P5A.4 VERTICALLY POINTING PROFILERS USED TO CALIBRATE AND MONITOR THE REFLECTIVITY ESTIMATED BY SCANNING RADARS

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1. INTRODUCTION

The quantitative measurement of surface rainfall from scanning radar observations is dependent on the transformation of radar observables into hydrologic approximations. The most common transformation is the Z-R transformation that converts measured radar reflectivity into estimates of surface rainfall rate. While there are many Z-R relationships used by radar meteorologists around the globe, the utility of this transformation is dependent on the absolute calibration of the scanning radar.

Our technique called up-scaling calibration enables scanning radars to be absolutely calibrated through the combination of surface disdrometers and vertically pointing profilers. The surface disdrometer measures the rain drop size distribution (DSD) at the surface and is used to estimate the surface reflectivity, rain rate, and mean rain drop size. Through simultaneous surface disdrometer and profiler observations, the profiler calibration is adjusted until the observations in the lowest range gates of the profiler agree with the surface observations. The absolute calibration of the scanning radar is achieved by comparing the profiler with scanning radar reflectivities in commonly sampled volumes.

After the scanning radar has been initially calibrated to the surface disdrometer and vertically pointing profiler, the stability of the scanning radar can be monitored by routinely comparing the scanning radar and profiler reflectivities. As long as the disdrometer and profiler reflectivities are consistent, any deviations between the scanning radar and profiler indicate a change in the scanning radar reflectivity and warrant further investigation by the scanning radar's engineering team.

2. OBSERVATIONS

The NOAA Aeronomy Laboratory deployed vertically pointing precipitation profilers operating at 915 and 2835 MHz in support of the Ground Validation Program of the NASA Tropical Rainfall Measuring Mission (TRMM) (Gage et al. 2002, 2003). As an example of up-scaling calibration, this paper uses observations made in August-September 1998 in Central Florida to calibrate the Melbourne, Florida, NEXRAD scanning radar.

2.1 Disdrometer

The RD-69 impact disdrometer manufactured by Disdromet, Switzerland, was used as the calibration standard at the profiler site. The RD-69 disdrometer is also called the Joss-Waldvogel disdrometer (Joss and Waldvogel, 1967). The Joss-Waldvogel disdrometer (JWD) estimates the number and size of rain drops reaching the surface. The observed rain drop size distribution (DSD) is used to estimate the surface reflectivity, rain rate, and mean rain drop diameter. The surface reflectivity has a temporal resolution of 1 minute and a volume resolution on the order of 1 -to- 2 m^3.

2.2 Profiler

The vertically pointing profilers operated at 915 and 2835 MHz and were sensitive to the precipitating cloud systems that passed overhead (Carter et al. 1995, Ecklund et al. 1999). While either of the two profiler observations could be used for comparison with the scanning radars, only the 915 MHz profiler observations are shown in this extended abstract. The vertical profiles of reflectivity directly over the profiler have a temporal resolution of 1 minute, a vertical resolution of 100 meters, and a volume resolution on the order of 10^6 m^3.

2.3 Scanning Radar

In this study, the observations from the operational Melbourne, Florida, NEXRAD radar are used to show the utility of this calibration and monitoring method for operational systems. Using the NEXRAD operational volume scans provided a temporal resolution of 5 minutes. The horizontal distance of 36 km between the NEXRAD and the profiler and the 1 degree NEXRAD beamwidth yields a NEXRAD vertical resolution of 625 meters directly over the profiler. The NEXRAD observations have a volume resolution on the order of 10^8 m^3 directly over the profiler.

3. UP-SCALING CALIBRATION

Up-scaling calibration uses the surface disdrometer to calibrate the profiler and the profiler to calibrate the scanning radar. In this scenario, the surface disdrometer is the reference and the profiler is the

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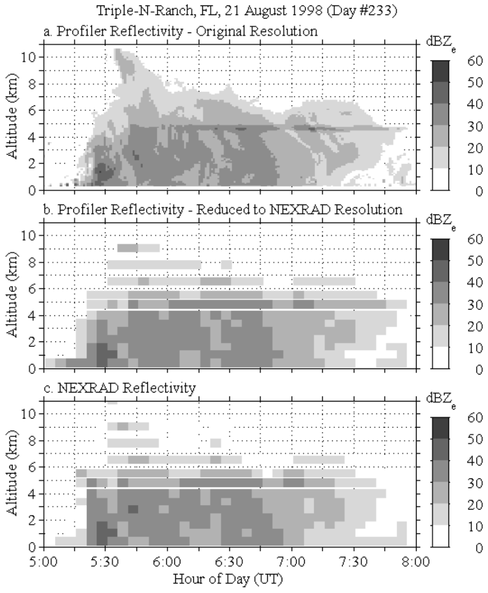
transfer standard used to calibrate the scanning radar.

3.1 *Profiler Calibration using Disdrometer*

The profiler calibration is determined by comparing the simultaneous one-minute disdrometer and profiler observations. As described in detail in Gage et al. (2002), the profiler reflectivity is adjusted until the reflectivity difference between the surface disdrometer and lowest usable range gate of the profiler are minimum. This adjustment enables the profiler to be calibrated for each field deployment.

3.2 *Scanning Radar Calibration using Profiler*

Figure 1 shows the vertical structure of reflectivity over the profiler observed by the profiler and by the NEXRAD scanning radar. The top panel (Figure 1a) shows the profiler reflectivity in the original 1 minute temporal and 100 meter vertical resolution. The middle panel (Figure 1b) shows the profiler reflectivity reduced to the NEXRAD 5 minute temporal and 625 meter vertical resolution. And the bottom panel (Figure 1c) shows the NEXRAD reflectivity in its original 5 minute and 625 meter vertical resolution.


Triple-N-Ranch, FL, 21 August 1998 (Day #233)

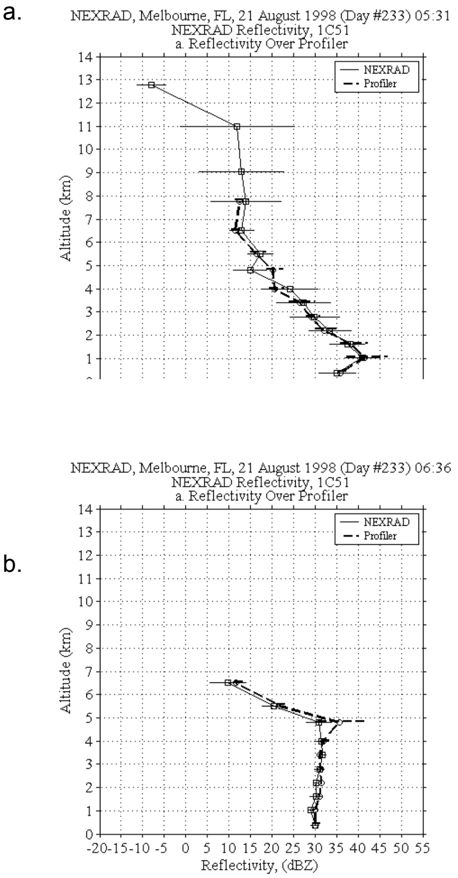
a. Profiler Reflectivity - Original Resolution

b. Profiler Reflectivity - Reduced to NEXRAD Resolution

c. NEXRAD Reflectivity

Figure 1. Reflectivity over Profiler on 21 August 1998, a) Profiler observations with original resolution, b) profiler observations reduced to 5 minute and 625 meter vertical resolution, and c) NEXRAD observations at the original resolution of 5 minutes and 625 meter vertical resolution.

The vertical profile of reflectivity from both radars for individual volume scans are shown in Figure 2. The 05:31 UT volume scan (Figure 2a) was made when a convective cell was over the profiler. The horizontal bars at each altitude represent the reflectivity standard deviation during the 5 minute volume scan. The NEXRAD variation is estimated from the reflectivity observed at the nine nearest 1 km square gridded neighbors around the profiler site, and the profiler variation is estimated from the 5 one-minute profiler observations made during the volume scan. Stratiform rain was over the profiler during the 06:36 UT volume scan (Figure 2b).


a.

NEXRAD, Melbourne, FL, 21 August 1998 (Day #233) 05:31
NEXRAD Reflectivity, 1C51
a. Reflectivity Over Profiler

b.

NEXRAD, Melbourne, FL, 21 August 1998 (Day #233) 06:36
NEXRAD Reflectivity, 1C51
a. Reflectivity Over Profiler

Figure 2. NEXRAD and Profiler Reflectivity during individual volume scans. a) Convective rain at 05:31 UT, and b) Stratiform rain at 06:36 UT.

By reducing the vertical and temporal resolution of the profiler observations to agree with the NEXRAD observations, reflectivity differences can be calculated for each range gate as is shown in Figure 3. To better quantify the difference in reflectivity between the two instruments, only the stratiform rain profiles are compared and shown in Figure 3. The left panel (Figure 3a) shows the number of observations at each range gate with over 270 observations at the lowest range gate and a sharp decrease in number above the freezing level. The right panel (Figure 3b) shows the histogram of reflectivity differences at each range gate. The black line indicates the median in the distribution and is an estimate of the reflectivity bias between the two instruments. The bottom panel (Figure 3c) shows the mean bias below and above the freezing level. The mean bias indicates that the NEXRAD reflectivity is 0.3 dBZ less than the profiler reflectivity at range gates below the freezing level and about 1.3 dBZ less at range gates above the freezing level. Given the absolute uncertainties of the disdrometer and profiler of about 0.5 dBZ, the NEXRAD and profiler reflectivities below the freezing level essentially agree.

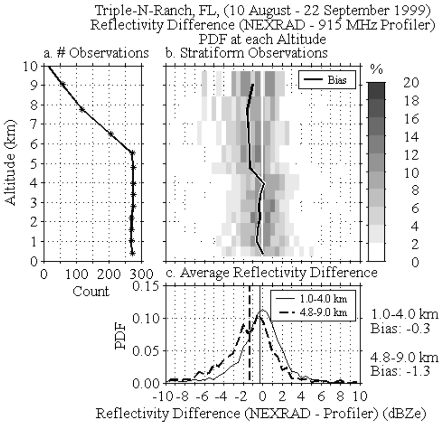


Figure 3. Reflectivity difference (NEXRAD - Profiler) at each range gate. a) Number of observations at each range gate, b) histogram of the reflectivity difference with the median shown with line, and c) mean reflectivity distribution below the freezing level (1.0-4.0 km) and above the freezing level (4.8-9.0 km).

4. CONCLUDING REMARKS

Up-scaling calibration uses a surface disdrometer and a vertical pointing precipitation profiler to calibrate scanning radars. The surface disdrometer reflectivities are considered the reference observations. Using simultaneous disdrometer and profiler observations, the calibration of the vertical pointing profiler is adjusted until the profiler reflectivity agrees with the surface disdrometer reflectivity. Using coincident profiler and scanning radar observations over the profiler, the difference in reflectivities indicates the offset in calibration of the scanning radar relative to the profiler, and thus, relative to the surface disdrometer observations.

The up-scaling calibration procedure was applied to observations made during a two month field campaign held in Central Florida in August and September 1998. Using the profiler and scanning radar observations below the freezing level suggest that the Melbourne NEXRAD scanning radar reflectivity was approximately 0.3 dBZ below the surface Joss-Waldvogel disdrometer observations. When the profiler and scanning radar observations above the freezing level are used, the difference increases to 1.3 dBZ (NEXRAD less than the surface disdrometer). This is probably due to the difference in beam matching between the profiler and scanning radar. As shown in Figure 2b, above the freezing level the reflectivity decreases with altitude. Any misalignment in altitude or beam shape will cause an offset in the reflectivity differences. The beam mismatch is not a dominant factor below the freezing level during the stratiform rain because the reflectivity is nearly uniform with altitude.

The up-scaling calibration presented in this work is independent of the calibration operations performed by the NOAA National Weather Service. After the initial calibration, the procedure outlined in this work can be used to monitor the NEXRAD reflectivity and identify changes in the NEXRAD reflectivity relative to the surface disdrometer and vertically pointing profiler.

5. ACKNOWLEDGMENTS

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