P2.7 A STUDY OF PRECIPITATION MICROPHYSICS USING S- AND X- BAND POLARIMETRIC RADAR AND DISDROMETER MEASUREMENTS

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1. INTRODUCTION

Polarimetric radars measure reflectivity at horizontal polarization, differential reflectivity, specific differential phase, and copolar cross correlation coefficient that depend on cloud/precipitation physics (Cao et al., 2008; Zhang et al. 2001; Zrnic and Ryzhkov, 1999). While S-band polarimetric radar (like the WSR-88D) provides a large spatial coverage, a network of X-band radars offers finer resolution and better observations of low-level weather condition. A 2D video disdrometer (2DVD) provides accurate measurements of precipitation microphysics, including the shape, size and falling velocity of precipitation particles, which is essential for interpreting polarimetric radar data.

In this paper, we present observations and data analysis of 09 May 2007 rain event collected with an S-band radar, an X-band network and a 2DVD in Oklahoma. Storm structure and evolution are studied through polarimetric S- and X-band radar observations. Then, raindrop size distributions (DSDs) are retrieved from the S- and X-band polarimetric radar data (PRD). The retrieved rain DSDs are used to cross-verify the attenuation correction for the X-band measurement. Further, disdrometer data is used to validate the DSD retrieval of storm events. We also compare and evaluate the performance of the radars at two-frequencies for quantitative precipitation estimation (QPE).

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2. DATASET

Dataset used in this paper were collected with S-band polarimetric weather radar (KOUN), three X-band polarimetric radars, a part of the CASA Integrative Project One (IP1) testbed in southwest Oklahoma and a 2D video disdrometer. The disdrometer location was roughly at center of the triangle formed by three CASA IP1 radars (KSAO, KCYR and KRSP) located at Chickasha, Cyril, and Rush Springs, respectively. Their relative locations are shown in Fig. 1. The KOUN radar is located at (0, 0) point (upper right corner, outside of the picture), while disdrometer location is marked with "o" and three CASA radars with an "x". KSAO is located at the center of the picture, KCYR at left bottom corner and KRSP at bottom center. The KOUN and KSAO radar reflectivity was recorded for a rain event on May 9 2007 and their comparison is shown in Fig.1 and 2.

3. METHODOLOGY

Raindrop size distributions (DSDs) contain fundamental information associated with rain microphysics. In recent years, the gamma distribution has been widely accepted to model rain DSDs (Brandes et al. 2004). The gamma distribution has the form:

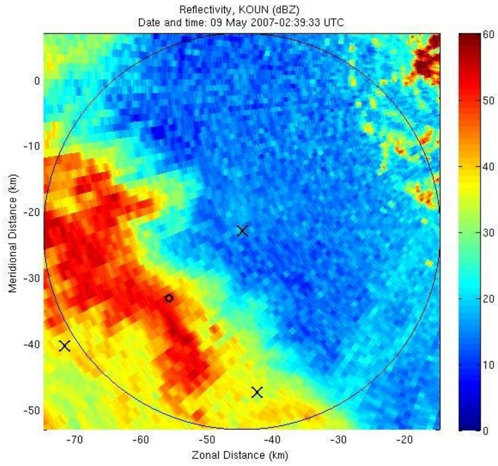

Figure 1: KOUN reflectivity at KSAO site (location of the KSAO radar is in the center of the picture). Black markers "x" represent location of the CASA radars. The middle marker "o" represents the disdrometer location. Elevation: 0.5°.

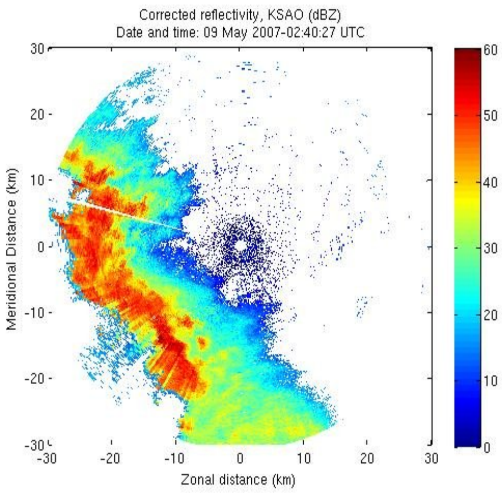

Figure 2: KSAO corrected reflectivity, Elevation: 2°

$$N\,(D) = N_0\,D^{\,\mu}\,exp\,(-\Lambda D), \qquad (1)$$

where $N(D)$ denotes the DSD, N_0 $(mm^{-1-\mu}\,m^{-3})$ is the number concentration parameter, μ is the distribution shape parameter, Λ (mm^{-1}) is the slope parameter and D (mm) is the equivalent volume diameter. In this paper we use the fallowing constraining relation (Cao et al., 2007):

$$\mu = -\,0.0201\Lambda^2 + 0.902\,\Lambda - 1.718 \qquad (2)$$

Thus, the gamma DSD model reduces to a two-parameter model whose parameters N_0 and Λ can be retrieved from the radar measured reflectivity at horizontal polarization (Z_H) and differential reflectivity (Z_{DR}). The dual-pol. integral equations for solving Λ and N_0 from Z_H and Z_{DR} are fallowing (Zhang et al. 2001):

$$Z_{h,v} = \frac{4\lambda^4}{\pi^4 |K_w|^2} \int_{D_{\min}}^{D_{\max}} |f_{hh,vv}(\pi, D)|^2\, N(D)dD \qquad (3)$$

$$Z_{DR} = 10\,log_{10}\,(Z_{hh} / Z_{vv}), \qquad (4)$$

where backscattering amplitudes are represented by $f_{pp}(\pi,D)$ where index *pp* represents either horizontal *(hh)* or vertical *(vv)* polarization, λ is the wavelength, $K_W = (\varepsilon_r - 1)/(\varepsilon_r + 2)$ where ε_r is the complex dielectric constant of water. The scattering amplitudes were calculated based on T-matrix method and used for the retrieval. The scattering amplitudes are shown in Fig. 3.

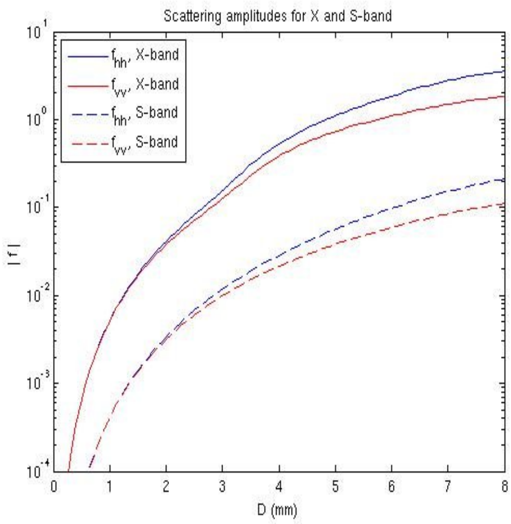

Figure 3: Scattering amplitudes for X and S band. Solid line represents the X band, dashed line the S band. Horizontal polarization: blue, vertical: red.

4. RESULTS

Case of rain event in 9 May 2007 is studied. Data were collected with disdrometer, S and X band polarimetric radars. Comparison of reflectivity (Z_H, PPI plot) and differential reflectivity (Z_{DR}, RHI plot), between two polarimetric radars, KOUN and KSAO are shown in Figs. 1, 2 and Figs. 4, 5 respectively at 02:40 UTC. The attenuation correction for X band can be verified in this way, since attenuation is not significant at S band frequency.

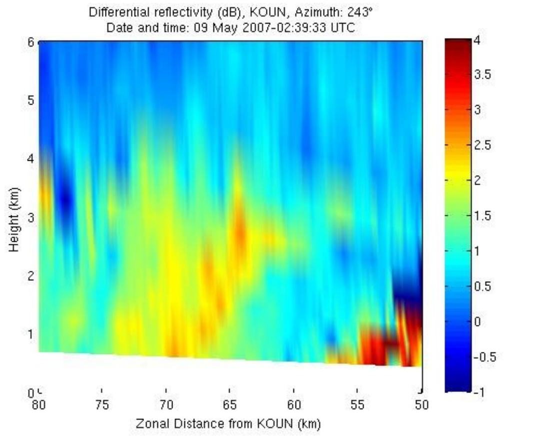

Figure 4: KOUN, Differential reflectivity at KSAO site, time 02:40 UTC, Azimuth: 243°

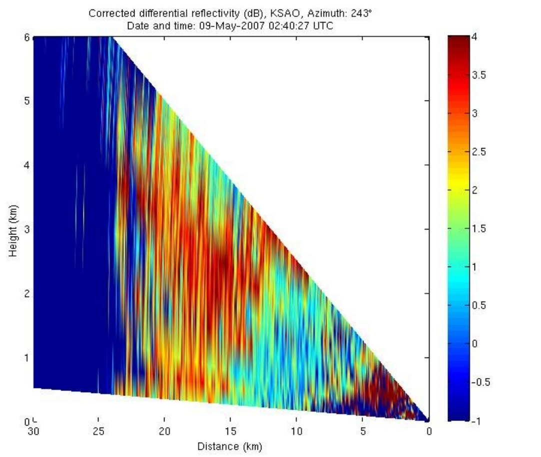

Figure 5: Corrected differential reflectivity, KSAO, time 02:40 UTC, Azimuth: 243°

As seen on Fig 1. S-band reflectivity and Fig. 2 corrected X-band reflectivity match very well. Corrected differential reflectivity at X-band has slightly higher values that of S-band (Figs. 4 and 5) which is expected if we look at the values (Fig. 3) of the scattering amplitudes for both frequency ranges.

Next, we'll look at the radar/disdrometer comparison. Disdrometer data are considered as a ground truth and lately, often used as verification of the radar measurements, in this case variables R and D_0 obtained from DSD retrieval. DSD retrieval is based on Z_{DR} -Λ and Z_H -N_0 -Λ dependence as shown in eq's 3-4.

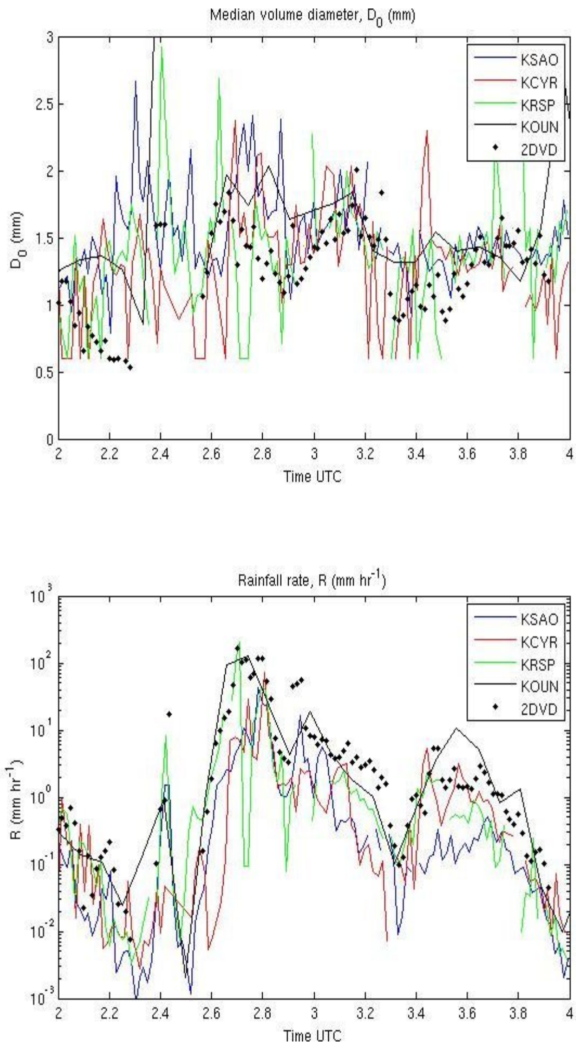

Figure 6: Comparison of rainfall rate and median volume diameter obtained from radar DSD retrieval (three CASA radars and KOUN) and disdrometer, time series

Comparisons between S- and X-band DSD retrievals and 2DVD measurements of rainfall-rate R and median volume diameter D_0, are shown in Fig. 6. As we can see, results are in fair agreement. Median volume diameter is slightly overestimated with radars, although it seams that KOUN values are closer to disdrometer. Also, X-band data are nosier than S-band. Regarding the rainfall rate and QPE, S-band estimation is very good and X-band seems to have slightly lower values than disdrometer. X-band estimation highly depends on attenuation correction, which could be the cause of under/overestimation. The storm microphysics can also be observed through DSD evolution measured by disdrometer (Fig. 7).
The broadest DSD occurred between 02:40 and 02:55 UTC in the time when developing convective cell was passing over the disdrometer. If we look at the DSD retrieval plots shown in Fig. 6, the rainfall rate and the median volume diameter are the largest at that moment. In period form 02:55 to 03:25, DSD measured from 2DVD started to be more narrow, as convective cell started to decay, and also, minimum in rainfall rate and D_0 occurred. From 03:25 UTC DSD started to be broader again, probably because new developing convective cell approached to disdrometer site, fallowed by local peak in the rainfall rate and D_0.

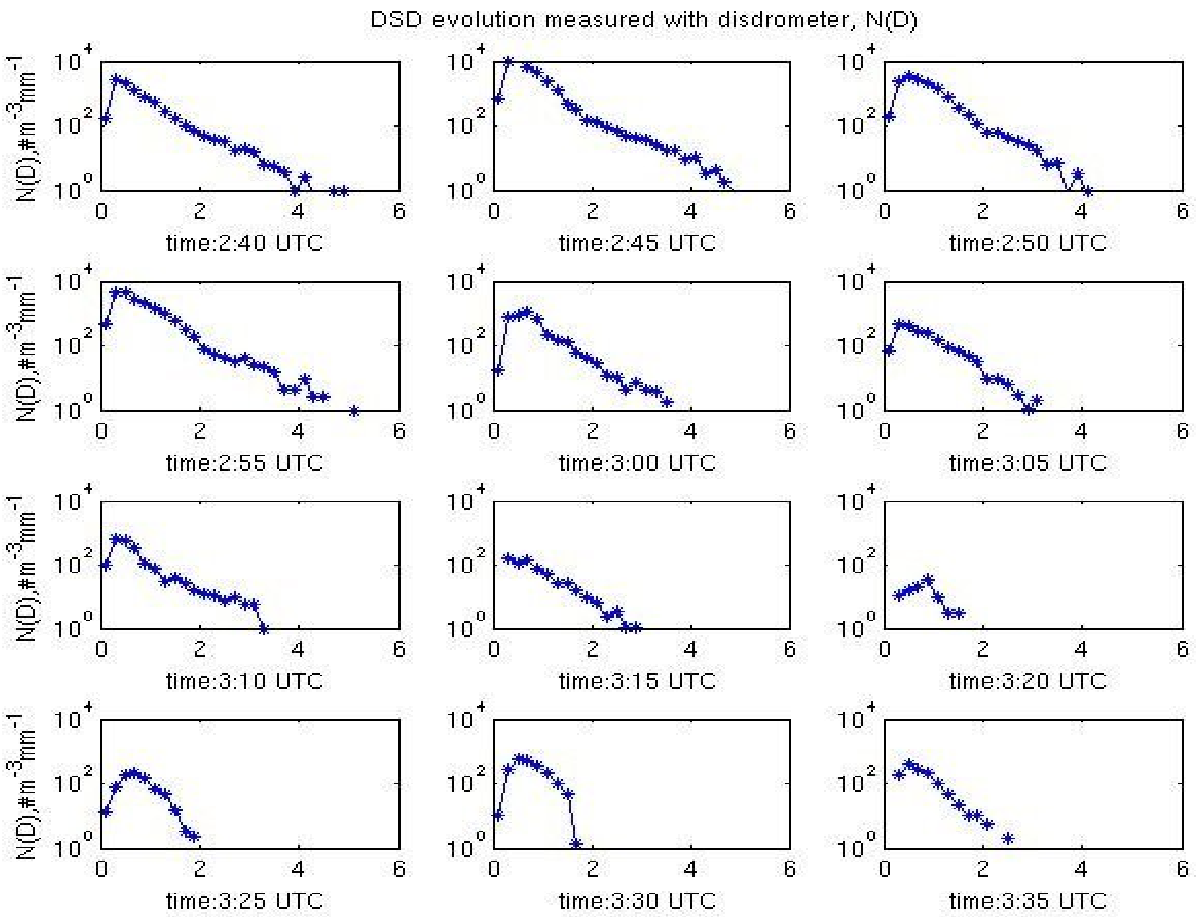

Figure 7: DSD evolution

5. SUMMARY AND DISCUSIONS

In this paper, we presented comparisons between S and X-band polarimetric variables along with DSD retrievals obtained with constrained gamma drop size distribution model. Also, comparison has been made with disdrometer data. The DSD parameters retrieved from radar measurements are in fair agreement with disdrometer measurements. Quantitative precipitation estimation and comparison showed that radar data are in agreement with disdrometer measurement, especially S-band. The DSD evolution of the storm was observed using disdrometer. Further improvement should be done in attenuation correction and DSD retrieval with by including multiple species hydrometeors and by jointly and optimally utilizing dual frequency and dual pol. measurements for better characterizing microphysical properties.

Acknowledgement

This work was partially supported by NSF grant ATM-0608168 and Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma. The use of the CASA radar data is greatly appreciated.

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