Technical Challenges in Transferring of the R(A) Methodology for Rainfall Estimation to Operational Weather Radar Systems

Pengfei Zhang, Alexander Ryzhkov, Stephen Cocks, and Lin Tang

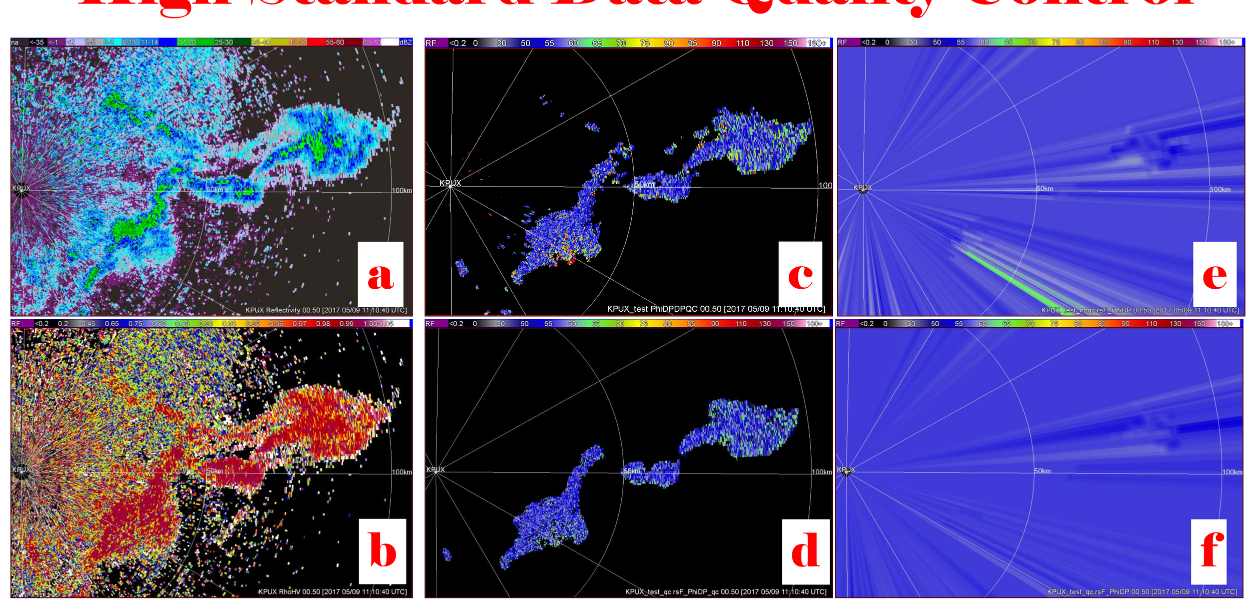
CIMMS, University of Oklahoma, Norman, Oklahoma

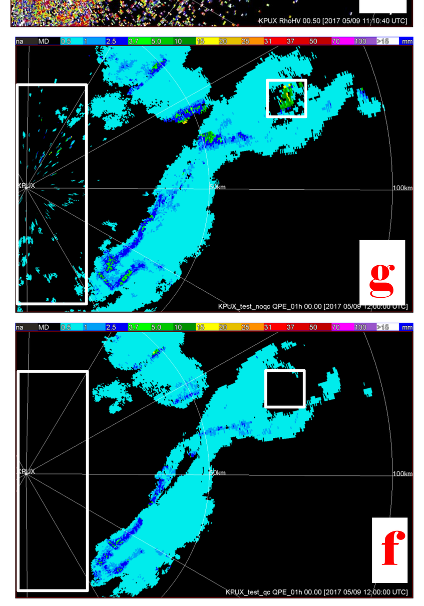
Abstract

The technique for using specific attenuation *A* for rainfall estimation R(A) for S-, C-, and X-band polarimetric radars (Ryzhkov et al. 2014) has been recently introduced and widely adopted internationally. The merits of the method include its immunity to attenuation, radar calibration errors, partial beam blockage, and wet radome. The algorithm has been developed and is planned to be deployed on a whole fleet of the WSR-88D operational radars. Many cases with different precipitation types over CONUS in different climatically regions have been selected to evaluate the robustness and performance of R(A) for WSR-88D radars. Many issues which affect the accuracy of R(A), such as hail contamination, automatic estimation of the net ratio $\alpha=A/K_{dp}$ which varies with drop size distributions and is a key parameter for rain rate estimation using the R(A) method, automatic determination of the range interval of the R(A) applicability, etc., are discussed and addressed.

To minimize the contamination from hail, segmentation of the ray is needed and the $R(K_{dp})$ relation is used in hail-affected area. Integration in the ZPHI formula for estimation of A has to be performed only over the rain range intervals and the contribution of hail to the total span of differential phase should be subtracted. Although the magnitude of a depends on differential reflectivity Z_{dr}, a slope of the Z_{dr} dependency on Z is utilized to estimate a in order to avoid Z_{dr} calibration errors. Linear and nonlinear relations between Z-Z_{dr} slope and a have been selected. Thus an optimal value of a is automatically estimated for each radar scan. It has been found that continuous refinements of R(A) are definitely needed before and after the transfer to an operational system.

High Standard Data Quality Control



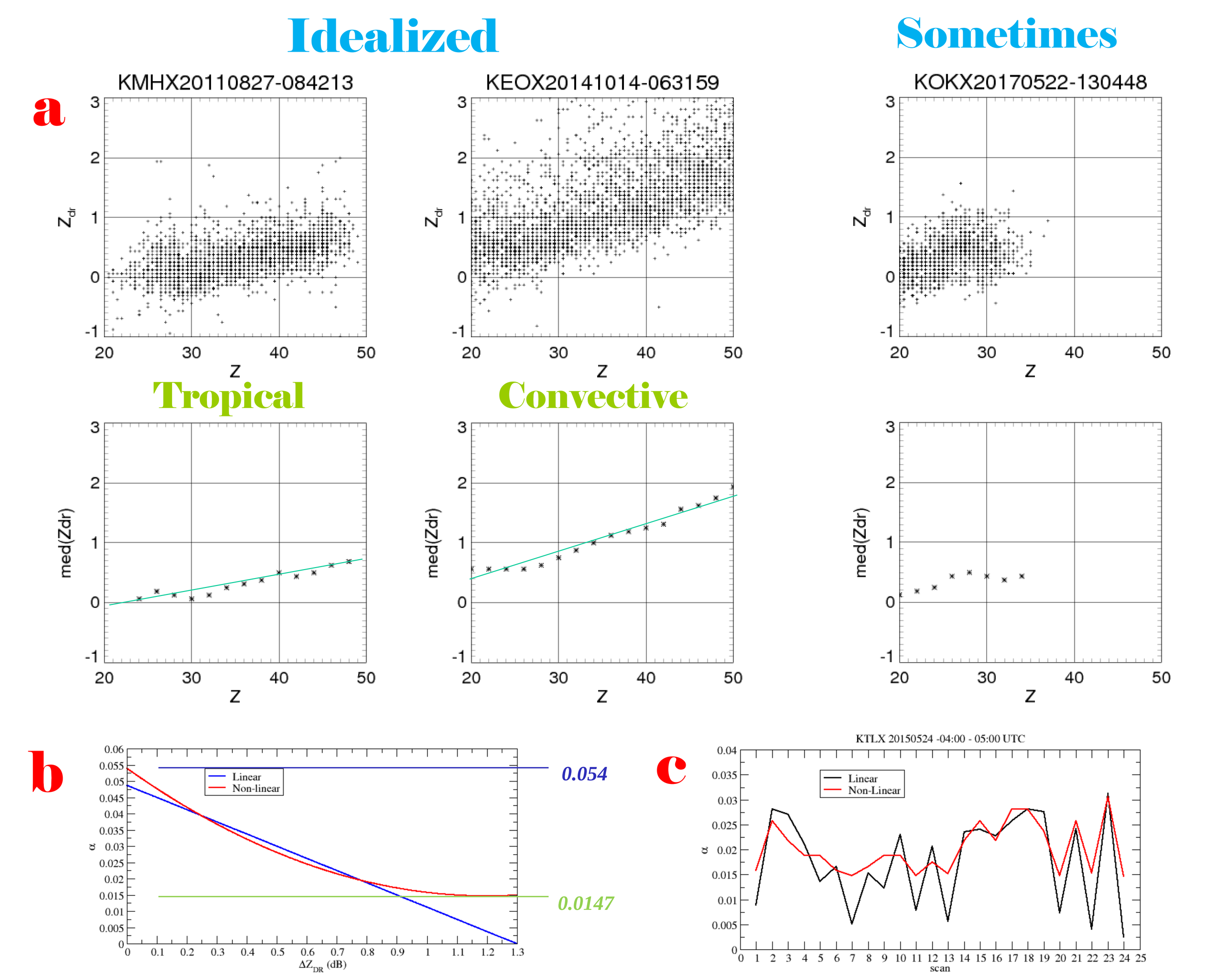


(a) Reflectivity, (b) ρ_{hv}, (c) Φ_{dp} before improved QC, (d) Φ_{dp} after improved QC, (e) processed Φ_{dp} before improved QC, and (f) processed Φ_{dp} after improved QC at 11:10 UTC on 9 May 2017 at elevation angle of 0.5º for KPUX radar. One hour accumulated rainfall amount (g) before/(f) after improved QC between 11:00-12:00 UTC on 9 May 2017.

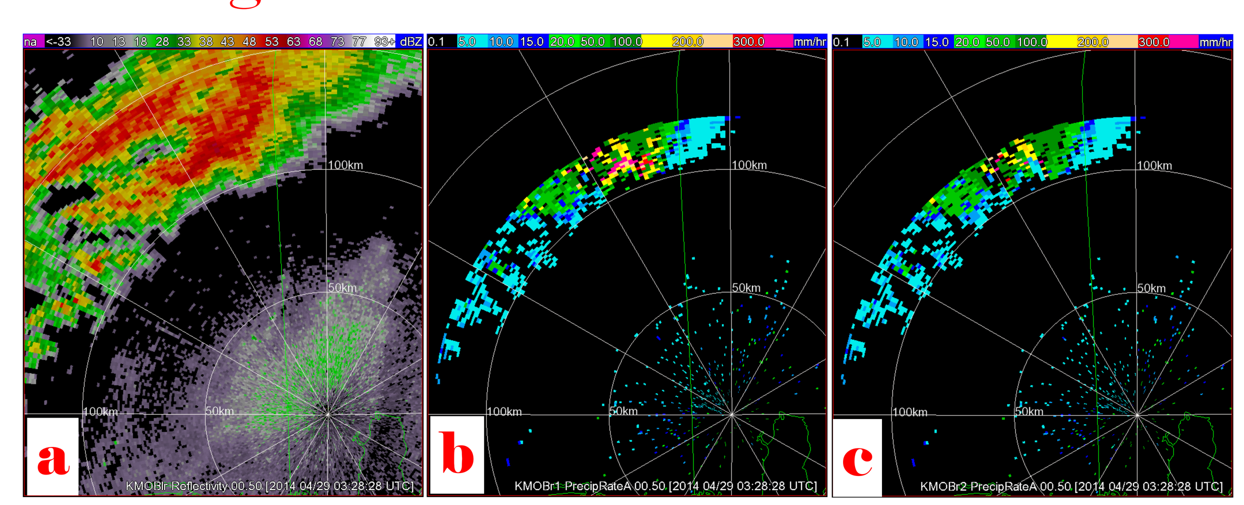
High quality of data quality control is critical to produce accurate R(A) QPE because a missed QC gate will affect QPE not only at the gate itself like traditional R(Z), but also along the whole radial where bad gate is. After fully cleanup of clear air echoes in the white boxes showed in panel (g) and (f), the accuracy of R(A) QPE in the entire domain has been improved.

Dynamical Determination of α

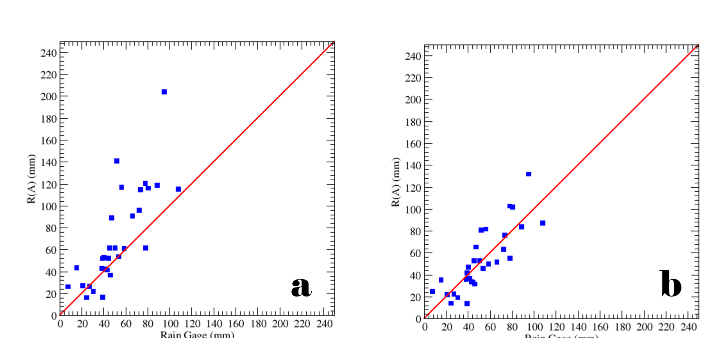
In order to catch the variability of drop size distribution in different types of precipitation and avoid the sensitive calibration of Z_{dr}, the slope of Z-Z_{dr} pairs for each scan at elevation angle of 0.5º is estimated (a) and then utilized to determine the parameter α the ZPHI formula (b). Sometimes due to lack of strong echoes (3rd panel in (a)) or not enough number of Z-Z_{dr} pairs in certain scans, default value of α is adapted. A time series of estimated α for KTLX observation between 04:05 UTC on 24 May 2015 at elevation angle of 0.5º is displayed in (c).



Mitigation of Hail Contamination

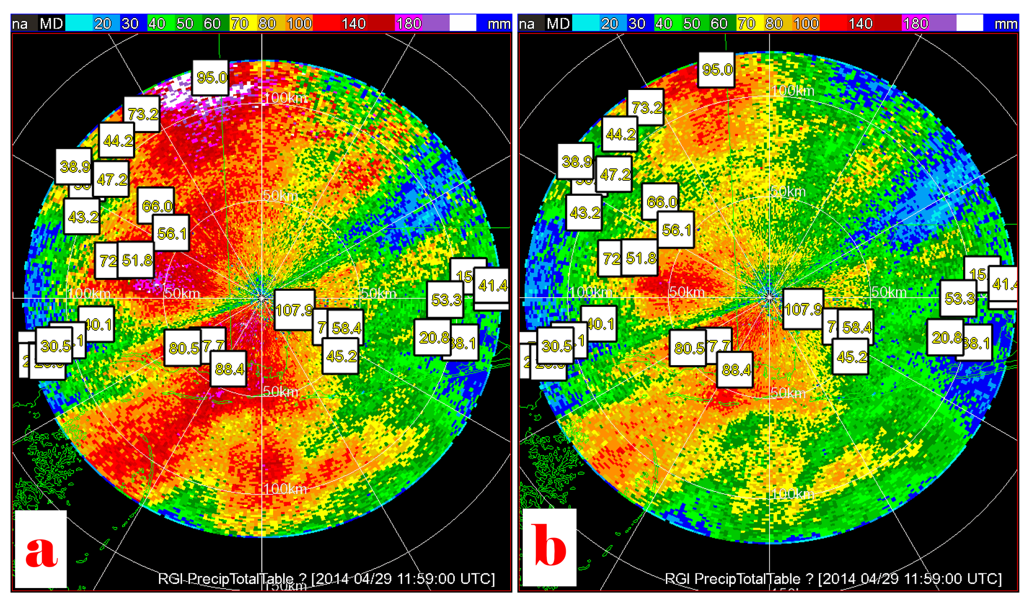


Composite PPI of (a) reflectivity Z, (b) R(A) without removal of hail contribution on $\Delta\Phi_{dp}$, and (c) R(A) after removal observed and estimated at KMOB radar at 03:28 UTC on 29 April 2014 as a squall line approaches Mobil, Alabama. Because R(A) algorithm is a radial-based algorithm, rain rate at gates without hail becomes distorted high (pink gates in panel b) if $\Delta\Phi_{dp}$ contributed from hail (Z > 50 dBZ) is not subtracted from total $\Delta\Phi_{dp}$. For example, total $\Delta\Phi_{dp}$ is 57.8 deg in azimuth of 333 deg. The $\Delta\Phi_{dp}$ contributed from 9 gates where Z > 50 dBZ (hail) is 53.8 deg.



12:00 – 12:00 UTC	*Correlation*	*BiasRatio*	*FRMSE*	*MFRMSE*
R(A) w/ simple HCA	0.800	1.364	0.661	0.315
R(A) w/ simple HCA and removed hail contribution on Φ_{dp}	0.829	1.026	0.311	0.209

Scatterplot of 24-hr rain totals measured by 30 rain gauges versus their estimates by the KMOB WSR-88D radar using the R(A) algorithms without (a)/with (b) hail contribution removal for the 28 April 2014 event. R(A) with α = 0.015 dB/deg is used. The statistical scores are listed below. It can be seen overestimation caused by hail contamination has been corrected after removal of the hail contribution on total $\Delta\Phi_{dp}$.



The fields of 24 hours (12 UTC April 28 – 12 UTC April 29, 2014) rain total estimated from the R(A) without (a)/with (b) hail contribution removal at KMOB radar.

Summary

		G/Q	MAE	CC
5/19/2017	Q3RAD	0.939	0.167	0.887
	Q3DP	0.993	0.156	0.906
5/20/2017	Q3RAD	1.055	0.204	0.898
	Q3DP	1.026	0.193	0.915
5/21/2017	Q3RAD	1.022	0.192	0.898
	Q3DP	0.970	0.184	0.923
5/22/2017	Q3RAD	1.082	0.177	0.850
	Q3DP	0.997	0.151	0.889

Now R(A) algorithm is on testing stage and will be the cornerstone of dual-polarimetric QPE in MRMS (Multi-Radar/Multi-Sensor) operational system. After implement of latest version of R(A) in MRMS, a 4 days QPE evaluation over CONUS domain is listed above. It can be seen the new $R(A)+R(K_{dp})+R(Z)$ synthetic QPE (Q3DP) performs consistently better than multi-R(Z) (Q3RAD) in warm environment especially with heavy rain. But we also found that there seems to be a persistent issue of Q3DP (R(A)) underestimation for light rain in the cool environment. There are more challenges on the way to keep improving the accuracy of operational R(A) such as determinations of inhomogeneous height of melting layer bottom, spatially varied parameter α when stratiform and convective rain coexist in one radar scan, and etc.

Reference:

Ryzhkov, A., M. Diederich, **P. Zhang**, C. Simmer, 2014: Potential utilization of specific attenuation for rainfall estimation, mitigation of partial beam blockage, and radar networking. *Journal of Atmospheric and Oceanic Technology*, **31**, 599–619.

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