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# Rain Microphysics Retrieval with a Polarimetric WSR-88D

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## 1. INTRODUCTION

In the spring and early summer of 2005 a field experiment was conducted in Oklahoma to determine the utility of a prototype polarimetric WSR−88D for retrieving drop-size distributions (DSDs) and microphysical properties in rainstorms. For most storms NCAR's 2-D video disdrometer was positioned 28 km south-southwest of the KOUN radar operated by NSSL. For other storms the disdrometer was placed 13 m from a similar instrument at NSSL. The side-by-side disdrometer comparisons will hopefully answer questions regarding sampling issues and help define error levels in the observations. Although conditions were dry, a significant dataset of polarimetric radar and disdrometer observations was acquired from a number of mesoscale convective systems that passed through the area.

## 2. DATA AND ANALYSIS

Depending on the storm, the radar made either high temporal measurements at a constant low antenna elevation or 5-min volumetric measurements. Recorded variables included radar reflectivity ($Z_H$), differential reflectivity ($Z_{DR}$), differential propagation phase ($\Phi_{DP}$), and correlation coefficient ($\rho_{HV}$). Radar calibration procedures for $Z_H$ and $Z_{DR}$ are described by Giangrande et al. (2004). A technical description of the 2-D video disdrometer is given by Kruger and Krajewski (2002).

Drop-size distribution parameters were retrieved from the radar measurements using an adaptation of the method described by Zhang et al. (2001) and Brandes et al. (2004). The procedure assumes that drops are represented by a gamma distribution

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

where $N_0$ ($\mathrm{mm}^{-\mu-1}\ \mathrm{m}^{-3}$) is a number concentration parameter, $\mu$ is a distribution shape parameter, $\Lambda$ ($\mathrm{mm}^{-1}$) is a slope term, and $D$ (mm) is the drop equivalent volume diameter. The three governing parameters of the distribution are determined from radar measurements of radar reflectivity and differential reflectivity and an empirical relation between the DSD shape and slope terms. The $\mu$−$\Lambda$ relation was computed from NCAR disdrometer measurements using the 2nd, 4th, and 6th moments of observed drop distributions. A preliminary fit to the data is

$$\Lambda = 2.296 + 1.071\mu + 0.04325\mu^2 \ . \quad (2)$$

Potential issues regarding this retrieval approach are addressed by Zhang et al. (2003). Curiously, Eq. (2) has a smaller slope than that found previously for Florida rains (Brandes et al. 2003). The cause is attributed to differences in instrumentation and meteorology.

## 3. DISDROMETER COMPARISON

An example of DSD attributes computed from observations made by the two disdrometers, using the same computer code, is presented in Fig. 1. One-minute samples are shown.

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Inspection shows small differences. The number of drops detected by the NCAR disdrometer is slightly larger than that detected by the NSSL disdrometer. Also, median volume diameters and maximum drop diameters tend to be larger with the NCAR unit. Differences are believed to result primarily from higher spatial resolution and temporal scanning with the NCAR disdrometer. Another factor, which may be important at times, is that the NSSL disdrometer resides within a pit to minimize wind effects. The NCAR unit was placed on the ground within a wind fence. The sampling region was ~1 m above ground level. Wind effects for these two configurations are also subject of study.

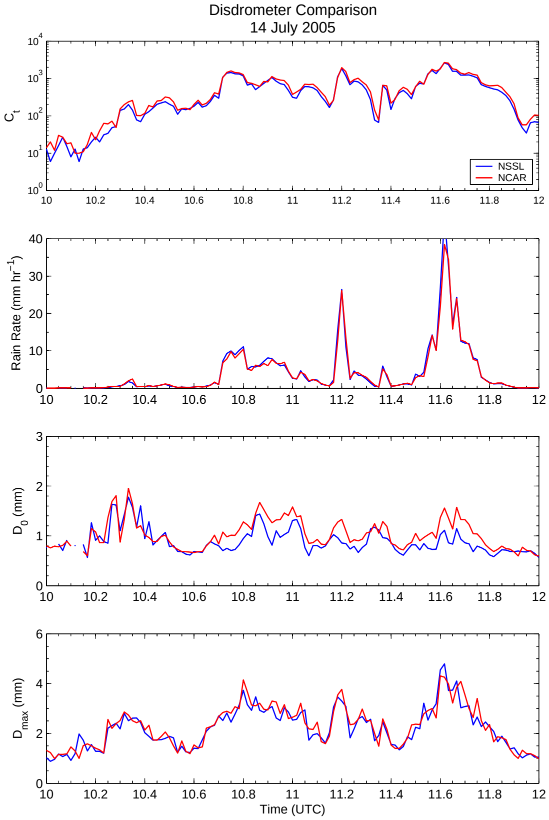

*FIG. 1: Side-by-side disdrometer comparison showing the total number of drops detected per min ($C_T$), rain rate, drop median volume diameter ($D_0$), and drop maximum diameter ($D_{max}$).*

## 4. RADAR RETRIEVALS

Radar and disdrometer data were processed for a mesoscale convective system probed on 13 May 2005 (Fig. 2). The storm was characterized by a leading line of strong convection followed by a small transition zone and then a region of enhanced stratiform rain. Figure 3 shows a time series of radar reflectivity and differential reflectivity as measured by radar and computed from disdrometer observations. The radar measurements are 5-min samples from 0.44° antenna elevation (~200 m above the disdrometer) and have been averaged over 5 range gates centered on the disdrometer site. The gate length is 0.25 km. Disdrometer calculations are for 1-min samples.

Preliminary analysis (not shown) uncovered significant instrument offsets. Of primary concern is the observation that radar-measured differential reflectivity values average several tenths of a dB larger than disdrometer calculations. The source of the discrepancy has been difficult to determine. The WSR−88D can not be pointed vertically. Hence, this procedure can not be used to verify the $Z_{DR}$ measurement. Instead, the measurement is verified subjectively by examining $Z_{DR}$ values for dry low-density aggregates above the bright band. It is also possible that the much larger radar sampling volume simply “sees” larger drops which increase radar-measured $Z_{DR}$ values relative to the disdrometer. Because calculations of $Z_{DR}$ with the side-by-side disdrometer observations showed good agreement, it was decided for this preliminary study to force the radar measurements to match the disdrometer in the mean. However, this adjustment created significant areas of negative $Z_{DR}$ in upper levels of the storm.

In general, trends in the time series (Fig. 2) are well matched indicating meteorological details are readily reproduced by both instruments. Largest discrepancies are with the convection along the leading edge of the storm system. This is expected because of the strong precipitation gradients and wind shears found there. The larger sampling volume tends to reduce the short-term scatter in the radar data.

Using the tuned $\mu$−$\Lambda$ relationship (2) and adjusted radar measurements, DSD attributes are retrieved for the time series in Fig. 3. Retrievals for total drop concentration and drop median volume diameter are fair to good (Fig. 4). Retrieved concentrations for the convective line are good, but drop concentrations are underestimated throughout much of the stratiform rain period. Trends in drop median volume diameters generally agree. $D_0$ is overestimated when the number concentration is underestimated.

A retrieval in radar space for a portion of the 13 May squall line at 0700 UTC is presented in Fig. 5. High reflectivity associates with large $Z_{DR}$ and $D_0$. Drops are large ($D_0 \geq 3$mm) at the leading

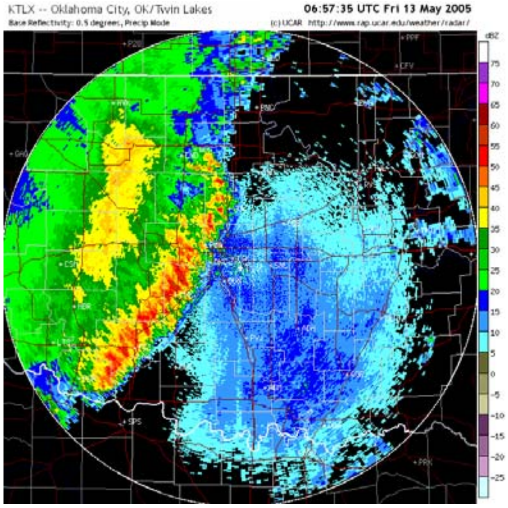

*Fig. 2: Radar reflectivity measurements made with the Twin Lakes WSR-88D (KTLX) on 13 May at 0657 UTC.*

edge of the convection and become small in the mean toward the rear of the convective zone (< 1mm). With some exceptions highest drop concentrations and heaviest rain rates are found in reflectivity cores. Retrieved drop distributions are typically broad in regions of high reflectivity and narrow in trailing portions of the convective zone and stratiform rain shield (not shown).

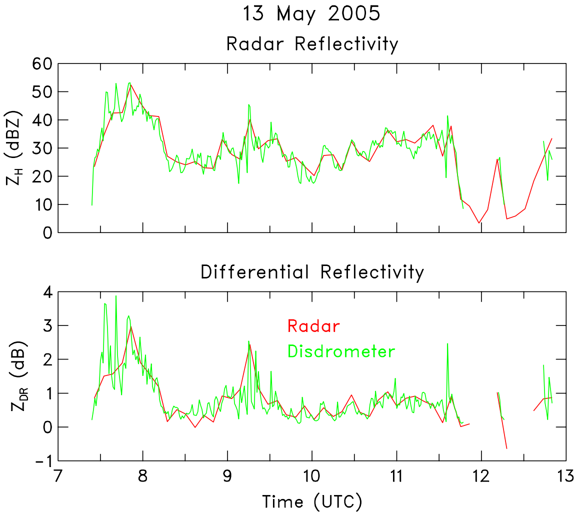

*FIG. 3: Radar reflectivity and differential reflectivity as measured by radar and calculated from disdrometer observations.*

## 5. SUMMARY AND CONCLUSIONS

The utility of a polarimetric WSR−88D for retrieving drop-size distributions was investigated. Comparisons between measurements from NSSL's KOUN radar and a disdrometer revealed trends in radar reflectivity and differential reflectivity were well matched. This is encouraging because it indicates that detailed microphysical information is contained in the radar measurements. However, systematic offsets that varied from storm to storm were found for both variables. Application of a drop-size distribution retrieval model that utilizes measurements of radar reflectivity and differential reflectivity and an empirical relation between the shape and slope parameters of the gamma drop-size distribution disclosed significant sensitivity to the offsets. At this writing we are not sure whether the problem resides with radar calibration or stems from radar−disdrometer sampling differences.

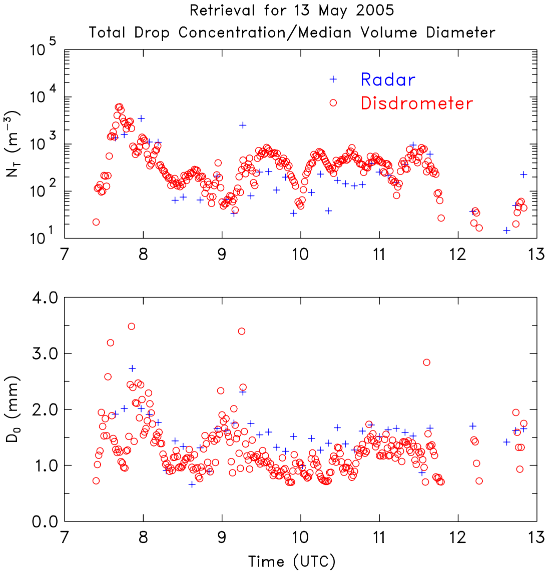

*FIG. 4: Radar retrievals of total drop concentration ($N_T$) and drop median volume diameter ($D_0$) plotted against disdrometer observations.*

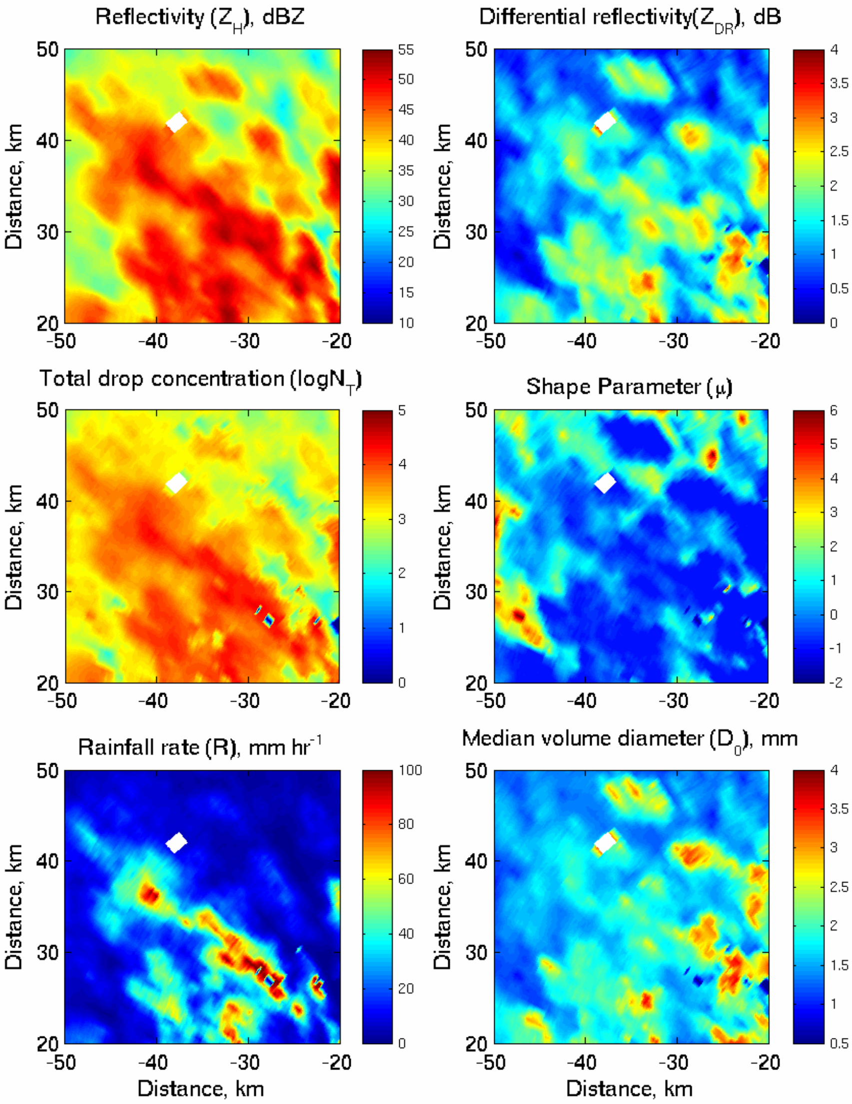

*Fig. 5: DSD retrieval for a portion of the squall line observed on 13 May at 0700 UTC.*

For this preliminary study, forcing the radar measurements to match the disdrometer observations gave plausible DSD retrievals.

There are other issues. For example, the retrievals are sensitive to the assumed maximum drop size in the radar volume. While the retrieval is not overly sensitive to the $\mu$−$\Lambda$ relationship, the contribution of error in the estimated DSD moments used to derive the relation and likely meteorological variations are of concern. Also, retrievals at the leading edge of convection often overestimate small drop populations. We believe that the problems are resolvable and that a national network of polarimetric WSR−88Ds will present important opportunities for improving the understanding of microphysical processes in storms and their parameterization in numerical models.

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