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Rainfall estimation using a C-band polarimetric radar

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1. Introduction

This paper analyses one squall line event that occurred on 29 May 2011. Three radar rainfall estimators R(Z,Zdr), R(Zdr, Kdp) and R(Kdp) are used to retrieve instantaneous rainfall rates.

The rain retrieval algorithm used is independent of drop shape-size relationship, meaning that we do not need an a priori information about the equilibrium raindrop shape. Instead, it uses the capabilities of the polarimetric radar measurements to estimate a mean raindrop shape-size relationship and includes this information in the rainfall estimation algorithms. The form of the algorithms is given by eqs 1, 2 and 3.

$$R_\beta\left(K_{dp}, Z_{dr}\right) = c_3 K_{dp}^{a_3} 10^{0.1 b_3 Z_{dr}} \quad (1)$$

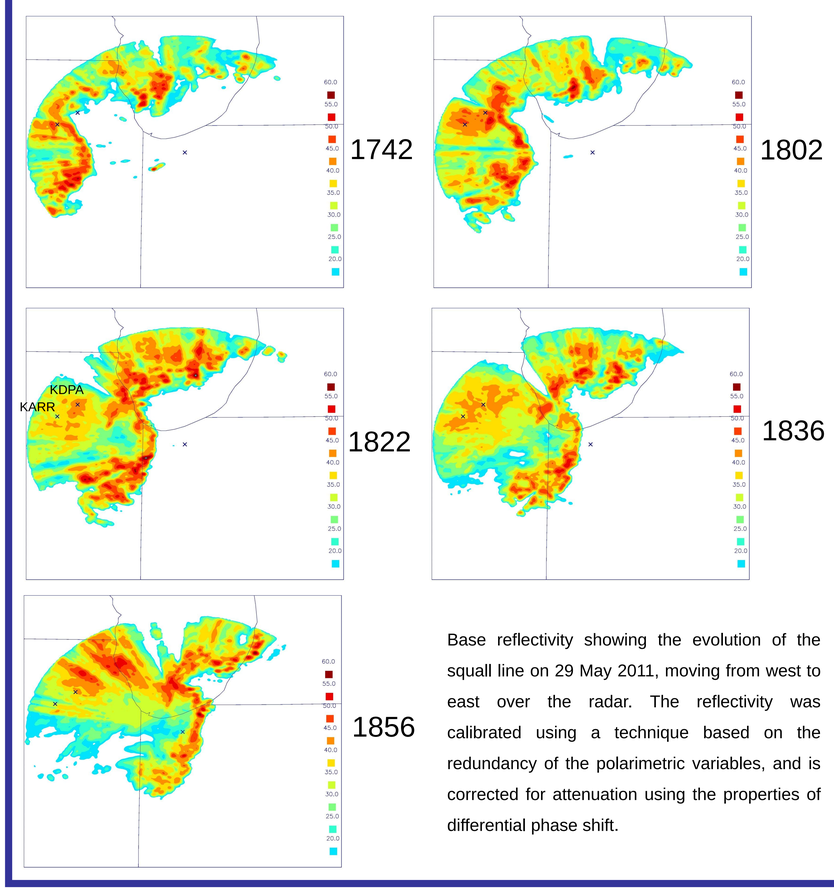
$$R_\beta\left(Z_h, Z_{dr}\right) = c_1 Z_h^{a_1} 10^{0.1 b_1 Z_{dr}} \quad (2)$$

$$R_\beta\left(K_{dp}\right) = c_2 K_{dp}^{a_2} \quad (3)$$

β, a parameter that relates axis ratio to equivolumetric spherical diameter, is estimated from Z, Zdr and Kdp. The coefficients (a_n, b_n, and c_n) in equations 1, 2, and 3 are dependent on β.

The coefficients were determined from simulations of radar measurements.

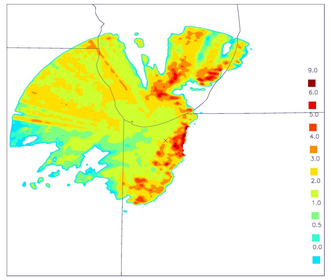
2. Evolution of the 29 May 2011 system



Base reflectivity showing the evolution of the squall line on 29 May 2011, moving from west to east over the radar. The reflectivity was calibrated using a technique based on the redundancy of the polarimetric variables, and is corrected for attenuation using the properties of differential phase shift.

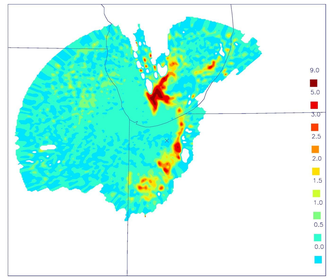
3. Polarimetric variables

Zdr 1856



Zdr at 1856 UTC. Zdr was calibrated at vertical incidence and corrected for differential attenuation.

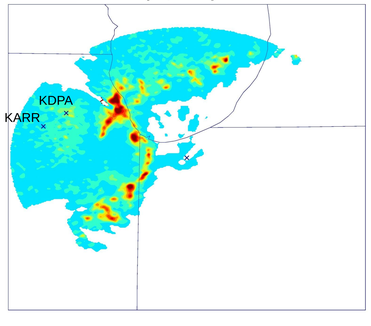
Kdp 1856



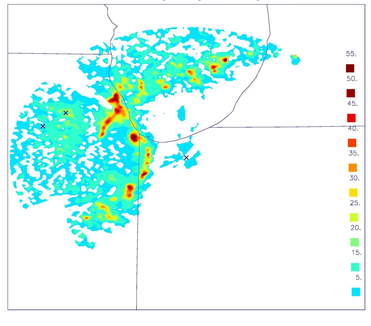
Kdp at 1856 UTC. Kdp, which is defined as the range derivative of the differential phase shift (Φdp), was computed by taking the difference between consecutive gates and dividing by the gate spacing, after properly filtering Φdp.

4. Rainfall Rate

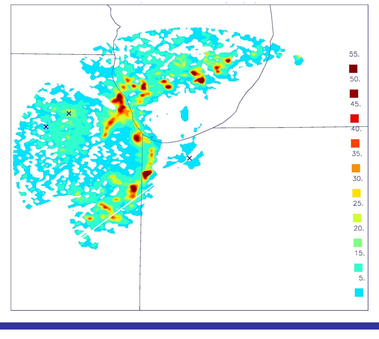
R(Z,Zdr)



R(Kdp,Zdr)



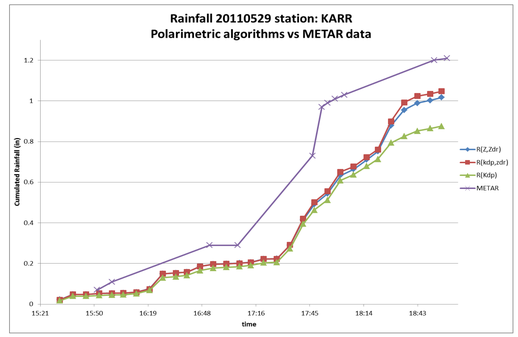
R(Kdp)

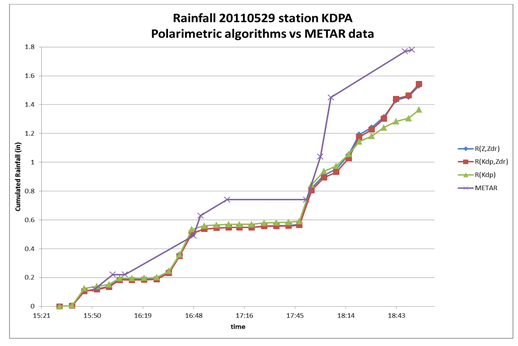


Rain rate in mm/h at 1836 UTC computed using the 3 algorithms. High rain rates (greater than 30 mm/h) are associated with the regions of convection and lower rain rates are seen in the rear of the system.

The blank areas in R(Kdp,Zdr) and R(Kdp) (no precipitation zones) appear as very low precipitation rates in R(Z,Zdr). This is due to negative Kdp values in those specific areas, likely due to the weak or even absence of rain.

5. Validation





Comparison between the observed rainfall and radar estimated with the 3 algorithms for 2 stations: Aurora (KARR) and DuPage (KDPA). The location of these station is shown in section 2 and 4. The estimated radar rainfall over each station was computed by finding the closest range and azimuth and averaging the rain rates of the 9 closest gates: 3 range bins along 3 contiguous rays. The rainfall accumulations are based on the assumption that the radar derived rain rate was constant over the period between the radar scans.

The three radar derived methods underestimate the amount of rain observed by the rain gauges. The amounts derived by R(Z,Zdr) are very close to the derived by R(Zdr,Kdp), while the amount calculated with R(Kdp) is a little below.

	KARR	KDPA
R(Z,Zdr)	0.338194	0.172944
R(Zdr,Kdp)	0.322148	0.17798
R(Kdp)	0.398572	0.185598

Normalized Bias

The NB associated with R(Z,Zdr) is very similar to the R(Zdr, Kdp), and the bias from R(Kdp) is slightly higher.

Still, the radar derived rainfall algorithms depict well the moments when rainfall was strong, and when it was steadier.

6.Discussion

All 3 algorithms underestimate the rain amount. The algorithms that use 2 of the radar measurements (R(Z,Zdr) and R(Zdr,Kdp)) perform sligthly better than R(Kdp), which uses only one radar variable.

We hypothesize that the discrepancy between radar derived rain accumulation and measured by rain gauge may not be due to the performance of the algorithm, but to some extent to the differences in the areal sampling of the 2 instruments, since the measured value from rain gauge represents a very small domain compared to that in one radar pulse volume (and noting that we used the average of the 9 closest gates).