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MICROPHYSICAL CHARACTERIZATION OF A SQUALL LINE IN TRMM LBA USING DUAL-POLARIZATION RADAR MEASUREMENTS

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1. INTRODUCTION

Polarimetric radar measurements of the WET AMC and TRMM LBA field experiment campaigns in Rondônia, Brazil, were used to classify hydrometeors within the 26 January 1999 squall line (Pereira Filho et al. 2001). Two hydrometeor classification methods were tested. The one developed by Straka et al. (2000) is based on observations and modeling; hydrometeors are classified according to arbitrary boundaries in a multidimensional polarimetric space. The other was developed by Vivekanandan et al. (1999) and applies a fuzzy logic algorithm. Both methods are also compared to Citation II aircraft data.

2. METHODOLOGY

2.1 Rule-based Method

This method divides the polarimetric variables into subsets related to specific hydrometeor types. It was slightly changed to prevent classifying ice below the freezing level, and to reduce ambiguities since all polarimetric variables were used. Table 1 shows the polarimetric variables and hydrometeor types.

	Z_h	Z_{dr}	$\lvert\rho_{hv}(0)\rvert$	K_{dp}	LDR
Rain	<60	> 0	>0.95	>0	<-25
Hail	45-80	-2 - 0.5	<0.97	-0.5 - 1	>-26
Grpl/hail	20-50	-0.5 - 2	>0.95	0 - 1.5	<-20
R/wet hail	45-80	-1 - 6	<0.95	>0	>-25
Snow	<45	-0.5 - 6	>0.5	-0.6 - 1	<-20

Table 1: Rule-based hydrometeor classification method (Straka et al. 2000). Polarimetric variables are: Z_h = reflectivity (dBZ); Z_{dr} = reflectivity diff. (dB); $\lvert\rho_{hv}(0)\rvert$ = correlation coeff. (%); K_{dp} = specific diff. phase (º km^{-1}); and LDR = linear depolarization ratio (dB).

2.2 Fuzzy logic-based Method

The fuzzy logic-based method makes use of a smooth transition in polarimetric observable boundaries among precipitation types. It is capable of identifying a variety of precipitation types that include single, mixed phase precipitation and also non-precipitation targets such as insects and ground clutter. The method consist of three steps: **i)** Fuzzification: Uses membership function to determine the degree to which each polarimetric variable belongs to each fuzzy set (e.g. rain, hail, snow, clutter, etc.). It produces a value between 0 and 1 for each fuzzy set; **ii)** Aggregation: The results of fuzzification are multiplied by a predetermined weight and summed to produce a single value for each fuzzy set; and **iii)** Defuzzification: The fuzzy set with the maximum value is identified as the particle type for the specified input radar variables.

2.3 Data Sets

The radar data set was obtained with the S-POL (Lutz et al. 1997), a dual Doppler S-band radar. The in-cloud hydrometeor measurements were made with the University of North Dakota Cessna Citation II aircraft. A particle measuring system consists of four probes mounted on the wing-tip pylons that measure size and concentration of particles in the range of 1 μm to several mm in diameter. Only the 2-D cloud probe data was used in this work.

3. RESULTS

Cross sections of hydrometeor types by the rule-based and fuzzy logic-based methods are shown in Fig. 1 and Fig. 2, respectively. The freezing level on 26 JAN 1999 was around 4.5 km (not shown). The rule-based method indicated rain below the freezing level, with snow crystals and a mixture of rain and hail above. On the other hand, the fuzzy logic-based method indicated dry snow and irregular ice crystals above the freezing level, and drizzle, light rain and moderate rain below.

Moreover, in the leading edge of the squall line about 75 km from the radar (Fig. 2), a column of heavy rain, rain-hail, graupel-small hail and graupel-rain going from low-levels to almost 10 km high was detected. In this region a vigorous updraft supported the lofting of super-cooled rainwater into the mixed phase zone and subsequent production of ice via drop freezing. The heavy rainfall below is a consequence of the cold phase aloft. Ahead of the squall line between 40 and 50 km from the radar, both methods indicate ice crystals right above the freezing level of newly formed cells. The high ice water content above the freezing level, especially between 7 and 9 km in altitude could be related to higher lightning flash density (Petersen and Rutledge 2001; Baker et al. 1999).

The Citation II made a descending spiral in the squall line. Two samples were analyzed: one at 2131 UTC at an altitude of about 5.5 km, and another at 2150 UTC at an altitude of 3.0 km. The airplane was about 40 km north of the S-POL radar. Both 2-D sample images

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are shown in Fig. 3. The first sample indicated irregular ice crystals. The rule-based method indicated snow crystals and the fuzzy logic-based method, irregular ice crystals (not shown). In the second sample, droplets and one large drop are seen. In this case, the rule-based method indicated rain and the fuzzy logic-based method, light rain (not shown).

4. CONCLUSIONS

Both methods of hydrometeor classification indicated large amounts of ice above the freezing level in the leading edge of the squall line. Strong updrafts carry droplets above the freezing level to produce large amounts of ice particles aloft. Indeed, ice particles were detected right above the freezing level in the early stages of convective development. The fuzzy logic-based method indicated that mixed-phase hydrometeors might be responsible for heavy rainfall shafts below the freezing level in the mature phase of cells at the leading edge.

The 2-D cloud sample images are in good agreement with both hydrometeor classification methods. Further work is underway to improve the quantification of the precipitation based on these polarimetric measurements.

5. ACKNOWLEDGMENTS

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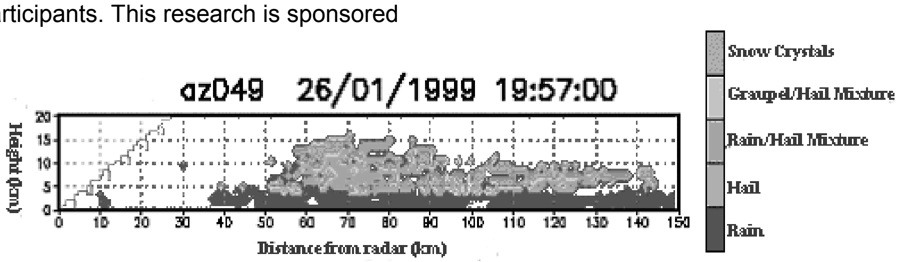

Figure 1: Hydrometeor cross-section classified by the rule-based method. The RHI at 49º azimuth on 1957 UTC 26 JAN 1999.

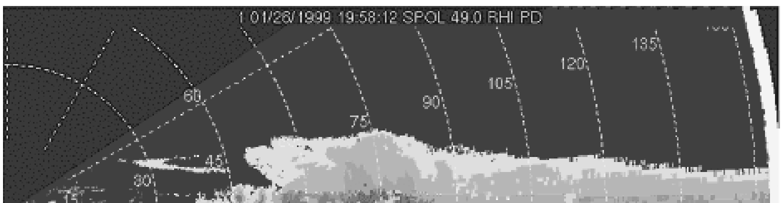

Figure 2: Cross-section of hydrometeor types classified with fuzzy logic-based method. The RHI at 49º azimuth on 1958 UTC 26 JAN 1999. The hydrometeor types are indicated: cld=cloud, drz=drizzle, lrn=light rain, mrn=moderate rain, hrn=heavy rain, hail=hail, rhm= rain-hail mixture, gsh=graupel-small hail, grn=graupel-rain mixture, dsn=dry snow, wsn=wet snow, icr= ice crystals, iicr=irregular ice crystals, sld=super-cooled liquid water droplets.

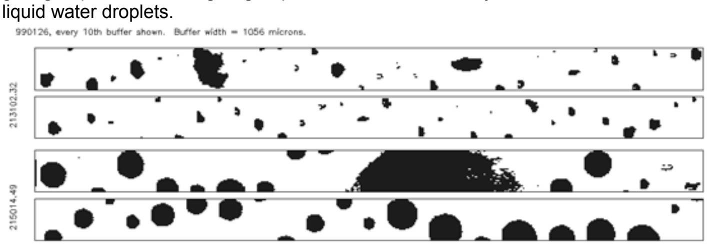

Figure 3: Sample images from the 2-D probe. The first two lines are at 2131 UTC, the third and forth at 2150 UTC on 26 JAN 1999.