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Estimation of Melting Layerand Propagation Impairments using Micro Rain Radar Dataat Coastal Locationof Andhra Pradesh

Krishna Reddy Maddikera, Sarat K Kotamraju, K. Ch. Sri Kavya,S. S. S Kalyan, Bala Gangadhar TilakGande

ABSTRACT: Abstract: In this work, estimation of melting layer height at coastal region of Andhra Pradesh using Micro Rain Radar (MRR) is presented. Micro Rain Radar is installed at K L University (16.44oN, 80.62oE) Andhra Pradesh, India. By using the recordings of the measured rain rate (RR) and fall velocity (W) from the Micro Rain Radar, the melting layer height is estimated. The estimated height of melting layer is compared with Radiosonde data of Machilipatnam (16.19oN, 81.36oE) separated at a distance of 70 Km, collected from Wyoming University website. The estimated result seems to be more reliable as the melting layer height calculation using MRR matches with the Radiosonde data.

Index Terms: Micro Rain Radar, Melting Layer,Radiosonde, Fall Velocity, Rain Rate.

I. INTRODUCTION

Micro Rain Radar is a very useful instrument for calculation of vertical profiles of the atmosphere. High frequency communications links are mainly affected by rainfall, precipitation, fog, hail etc., which have the extensive capabilities in applications involving mobile systems, personal communication, and meteorology [13]. Rain drops fall at a faster rate, which reduces the drop concentration per unit volume. This effect reduces the radar reflectivity. Therefore reflectivity of the melting layer is higher above or below it. High reflectivity always appears bright in its vertical profile and therefore in radar meteorology it is termed as bright band [3]. Bright band characteristics reveal important microphysical processes. Fabry and Zawadzki presented that the mixture of air, water and ice contribute to increase the radar reflectivity than that expected.Bright band is the most important parameter as it gives the location of the freezing precipitation which is most important to estimate rainfall from the brightness temperature [4-5].Rain attenuation at high frequencies can be estimated by knowing the height of freezing precipitation. In addition to knowledge over bright band can also determine the type of precipitation falling on the ground. The data has been collected from Micro Rain Radar (METEK,Germany) for 2017-2018 years or months at the K L University, at the altitude of 31m above the sea-level (ASL), Guntur, India. The readings were recorded for every 10 seconds without any clutters from aerial birds and other dust particles. The extracted MRR data is correlated with the Radiosonde data of Machilipatnam,separated with a distance of 70kms from MRR's location [1-2].

Radiosonde is used for the observations of temperature, humidity, pressure. It is a very small device which weighs about 250-500 grams which is carried out into air through a hydrogen balloon, below to it a parachute also placed to decrease the damage to the Radiosonde when the hydrogen or helium balloon bursts due to its pressure as it goes higher altitudes of atmosphere [6-8]. Throughout the world there are 1300 Radiosonde and the data has been collected from 800 usable Radiosonde balloons and this data is exchanged through international agreements with other countries. This is owned by National Weather Service-National Oceanic and Atmospheric Administration, NWS-NOAA. The extracted Radiosonde data can be used for weather prediction models, pollution search and satellite data.

II. METHODOLOGY

A. QUANTIFICATION LOCALE AND ERA

As shown in below Figure 1., the Micro Rain Radar (MRR) measurements are taken from CARE Lab (Centre for Applied Research in Electromagnetics laboratory) at KL University 16.4418^{o} N, 80.6222^{o} in Vaddeswaram, Guntur, A.P., India. For continuous measurements of Cloud Microphysical parameters MRR is installed along with other instruments of Disdrometer, OTT Pluvio etc., This is installed for the cloud microphysical measurements over the coastal location of A.P. at KLEF (Deemed to be University), Guntur which also provides the data of Orographic clouds for feasibility studies in India, analysed by the MRR data in 2017-2018.

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***** Correspondence Author (s)
Krishna Reddy Maddikera, Department of Electronics and Communication Engineering, KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur District, A.P, India-522502. (E-mail: krishnareddymaddikeras@gmail.com)
Sarat K Kotamraju, Department of Electronics and Communication Engineering, KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur District, A.P, India-522502.
K. Ch. Sri Kavya, Department of Electronics and Communication Engineering, KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur District, A.P, India-522502.
S. S. S Kalyan, Department of Electronics and Communication Engineering, KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur District, A.P, India-522502.
BalaGangadharTilakGande, Department of Electronics and Communication Engineering, KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur District, A.P, India-522502.

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MRR data is highly matched with Radiosonde data operated by National Weather Service (NWS) headed by US. The Radiosonde site is situated at Machilipatnam 16.12ºN and 81.09ºE, 3 meters ASL about 76 km to the CARE Laboratory.

Figure 1.24.23GHz MRR2 at CARE Lab installed at KLEF (Deemed to be University)

The MRR is an AMF (Atmospheric Measurement Facility's) category 2 instrument, manufactured by METEK, Germany and model is MRR2 Micro Rain Radar.

TABLE I. Physical Specifications of MRR2 at KLEF (Deemed to be University) (CARE Lab)

Parameter	Values
Parabolic Dish	60cm diameter (70cm largest)
Beam Width	1.5º
Frequency	24.23GHz
Transmit power	50mW
Antenna Heating (optional)	230 VAC
Averaging interval	10s-3600s
Height	6 km or 3.7 miles
Power	24 VDC, 25W
Range Gates	30
Modulation	FM-CW Sawtooth
Threshold Detection	1 mm/hr
Interface	LAN, RS232

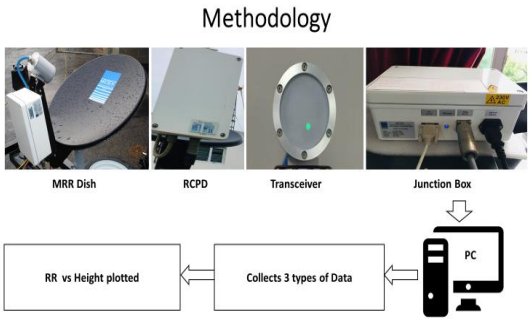

Figure 2.MRR2 Methodology which consists of Indoor and Outdoor Units

B. OPERATIONAL PRINCIPLE

From Figure 2, the Micro Rain Radar is a vertically pointing FM-CW Doppler Radar which operates at 24.230 GHz of compact in size used for measuring the profiles of Rain parameters such as Drop Size Distribution, Rain Rate, Liquid Water Content, Fall Velocity, Radar Reflectivity and Observing the Melting Layer with variation in the height of rain rate. The essence of this Radar is mixing diode integrated with frequency modulated GUNN-diode where the power is only 50mW. To enact range resolution frequency modulated signal is used at the receiving end echo of transmitting signal is always high [METEK, MRR2 Physical Basics].

C. DERIVATION OF RAIN PARAMETERS

A Raindrop Size Distribution or Drop Size Distribution is the number of drops per volume and diameter, given as

$$N(D,i)=\eta(D,i)/\sigma(D) \quad (1)$$

Rain Rate (mm/hr) is the volume of water passing through a horizontal surface per unit time and given as

$$RR=\frac{\pi}{6}\int_0^\infty N(D)D^3v(D)dD \quad (2)$$

The radar reflectivity (Z) factor is given as

$$Z=\int_0^\infty N(D)D^6dD \quad (3)$$

Z=Amount of power receiving after hitting the precipitation which is transmitted from a radar.

Liquid Water Content (LWC)

It is defined as the product of the total volume of drops to the scattering volume, which is proportional to the third moment of RSD or DSD.

It is given as

$$LWC=\rho_w\frac{\pi}{6}\int_0^\infty N(D)D^3dD \quad (4)$$

LWC=Measuring the amount of water content present in Clouds.

Fall Velocity (W), Falling Velocity is defined in numerous ways. Velocity of rain drops which have the large contribution to the total rain rate is said to be Fall Velocity (W) and it can be given as

$$W=\frac{\lambda}{2}\int_0^\infty \eta(f)fdf \,/\, \int_0^\infty \eta(f)df \quad (5)$$

Here the Spectral Reflectivity is given as

$$\eta_R(f)=\frac{N(D)\sigma R(D)}{(\partial f/\partial v)(\partial v)(\partial D)} \quad (6)$$

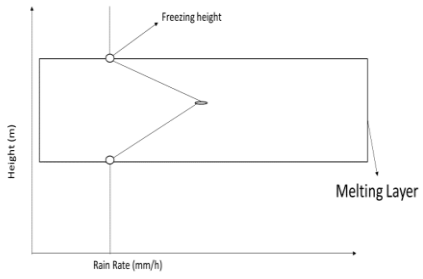

Figure 3. Schematic of how to estimate the Melting Layer Height from MRR data

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D. MELTING LAYER PERCEPTION

The height interval at which the ice-phase melts as it moves downward is said to be Melting Layer as shown in the above Figure 3. It is associated with the Stratiform rainfall where the transition from solid to liquid is seen or observed. It is also defined as the Zero degree or 0º isotherm is seen at an altitude of the MRR collected data or in Radiosonde data[12].

Rain Rate is increased rapidly in Melting Layer. Fall Velocity (W) of raindrops is low above the Melting Layer as it increases gradually in Melting Layer. Variation of vertical liquid water content is feeble than the Rain Rate, so we are using the extracted Rain Rate to find the Melting Layer Height. This method is so pragmatic where it does not require any threshold value of Reflectivity and considering the vertical variation of Rain Rate in the Melting Layer. In the Rain Rate (RR) versus Height chart pinnacle is seen in the Melting Layer [11]. The elite end and bottom end contrast of the Melting Layer gives the thickness of it.

MRR data is compared with Radiosonde data of Machilipatnam situated at 70km faraway from CARE Lab where MRR is placed. Radiosonde data of two years is taken for observing the 0º isotherm with respect to height of atmosphere [14]. Radiosonde is mainly used for the observation of three parameters Temperature, Pressure and Relative Humidity of earth's atmosphere consisting thermistor, hygristor, aneroid barometer, baroswitch (switching mechanism) inside of it. In India we are having 39 Radiosonde stations where those are released in to air for the upper air observations for the changes in weather and climate research [15]. In India these are owned or operated by the IMD (Indian Meteorological Department) and data is exchanged through the international exchange agreements to NWS-NOAA, US.

III. RESULTS

A. MRR RESULTS

The Fall Velocity (W) is very less at above the Melting Layer than below as it increases when moves to downward. The attenuation of radar signal is very high at the bright band which is associated with the Melting Layer and it spreads up to several hundreds of kilometres, thus high attenuation of radiated signal is seen in this region. In melting process, the size of precipitation particles is small as its thickness increases from snow to liquid water which leads to cutback in the echo signal of MRR at the point below the Melting Layer associated at 100m below the 0º isotherm.

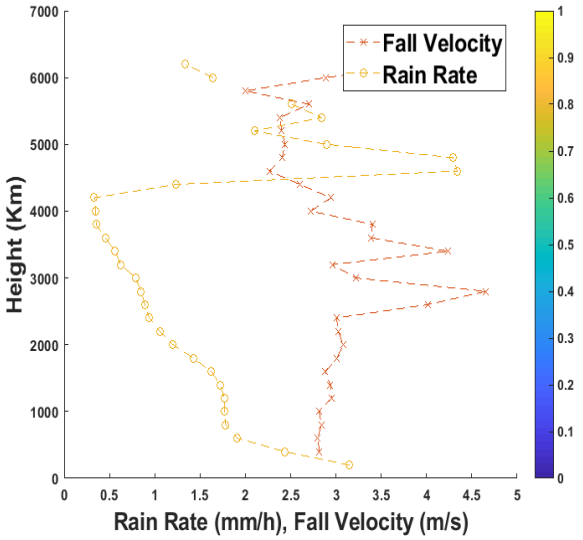

Figure 4. Characteristics of Rain Rate and Fall velocity to Estimate Melting Layer using MRR.

Figure 4shows the monthly mean of Rain Rate and Fall velocity precipitations for the month of July,2017 at KL University site. As above schematic clearly shows that, the peak rain rate attains at the altitude of about 4956m, thus we can say that Melting Layer is observed here. Fall velocity of raindrop particles is high below the Melting Layer and increases as it descends. Ice pellets are main cause of the higher reflectivity of radar signal and here the peak attenuation is also attained where the echoes are highly affected. The 0º isotherm is seen at this altitude is used to study the rainy condition of that location [9-10]. As we know that the constant altitudes of rain are not valid for all tropical locations.

Different altitudes of rain rates are plotted with the MRR data of 2017-2018 years for 200m, 1200m, 2200m, 3200m and 4200m respectively as shown in below Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9 respectively with sampling time of 10s where MRR gets the data for every 10s of time. Here we get distinct Rain Rates with respect to height in meters. Maximum vertical height is 6km from the MRR placed site, we attain the Melting Layer and peak rain rate at the altitude of 5km only from our station height.

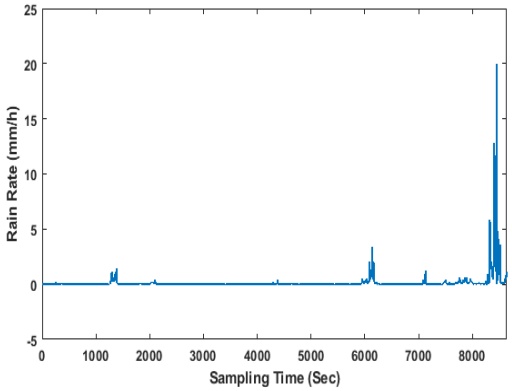

Figure 5. Rain Rate at 200m height attaining 20 mm rainfall

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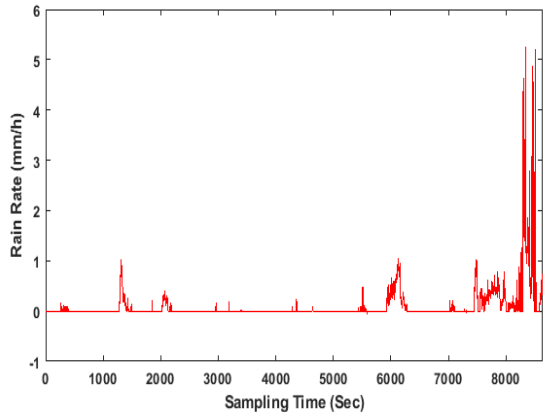

Figure 6.Rain Rate at 1200m height attaining 5.38 mm rainfall

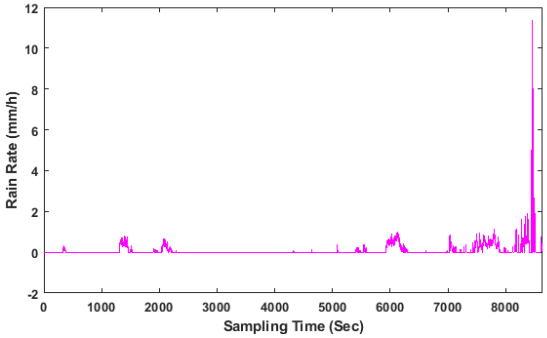

Figure 7. Rain Rate at 2200m height attaining 10.75 mm rainfall

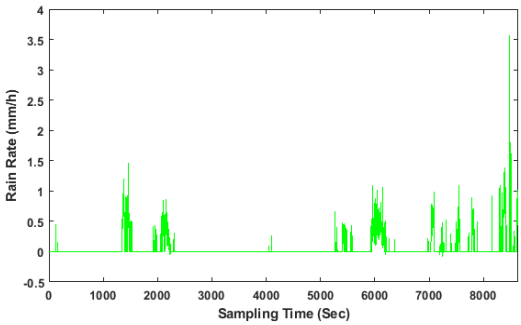

Figure 8. Rain Rate at 3200m height attaining 3.6 mm rainfall

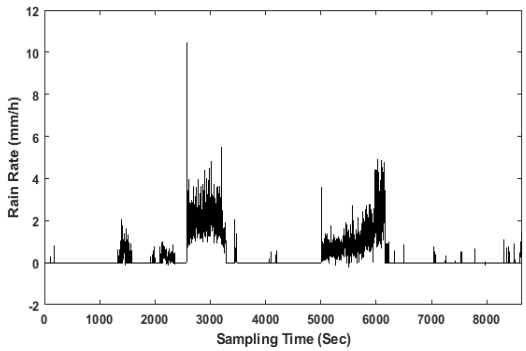

Figure 9. Rain Rate at 4200m height attaining 10.25 mm rainfall

B. RADIOSONDE RESULTS

Radiosonde data of Machilipatnam station is collected for two years 2017 and 2018 to observe the 0º isotherm where the rain height is measured. To compare with the MRR data, temperature parameter of Radiosonde data is taken at different altitudes of atmosphere, to observe where the temperature is at 0º C with respect to height for various seasons such as winter, summer, monsoon, pre-monsoon respectively.

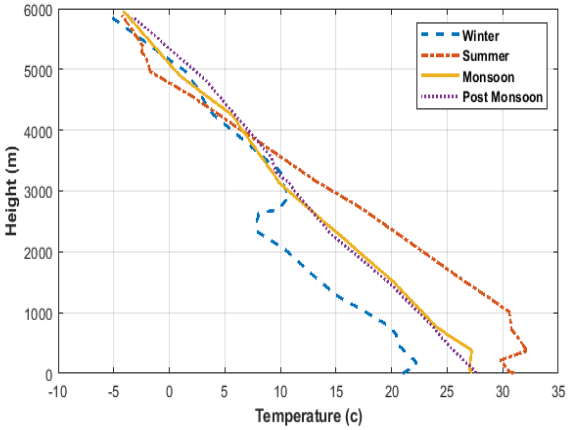

Figure 10. Characteristics of Temperature at distinct altitude profiles (Using Radiosonde data).

The variation of height with respect to temperature from the extracted data of Radiosonde,is plotted in Figure 10. It is observed that all the seasons 0º C isotherm is seen at the altitude of about above and below 5000m only with a variationof about 200m. In winter the 0º C is seen at above 5km but below the Post-monsoon season and above the summer, rainy seasons.

In summer the 0º C is observed below 5Km along withwinter, Monsoon and post monsoon seasons. In case of monsoon season 0º C appears at above 5km but below the winter and above the summer seasons. When coming to the post monsoon season the 0º C can be seen at 5km and its height is higher than the other three seasons. At some distinct altitude of around 4000m we observe all the four seasons temperature is constant.

IV. CONCLUSION

This work presented the estimation of melting layer height using Micro Rain Radar at coastal locations of Andhra Pradesh, India. Melting layer is observed at a height of 5000 meters using Micro Rain Radar at K L University shows a good compatibility with Radiosonde data of Machilipatnam as well. Hence it is clear that the melting layer height measured by using Micro Rain Radar shows a good indication of 0º isotherm height at rainy conditions. A variation in melting layer height of about 200 meters is also observed under different climatic conditions.

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AUTHORS PROFILE

Krishna Reddy Maddikera pursuing MTech degree in Communication and Radar Systems from K L E F. He received BTech degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Anantapur, (JNTU-A) India in 2013.

Sarat K. Kotamrajureceived the Bachelor’s and Master’s Degree in Electronics from PBSC and Bapatla Engineering College affiliated, AcharyaNagarjuna University, in 1999 and 2001 respectively, and M.Tech (ECE) with specialization in Radar & Microwave Engineering from Department of Electronics and Communication Engineering, AU College of Engineering, Andhra University, Visakhapatnam in 2004, Obtained Ph.D. Degree in Electronics from Sri Venkateswara University, Tirupati in 2009 worked in collaboration with Advanced Centre for Atmospheric Sciences, National Atmospheric Research Laboratory and Master Control Facility of ISRO along with European Space Agency, The Netherlands, for the thesis entitled “INSAT Ku and Ka band propagation impairment studies”. At present, he is working for research projects which are funded by Government agencies like Department of Science and Technology, and AICTE, ISRO related to Disaster Management and Satellite Propagation Studies at Ku and Ka band Frequencies.

K.Ch.SriKavyareceived Doctorate degree from KoneruLakshmaiah Education Foundation (KL University) for her research work on Array Antennas in 2014. She received her Bachelors’ in ECE and Masters’ in Communication and Radars systems, from KLCE affiliated to AcharyaNagarjunaUniversity in 2003 and in 2008 respectively. She has been currently working as a Professor in the Department of Electronics and Communication Engineering in KL University. Previously she carried out research work on various antennas for HAM Communications, which is sponsored by Ministry of Science and Technology, Government of India, New Delhi. She has 13 years of Teaching experience and more than 12 years of R & D experience and handled 6 R&D out sourcing projects from different agencies like DST, UGC, DRDO, & ISRO in the areas of Radars & Satellite Communication systems. She has published 33 papers in International, National Journals and Conferences.

S.S.S Kalyanworking as Senior Researcher Fellow (SRF) is a DST funded project, also pursuing Doctorate degree from KoneruLakshmaiah Education Foundation (KL University). His research interests include design of reconfigurable antennas and waveguides, reflect arrays, beam scanning antennas and Fade Mitigation studies in Earth-Space paths.

Bala Gangadhar Tilak Gandepursuing Doctorate degree from KoneruLakshmaiah Education Foundation (KL University). He received his Masters degree in Embedded Systems and VLSI Design, from GayatriVidyaParishad College of Engineering (A) affiliated to Jawaharlal Nehru Technological University, Kakinada (JNTUK) in 2014 respectively. He has 2 years of Teaching experience and more than 1 year of R & D experience in the areas of Radars & Satellite Communication systems.

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