International Journal of Advanced Research in Physical Science (IJARPS)
Volume 2, Issue 9, September 2015, PP 30-34
ISSN 2349-7874 (Print) & ISSN 2349-7882 (Online)
www.arcjournals.org

Improved Micro Rain Radar Rainfall Measurements using Doppler Spectra Post-Processing

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Abstract: *The Micro Rain Radar 2 (MRR) is a cost effective, minimum maintenance oriented, portable radar system used for conducting precipitation research. This system is prone to several draw backs such as lack of a sophisticated post-processing algorithm to improve its sensitivity, noise due to radar receiver and the lack of high quality Doppler radar moments. In this project work, we propose an improved processing method which is especially suited for rainfall observations and provides reliable values of effective reflectivity, Doppler velocity and spectral width. The proposed method is a noise removal based on recognition of the most significant peak. A dynamic dealiasing routine allows observations even if the Nyquist velocity range is exceeded. The proposed method exploits the full potential of MRR's hardware and substantially enhances the use of Micro Rain Radar for studies of precipitation.*

Keywords: *Rain drop size distribution (RSD), Rain rate, Mass weight diameter, Z-R coefficient*

1. INTRODUCTION

The quantitative estimation and investigation of rain rate from the radar reflectivity receive more constraints including Drop size distribution (DSD), the occurrence of ice in the illuminated volume, the evolution of rainfall from the height of the radar beam to the ground and the dissimilar volumetric and temporal scales while measuring different rain characteristics.

[1] suggested that the use of a low cost network of vertically pointing radars to enhance the performance of weather Radar scans by measuring the vertical reflectivity profile and detecting the melting layer. The measurement of the drop size distribution (DSD) allowed the investigation of methods to associate rainfall structure with DSD characteristics at ground level [2]. This represents a significant progress compared to the method measuring reflectivity with radar and rain rate with gauges. The vertical Doppler spectrum yields information on the DSD if an adequate relation between drop diameter and terminal falling velocity is given [3, 4]. A low cost vertically pointing Doppler radar may therefore be used to study the drop populations at higher altitudes, leading to an improvement of r-r relations. The change in both falling velocity and reflectivity in the melting layer is detectable in vertical profiles and allows an easier detection of the ice phase. An attempt is made in this paper to study the microphysical characteristics of southwest and north east monsoon heavy precipitations and their corresponding Z-R relations. The variability of mass weighted mean diameter (D_m) with normalized intercept parameter (N_w) during the selected heavy precipitations are also discussed. A new method is proposed and implemented to process MRR raw Doppler spectra, which is required for precipitation observations. This method improves the observed spectra with possible elimination of noise and aliasing effects providing favorable effective reflectivity (Ze), and Doppler velocity (W) in the effective processing of the obtained spectral data.

2. EXPERIMENTAL SITE AND SET UP

For the present study and analysis, the authors have chosen the site to be at a drought prone Kadapa city in the Rayalaseema region of Andhra Pradesh with a reason to elucidate the environmental information with regard to the rain details which will give some scope to manage the water dependant human plant systems. The observation site, Yogi Vemana University Campus (14^0 28' N 78^0 42' E, 150 m above mean sea level), [*figure 2.1*] is about 15 km from Kadapa city in the southern part of India. There are hills in the northern and southern sides of the observation site about 15 km distance and the average height of the hills is about 750 m, with a maximum height of about

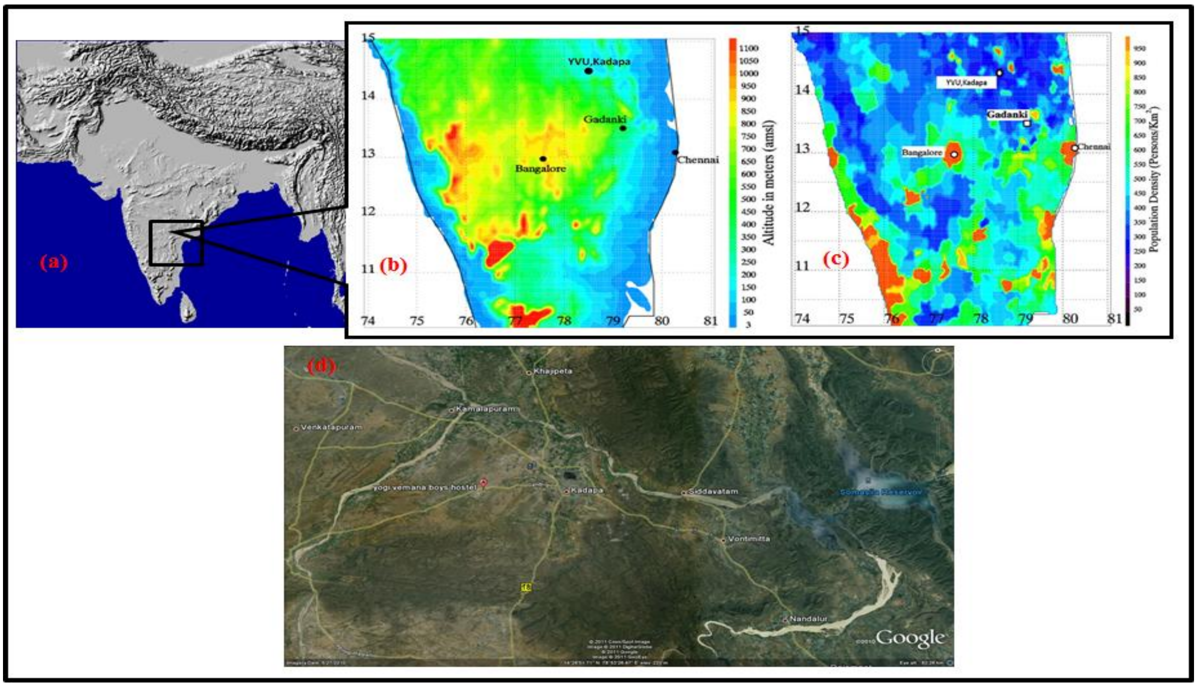

Figure 2.1. (a) *Map showing the geographical location of the observation site along with the information*

Micro Rain Radar is a Frequency Modulated-Continuous Wave (FM-CW) radar and is always measuring in the zenith direction. A picture of the radar is shown together with a block diagram in Figures 2.2. The radar measures the velocity spectra of the falling drops. From these data the rain rate and the liquid water density can be inferred. During the first year the radar was operating to a height of 7500 m with a range resolution of 250 m. The data so far used is the rain rate at the height of 200 m. This information is used to develop an independent method to firstly have an archive of rain events at the Onsala site, and secondly to assess the quality of microwave radiometer data used for propagation delay studies. A preliminary investigation concerning the use of rain radar data for automatic editing of microwave radiometer data was recently presented. It was found that the earlier used threshold value of 0.7 mm liquid water content is reasonable when trying to eliminate microwave radiometer data acquired during rain.

Figure 2.2. *Photograph of the observational showing ground based instruments Parsivel disdrometer, Automatic Weatehr Station (AWS) and Micro Rain Radar (MRR).*

The study of precipitation using radars and in situ techniques is challenging [5]. In addition, MRR can be affected by Doppler aliasing effects due to turbulence [6] as shown for rain.

The MRR records spectra at 32 range gate in which 28 exploitable range gates leads to an observable height range between 300 and 3000 m with a resolution of 100 m. The peak repetition frequency of 2-kHz results in a Nyquist velocity of $\pm 6ms^{-1}$.The unambiguous Doppler velocity range between 0 and $12ms^{-1}$ is derived according to Metek. The Processed Data, provides rain rate (R), radar reflectivity (Z) and Doppler spectra density (η) with a temporal resolution of 10 sec. Doppler spectra densities without noise and height corrections are available in 10 sec resolution in the product *Raw Spectra*. On average, 10 sec data consist of 58 independently recorded spectra. In this study, *Averaged Data* is used with a temporal resolution of 60 sec.

This study proposes a new data processing method for MRR. The method is based on non noise-corrected raw MRR Doppler spectra and features an improved noise removal algorithm and a dynamic method to dealiase the Doppler spectrum.

In contrast to Metek's standard method, the new proposed MRR processing method determines the *most significant peak* including its borders and identifies the rest of the spectrum as noise. After that, the dealiasing routines corrects for aliased data.

The proposed method is based on the spectra available in MRR *Raw Spectra*, which is the product with the lowest level available to the user. To save processing time, only spectra which pass a certain variance threshold are further examined, all other are identified to be noise. The threshold is defined as:

$$V_T = 0.6/\sqrt{\Delta t} \quad (4.4)$$

with V_T the normalized standard deviation of a single spectrum, and Δt is the averaging time. The threshold is defined very conservatively, because false positives are rejected later by post processing qualitative checks. The method followed for the process the data is given in the Fig 2.3 .

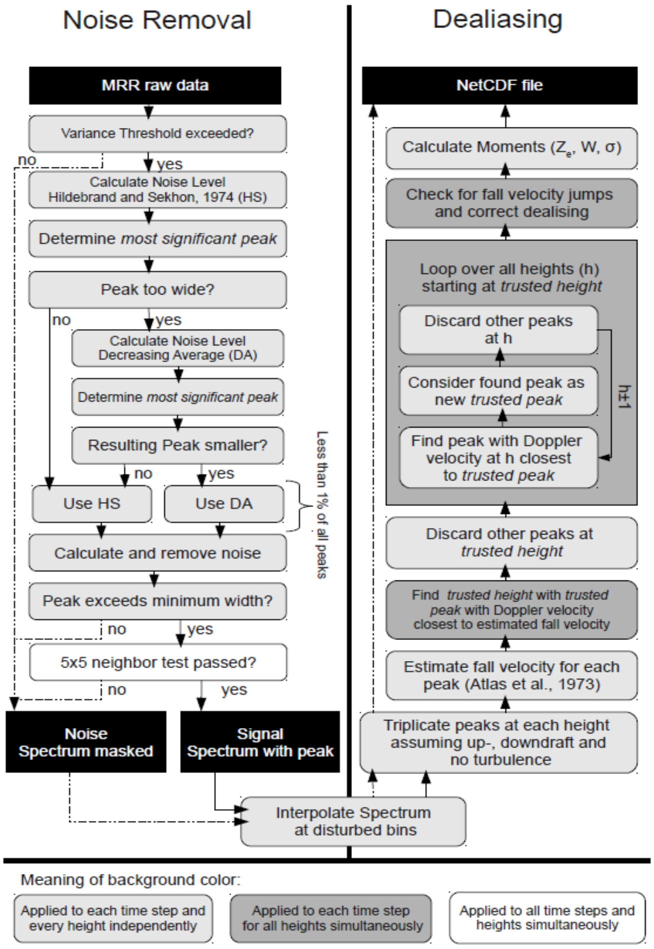

Figure2.3 *Flow chart diagram of noise removal and dealiasing of the proposed MRR processing method.*

3. Results and Discussions

To assess the suitability of MRR for precipitation observations and to demonstrate the improvements of the new method, observations of MRR on two more or less similar stratiform precipitation events are compared.

Comparison of Reflectivity

The scatter plot of Z derived from Metek's *Averaged Data* and Ze from MIRA35 [7] (Fig. 4.5, left) shows a general agreement between both data sets for Ze exceeding 5 dBz, but a very high spread which we attribute to the different methods to derive the reflectivity. Noise is not completely removed in the MRR *Averaged Data*, thus the distribution departs from the 1: 1 line for Ze < −5dBz. Below −10 dBz, the MRR observations are completely contaminated by noise.

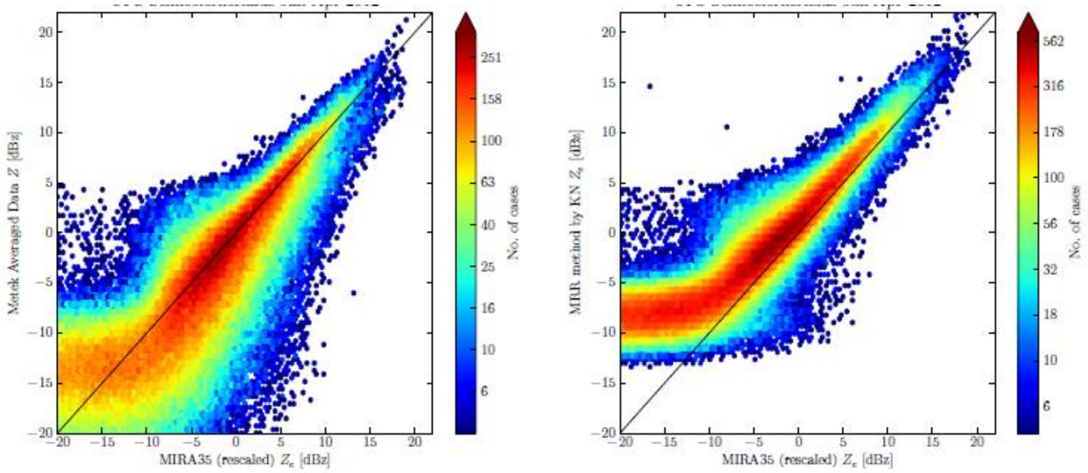

Figure.3.1 *Scatter plot comparing effective reflectivity (Ze) of evemt-1 with D6-based radar reflectivity (Z) derived by Metek's standard MRR product (left), and with Ze of MRR (event-2) using the new proposed MRR method (right).*

Comparison of Doppler velocity

The Doppler velocity observed by MRR on 19^{th} July 2012 is compared to the Doppler velocity measured by MRR using the methodologies described previously: Metek's *Averaged Data*, and the proposed method.

Metek's MRR software assumes only falling particles and thus no dealiasing is applied to the spectrum. This can be clearly seen from the comparisons of W between Metek's *Averaged Data* and MIRA35 (Fig. 4.6, left). Velocities below $0ms^{-1}$ appear at the other end of the spectrum at very high Doppler velocities. Due to the insufficient noise removal, a cluster of randomly distributed Doppler velocities is visible around $0ms^{-1}$. This cluster is attributed to cases, when MIRA35 detects a signal which is below MRR's sensitivity (e.g. clouds), but MRR detects only noise featuring a random.

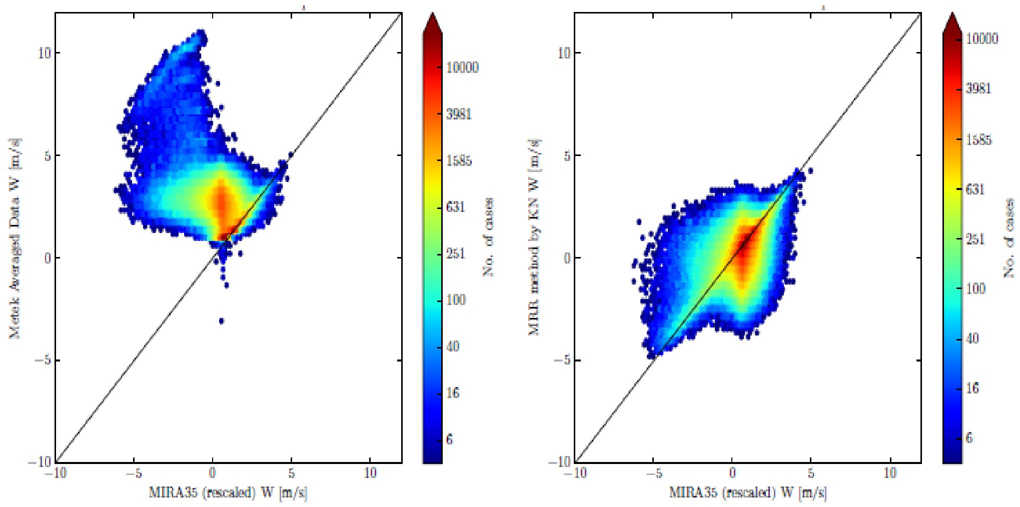

Figure. 3.2 *Scatterplot comparing Doppler velocity (W) of startiform event-1 with W of Metek's standard MRR product (left) and with W of MRR using the new proposed MRR method (right) stratiform event-2. The black line denotes the 1 : 1 line velocity.*

This cluster can also be seen in Fig. 3.2 (left), in which MIRA35 is compared to the two different stratiform events. Their simple dealiasing algorithm dealiases the spectra successfully, which results in the absence of artifacts. However, the spread remains very high due to the insufficient noise removal. For the new proposed method, the observed Doppler velocities agree very well. Due to the dynamic dealiasing method, MRR can also detect upwards moving particles reliably and is not limited to its unambiguous Doppler velocity range of 0 to 12ms^{-1}. The small offset of the spread with MRR (MIRA) detecting slightly larger values for positive (negative) Doppler velocities is most likely related to the coarser spectral resolution of MRR.

4. SUMMARY AND CONCLUSIONS

The Micro Rain Radar-2 (MRR) is a profiling Doppler radar developed to measure precipitation. The method is based on non noise-corrected raw MRR Doppler spectra and features an improved noise removal algorithm and a dynamic method to dealiase the Doppler spectrum. The new proposed method provides effective reflectivity (Ze), and Doppler velocity (W) besides other moments. The proposed method is evaluated by a comparison with a similar startiform precipitation. The new post-processing procedure for MRR removes signals from hydrometeor-free range gates and thus improves the detection of precipitation echoes, especially at low signal-to-noise conditions. The presented study suggests that proper post-processing of the MRR raw observables can lead to high quality radar measurements and detection of weak precipitation echoes.

ACKNOWLEDGMENTS

The authors are grateful to Prof. K. Krishna Reddy, HOD, Department of Physics and Coordinator, Semi-arid-zonal Atmospheric Research Centre (SARC), ISRO Project, Kadapa, A.P.India for providing all the necessary research facilities to carry out this project work.

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