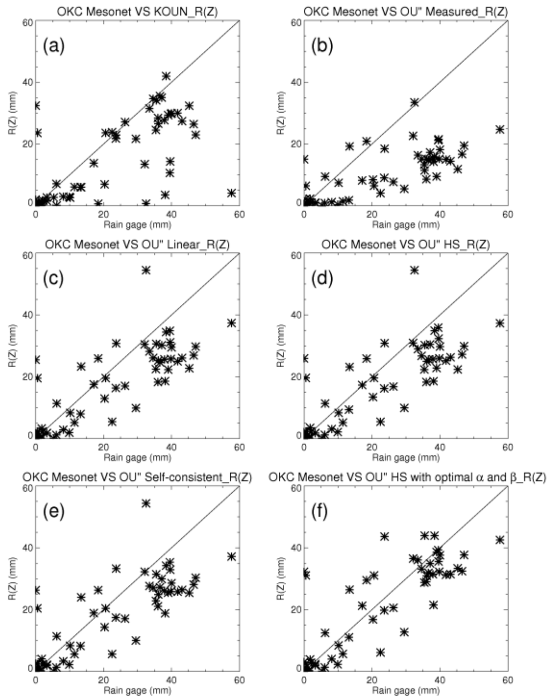


Fig. 7. Scatter plots of hourly rain totals measured by gages versus their radar estimates obtained for different attenuation correction schemes.

## 4. SUMMARY AND DISCUSSION

Validation of several attenuation correction schemes at C band has been performed using data collected by C band polarimetric radars in the Chicago metropolitan area and central Oklahoma. The data were collected by polarimetric radars belonging to the University of Valparaiso and University of Oklahoma (OU PRIME).

Four different polarimetric attenuation correction methods are tested including simple linear correction (Bringi et al. 1990), self-consistent method with constraints (Bringi et al. 2001), Hot-spot method described by Gu et al. (2011), and a newly suggested modified hot spot method. The self-consistent, Hot-spot, and modified Hot-spot methods demonstrate good performance. In the high Z areas, the Hot-spot and modified Hot-spot methods may perform better which underscores the need to treat strong cells separately in the attenuation correction techniques.

In the case of flash flood in Oklahoma City on 06/14/2010, attenuation correction according to the modified hot spot method results in the least biased estimates of hourly rain total by the R(Z) relation as the comparison with gages indicates.

## 5. ACKNOWLEDGMENTS

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