P9R.12 POLARIMETRIC RAINFALL MEASUREMENTS IN LOCALIZED STRONG CONVECTION

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1. Introduction

The Joint Polarization Experiment (JPOLE) provided strong validation of polarimetric estimates of rainfall (Ryzhkov et al. 2005). Particular success was achieved if the combination of radar reflectivity Z, differential reflectivity Z_{DR}, and specific differential phase K_{DP} were used according to a “synthetic” algorithm. Optimal performance of this synthetic algorithm was observed at close distance to the radar where melting layer contamination was negligible.

Although JPOLE findings favor the polarimetric estimates over the conventional one, there were unexplained outliers. In this study, we examine possible origins of such outliers. We use data from the polarimetric prototype of the WSR-88D radar (KOUN) and well-calibrated Agricultural Research Service (ARS) rain gage network in central Oklahoma. The ARS gages are located at close distance to the KOUN radar which mitigates melting layer contamination.

2. Origins of Rainfall Estimate Outliers

Outliers in the polarimetric rainfall estimates originate from various sources. The ones rooted in radar miscalibration and contamination from hail, frozen, or melting hydrometeors are common to both polarimetric and conventional estimates and are not examined in this study. Rather we focus on additional sources of error in polarimetric rainfall estimates. Specifically we emphasize outliers stemming from the use of polarimetric K_{DP} measurements, which are immune to radar miscalibration, attenuation in rain, and partial radar beam blockage.

One possible cause of estimate outliers is inadequate radar sampling of precipitation. Small, but intense cells (either isolated or embedded), may be missed due to relatively coarse spatial and/or temporal resolution. In these situations, we anticipate that both conventional and polarimetric estimators fail. An example of this problem is found in Figure 1, which highlights an hour of ARS network rainfall results for a JPOLE event on 5 June 2003. Scan-by-scan analysis (as in the lowest panel of Figure 1) reveals that the highlighted gage locations continually remain on the periphery of the more intense cells at scan updates, perhaps explaining the lower hourly radar-based accumulations.

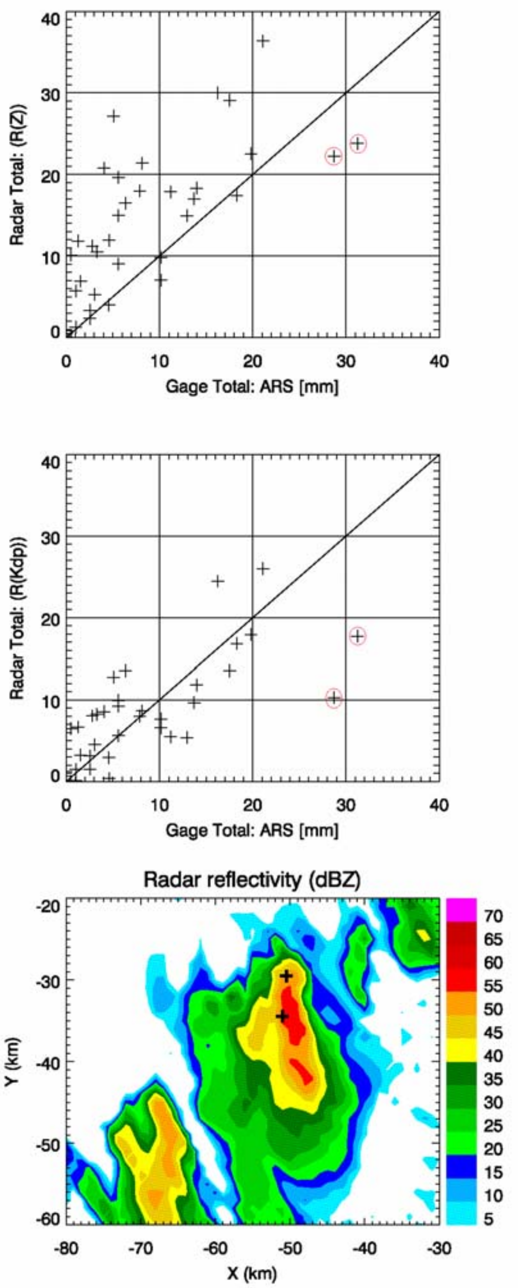

Figure 1: ARS rainfall results for the 5 June 2003 JPOLE event. Circled radar estimates underestimate gage totals, possibly because the gages are located at the periphery of the convective cells for available scans.

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Deficiencies in conventional K_{DP} processing may also introduce large errors in polarimetric rainfall estimates. In addition to noisiness of K_{DP} measurements at lower rainrates, errors in K_{DP}-based rainfall accumulations may result from coarse K_{DP} radial resolution and a vulnerability of K_{DP} to nonuniform beam filling. The former deficiency produces a smoothing effect for K_{DP}-based rainfall estimates in range, manifesting as underestimates of rainfall at the core of intense cells and overestimates at their periphery (e.g., Gorgucci et al. 2000). Nonuniform beam filling commonly manifests as spurious rainfall rate maxima and minima, minima often visible as non-intuitive negative rainrate estimates (Ryzhkov 2005). Both deficiencies are most pronounced in the cases of strong isolated convection and at longer distances from the radar. A more detailed discussion of these errors in K_{DP} processing is presented by Ryzhkov (2005).

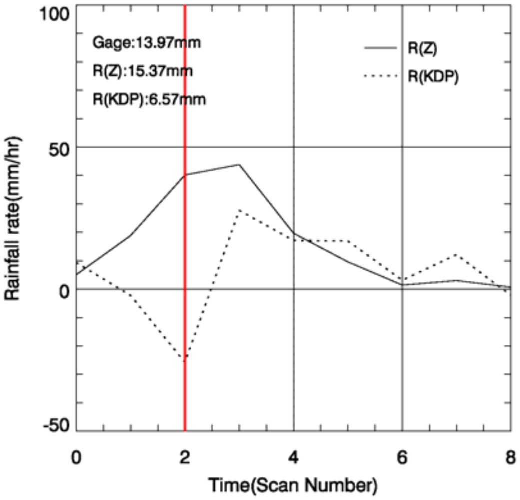

Figure 2: R(Z) and R(K_{DP}) rainfall rate estimates for a single gage location. Total gage and radar hourly accumulations are also plotted. Scan time with a pronounced negative rainrate is highlighted in red.

Figure 2 provides rainfall rate versus scan time over a gage location for which processing deficiencies in K_{DP} are observed. Over the example gage, negative values of K_{DP} are measured behind a strong convective cell, which results in a localized negative rainfall rate estimate for a single scan (highlighted with a red line) and an overall lower total radar rainfall accumulation for the hour. The corresponding K_{DP} field over the ARS network for this highlighted scan time is presented in Figure 3.

Additional outliers in polarimetric rainfall estimates may be attributed to unusual drop size distributions (DSDs) dominated by large drops, associated with very high values of Z_{DR}. In these situations, as illustrated in Figure 4, conventional R(Z) radar algorithms overestimate rainfall, whereas polarimetric methods which capitalize on Z_{DR} tend to underestimate rainfall due to the large Z_{DR} values. Possibly a weaker dependence on Z_{DR} would alleviate this problem? But finding a suitable polarimetric relation from disdrometer measurements is difficult because these instruments inadequately sample large raindrops (exceeding 3 mm). Further, radar observations indicate that areas containing large drops can be relatively confined and/or located at the periphery of high reflectivity cores. We note that obtaining reliable measurements of K_{DP} is also challenging in these regions due to the aforementioned inadequate radial resolution and nonuniform beam filling.

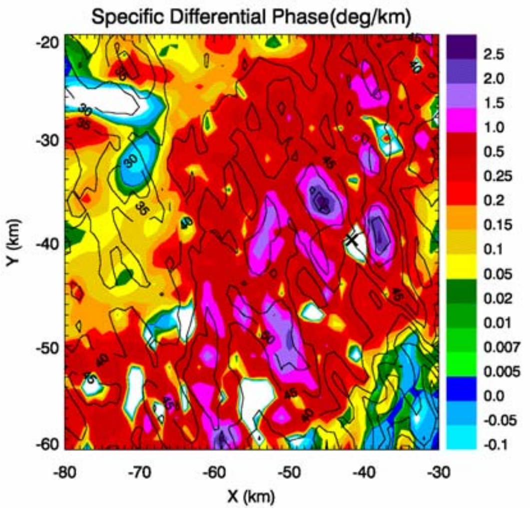

Figure 3: Plot of K_{DP} over the ARS network for the highlighted scan time in Figure 2. Corresponding gage location is denoted in the plot.

3. Overcoming Outliers in Polarimetric Rainfall Estimates

The previous section outlines several factors that may result in polarimetric radar rainfall estimate outliers. At present, little can be done to overcome inadequate temporal radar sampling of smaller-scale storm systems and their finer-scale evolution for operational WSR-88D radar rainfall estimation. Future platforms with faster update intervals may help alleviate these problems.

Outliers related to K_{DP} measurement errors and K_{DP} processing techniques are discussed in Ryzhkov (2005). As a first step, the Ryzhkov (2005) paper recommends avoiding noisy K_{DP} measurements in light rain, similar to what is described in the synthetic algorithm approach. The study also introduces improvements that require a significant change to the current methodology of differential phase processing. These changes capitalize on reflectivity measurements obtained at higher radial resolution to more precisely identify cell boundaries and address the smearing effects of conventional K_{DP} processing. Spurious K_{DP} measurement outliers associated with nonuniform beam filling are identified by comparisons of the performance of this new, more precisely cell-mapped

K_{DP}-based rainfall algorithm with a 'reference' estimate obtained by taking an average of a polarimetric R(Z, Z_{DR}) and conventional R(Z) estimate.

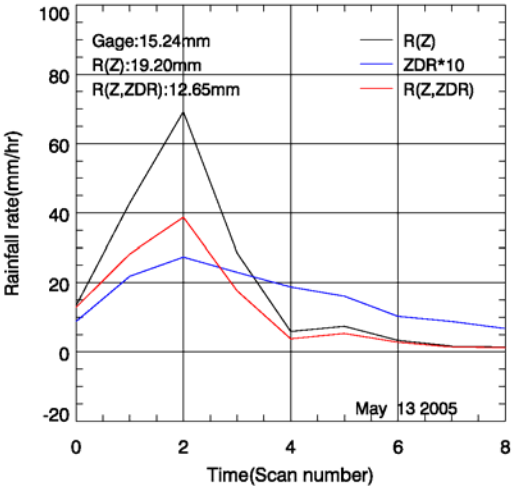

Figure 4: As in Figure 2, plot of R(Z) and polarimetric R(Z,Z_{DR}), for an event with moderate to high Z_{DR} values (mean Z_{DR} over the gage location plotted in blue). The conventional algorithm overestimates total accumulation, the polarimetric algorithm underestimates the total accumulation.

Following the Ryzhkov (2005) suggestions, several events observed by KOUN have been examined implementing the new K_{DP} processing guidelines. Figure 5 illustrates rainrate as a function of scan time for several gages as in Figures 2 and 3. Results from a conventional R(Z) and polarimetric R(K_{DP}) algorithms following traditional and the new methodology for K_{DP} processing are plotted, with hourly rainfall accumulations listed on the image to highlight improvements in the rainfall estimates. For these gages, a significant improvement in the K_{DP}-based rainfall estimate is typically observed, largely due to the correction of spurious negative values.

We note that while the improvements for gages with obvious negative outliers due to nonuniform beam filling are substantial, results across the remaining ARS network gages for several events are inconclusive. For select gages, the new K_{DP} approach creates problems for previously acceptable K_{DP}-based rainfall totals. These situations arise for gages where the reference estimate and a valid K_{DP}-based rainfall rate estimate differ by a substantial margin, which results in the K_{DP}-based estimate becoming invalidated. We anticipate similar errors may be most significant in regions of hail contamination, large drops, and in situations of Z and Z_{DR} calibration bias, e.g., circumstances when reflectivity-based estimates are less reliable references. Furthermore, this new approach to K_{DP} estimation requires additional study into potential rainfall estimate bias with these new measurements, its usefulness in synthetic-type rainfall estimators, and for the tolerance to which one considers these new K_{DP} estimates reliable.

Acknowledgments

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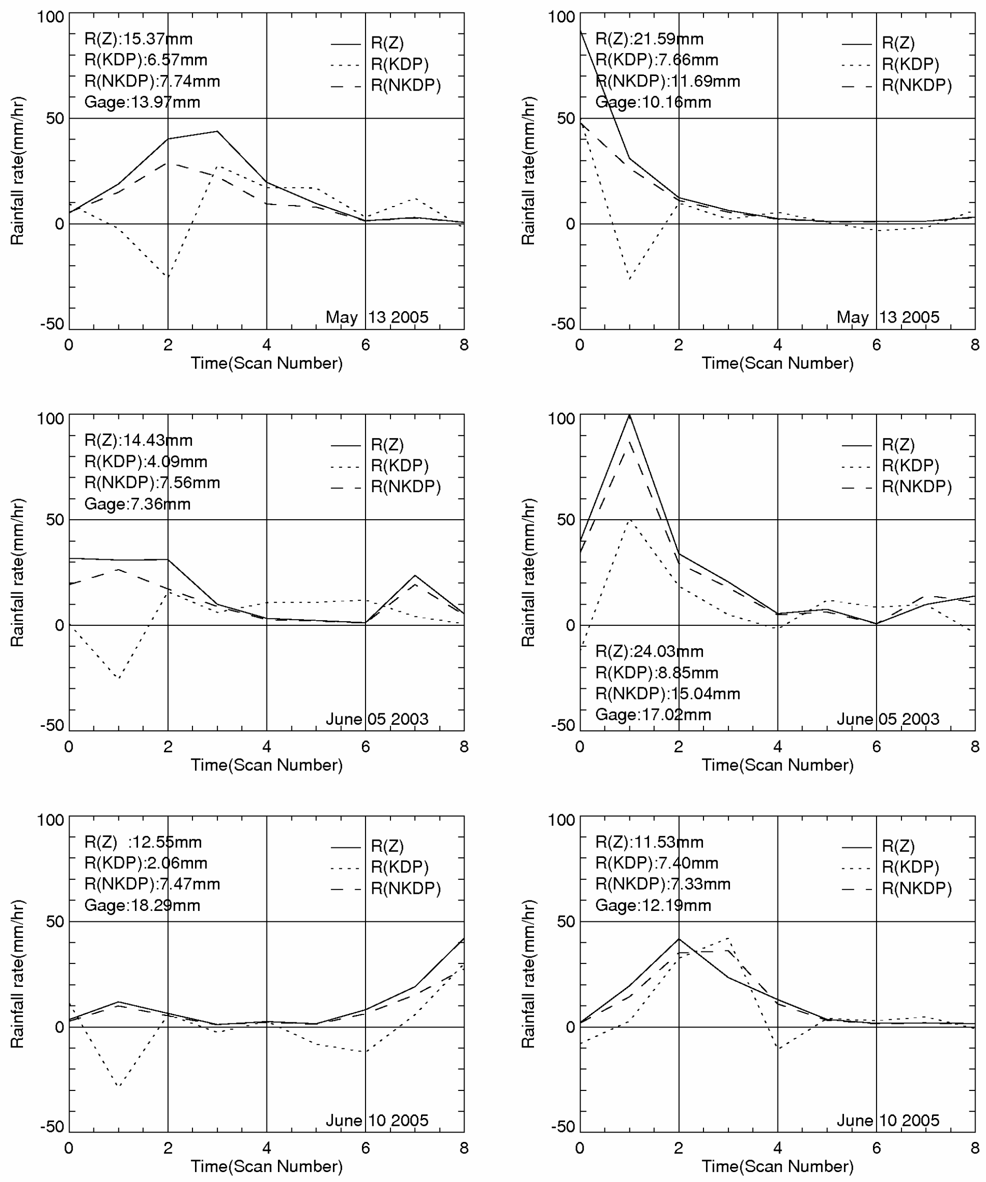

Figure 5: As in Figures 2 and 4, rainfall rate comparisons between R(Z), R(K_{DP}), and a modified R(K_{DP}) following the new approach to K_{DP} estimation of Ryzhkov (2005) for select gage locations with obvious processing outliers. Total hourly accumulations listed on the images.