Introduction
In spring 2013 all 122 NWS WSR-88D radars have been upgraded by adding dual-polarization capability. The improvement of quantitative precipitation estimation (QPE) with dual-polarization measurements is one of the primary goals of the upgrade. In addition to radar reflectivity, differential reflectivity, and specific differential phase, the specific attenuation $A$ emerges as a promising variable for a more accurate QPE. The specific attenuation can be reliably estimated by a polarimetric radar from the combinations of the measurements of radar reflectivity and total differential phase. The advantages of the $R(A)$ estimator of rain rate $R$ include its low sensitivity to DSD variability and immunity to partial beam blockage, radar miscalibration, and impact of wet radome. Dual-polarimetric observations by several upgraded WSR-88D radars are utilized to examine the performance of $R(A)$. The results of observations confirm all mentioned benefits of the $R(A)$ technique. To validate the accuracy of $R(A)$ estimate under different atmospheric conditions, the $R(A)$ rainfall accumulations have been obtained for the events with different precipitation types and compared with rain gauge measurements. The results are promising, especially in the areas affected by partial blockage of the radar beam.

Methodology

In pure rain

Specific Attenuation:

$$
A(r) = \left( \frac{Z_{\text{rad}}(r)}{r^2} \right)^{\frac{1}{2}} \exp(0.29a_{\text{att}}\Delta \Phi) - 1
$$

$$
I(r_1, r_2) = 0.46b \int \left( \frac{Z(s)^{1/2}}{s^{3/2}} \right) ds
$$

Rain Rate:

$$
R(A) = 4.12 \times 10^3 A^{0.63} \quad T=20^\circ C
$$

$$
R(Z) = 1.69 \times 10^{-2} Z^{0.717}
$$

Conclusion
Although the $R(A)$ method may fail in hail region and its accuracy may be affected by precipitation type or atmospheric temperature, compared with the existing dual polarimetric QPE estimators based on $Z$, $Z_R$, and $K_{DP}$, the $R(A)$ estimator has advantages being immune to radar miscalibration, partial beam blockage, attenuation, and wet radome as many case studies indicate. The method only requires the radial profile of measured reflectivity and total span of differential phase along a radar beam in pure rain environment. This method is also applicable for $C$ and $X$ band dual polarimetric radars.

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