P2B.14 EVALUATION OF AN OPERATIONAL POLARIMETRIC RAINFALL ALGORITHM

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1. INTRODUCTION

A number of studies have demonstrated improvement in rainfall estimation with polarimetric techniques compared to traditional horizontal reflectivity (Z_H) – rainrate (R) methods. However, the degree of improvement appears to vary with storm type and/or geographic location, and this topic continues to be an area of active research (e.g., Brandes et al. 2001; Ryzhkov and Zrnic', 1995).

Following the devastating Fort Collins flash flood in 1997, an algorithm was developed at Colorado State University (CSU) to estimate rainfall from CSU-CHILL dual-polarization radar data (Carey and Rutledge, 1998; Petersen et al. 1999). The flash flood event was unusual in it's drop size distribution characteristics and the polarimetric algorithm provided significantly improved rain accumulation estimates compared to the National Weather Service (NWS) NEXRAD Z-R technique. Over the last several years, the algorithm has undergone several iterations in order to make improvements in the estimation procedure.

During the summer of 2002, a UCAR-COMET grant provided an opportunity to apply the polarimetric algorithm in a real-time environment and quantitatively evaluate the performance in comparison to the standard NEXRAD Z-R technique on a variety of rainfall events in northeast Colorado. Maps of warm season accumulated rainfall are now generated routinely and are available at the CSU-CHILL web site (http://chill.colostate.edu/).

2. METHODOLOGY

The algorithm first attempts to remove ground clutter using thresholds on the correlation coefficient (ρ_{HV}) and standard deviation of the total differential phase (ϕ_{DP}) following Ryzhkov and Zrnic´ (1998). Specific differential phase (K_{DP}) is then calculated from ϕ_{DP}. The radar data are interpolated to a 2 km resolution Cartesian grid using the REORDER software package (Mohr et al. 1986) and rainfall estimates at each grid point at a height of 1 km AGL are determined using an optimization procedure (Chandrasekar et al. 1993; Carey and Rutledge, 1998; Petersen et al. 1999).

In the current form, the procedure picks the "best" estimate of rainfall based on measurement thresholds of K_{DP}, differential reflectivity (Z_{DR}), and horizontal reflectivity (Z_H) as shown in Fig 1. The fraction of ice at each grid point within the domain is determined from a difference reflectivity (Z_{DP}) relationship (Golestani et al. 1989), based on results from a severe northeast Colorado hail storm (Carey and Rutledge, 1998). The rain rate relations used in the algorithm are shown in Fig. 2.

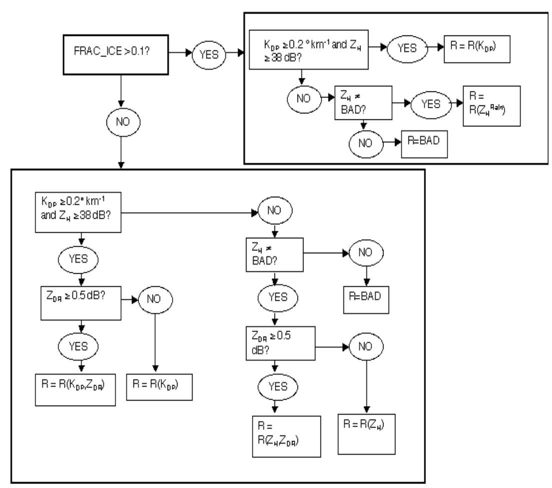

Figure 1. Flow diagram showing the polarimetric rainfall algorithm decision tree.

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A hydrometeor identification (HID) algorithm was also used to identify the presence of various forms of precipitation ice over the rain gauge networks for each event. The HID is based on the fuzzy logic approach of Liu and Chandrasekar (2000). For the purposes of this study, precipitation ice included the following categories: dry snow, wet snow, dry graupel, wet graupel, small hail, large hail, small hail and rain, and large hail and rain.

1. $R(K_{DP}, Z_{DR}) = 87.6 \cdot (K_{DP})^{0.934} \cdot (10)^{(0.1 \cdot -1.59 \cdot Z_{DR})}$ mm h^{-1}

2. $R(Z_H, Z_{DR}) = 6.70 \times 10^{-3} \cdot (Z_H)^{0.927} \cdot (10)^{(0.1 \cdot -3.433 \cdot Z_{DR})}$ mm h^{-1}

3. $R(K_{DP}) = 53.8 \cdot (K_{DP})^{0.85}$ mm h^{-1}

4. $R(Z_H) = 0.0033 \cdot (Z_H)^{0.7143}$ mm h^{-1}

Figure 2. Rain rate relations utilized in the CSU-CHILL rainfall algorithm. Equations 1-3 were taken from Bringi and Chandrasekar (2001), while equation 4 is the NEXRAD Z-R relation.

3. RESULTS

Validation of the polarimetric and NEXRAD Z-R rainfall algorithms was made using 24-hour accumulated precipitation data from the Community Collaborative Rain and Hail Study (CoCoRaHS - http://ccc.atmos.colostate.edu/~hail/), which includes hundreds of volunteers across northeast Colorado. A total of nine events were analyzed from the summer 2002 data set. The events ranged in duration from 2.5 to nearly 9 hours and the number of rain gauge reports for each event ranged from 32 to 250 (Fig. 3).

Inspection of Fig. 3 shows that the polarimetric technique performed better than the NEXRAD Z-R algorithm for most cases in terms of root mean square (RMS) and bias statistics; however, the improvement varies significantly from one event to another.

Because the events represented a large spectrum of precipitation types (light rain to rain mixed with hail), it was of interest to quantify the performance as a function of HID-derived precipitation ice over the rain gauge network. The amount of precipitation ice for each event compared to the difference in RMS between the NEXRAD Z-R and polarimetric techniques is shown in Fig. 4. As anticipated, the difference in the RMS between the NEXRAD and polarimetric techniques becomes large as the amount of precipitation ice in the rain gauge network increases. In situations where precipitation ice is present, the NEXRAD Z-R technique tends to overestimate rainfall significantly relative to the gauges and the advantage of polarimetric techniques utilizing methods that are largely immune to precipitation ice (i.e., K_{DP}) are apparent.

Event	NG	Time (hr)	RMS_N (mm)	RMS_P (mm)	$Bias_N$	$Bias_P$
020516	119	2.5	4.3	4.6	1.16	1.51
020603	107	8.75	10.6	15.0	1.05	0.81
020703	132	4.5	14.4	9.7	0.76	1.09
020710	100	3.0	15.0	8.6	0.70	1.30
020827	54	7.0	33.6	17.4	0.10	0.23
020828	32	6.25	6.9	5.6	0.53	0.70
020829	185	4.5	9.3	7.4	0.75	1.04
020912	250	8.5	17.6	11.6	0.47	0.65
020913	78	3.5	12.7	8.7	0.64	0.92
Average	**117**	**5.4**	**13.8**	**9.8**	**0.69**	**0.92**

Figure 3. Summary of rainfall events used in this study. "NG" refers to number of gauges and subscripts "N" and "P" denote NEXRAD and polarimetric, respectively. Bias is calculated as $\Sigma G/\Sigma R$, where "G" and "R" denote gauge and radar, respectively.

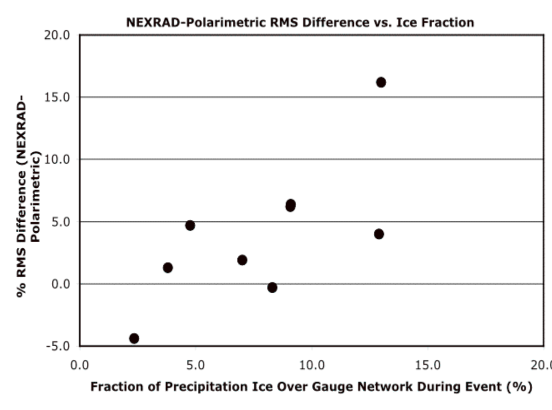

Figure 4. Scatter plot of percentage ice over rain gauge network during event vs. the RMS difference between the NEXRAD Z-R and polarimetric rainfall methods (NEXRAD RMS minus polarimetric RMS). Large positive values on the ordinate indicate large RMS errors in the NEXRAD method compared to the polarimetric method.

An example of differences in algorithm performance are shown in Fig. 5. This event (27 August 2002) contained the largest fraction of precipitation ice over the rain gauge network (~13%). Note that although significant improvement in rainfall accumulation occurs with the polarimetric method, this technique nevertheless produces a substantial high bias relative to the rain gauges (see Fig. 3). The reason for the overestimate is not clear, especially since the gauge network for this event is located 80-120 km from the CHILL radar. Because the majority of rainfall in all events is determined using the $R(Z_H\text{-}Z_{DR})$ technique (Fig. 6), it is possible that a Z_{DR} bias exists in the data, though calibration tests performed have not confirmed this. Another potential source of error is the $R(Z_H\text{-}Z_{DR})$ relation. If the assumed drop shape is more oblate compared to reality, the $R(Z_H\text{-}Z_{DR})$ relation will produce an overestimate of rainfall. A possible remedy for this effect would be to implement a variable correction for the drop shape with size relation as recommended by Gorgucci et al. (2000).

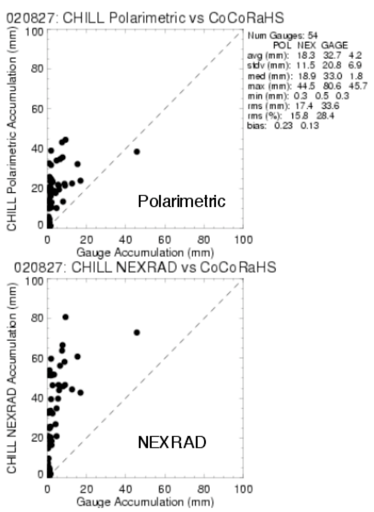

Figure 5. Scatter plot of rain gauge vs. radar accumulated rainfall (mm) using the polarimetric (top) and NEXRAD Z-R (bottom) techniques.

4. SUMMARY

The CSU-CHILL polarimetric rainfall algorithm has been tested on a number of events during the summer of 2002 in northeast Colorado. Comparisons with the NEXRAD Z-R technique shows that the polarimetric method is a superior measure of rainfall accumulation in most cases; however, the degree of improvement varies significantly with precipitation intensity and/or type. Moreover, identification of precipitation ice is important for identifying situations where the NEXRAD Z-R method will likely provide poor precipitation estimation, with resulting implications for NWS flash flood warnings. Additional testing of the CSU polarimetric algorithm is planned for the summer of 2003.

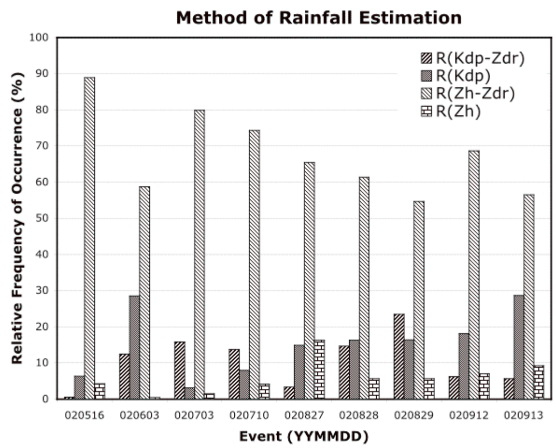

Figure 6. Relative frequency of occurrence of the rainfall estimation procedure used in the polarimetric algorithm for each event.

Acknowledgements

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