Some Melting Layer Characteristics at Two Tropical Locations in Indian Region

***Saurabh Das*[1] and *Animesh Maitra*[2]**

Institute of Radio Physics and Electronics, University of Calcutta, 92, A. P. C. Road, Kolkata- 700009, India
[1]e-mail: das.saurabh01@gmail.com, [2]e-mail: animesh.maitra@gmail.com

Abstract

Hydrometeors pose a serious threat to satellite communication operating above 10 GHz. The designing line of sight link usually is based on the ITU-R models, which are often inadequate for tropical region. ITU-R model uses a yearly averaged constant rain height for the attenuation calculation, which may not be valid for tropics. This paper reports the study of rain height based on Micro Rain Radar and Radiosonde observations at two tropical locations in Indian region. Results suggest a possible modification in the rain attenuation model taking into account the melting layer height variation with the season and rain rate.

1. Introduction

Rain attenuation is the primary impairment at frequency bands operation above 10 GHz [1, 2]. In the absence of actual slant path attenuation measurements, system designers are often forces to rely on the rain attenuation models. These models are based on certain assumptions and on the measured meteorological parameter in temperate locations. These models are found to be inadequate for attenuation prediction in tropical region due to the different characteristics of rain and other hydrometeors [3, 4].

One of the globally used models for calculation of attenuation is ITU-R model P. 618-9 [5]. This model uses the assumption of a constant rain height for the calculation of effective path length. The rain height is derived from yearly averaged zero degree isotherm height. But, in topics, it is found that the rain height is not invariant with time, and shows significant variation with the rain rate [6].

In this work, the variation of rain height with rain rate for two tropical locations in India has been studied. The data has been obtained using Micro Rain Radar (MRR) for 3 years at two tropical locations, namely Trivandrum (08^{o}29’ N, 76^{o}57’ E, 4 m) and Shillong (25^{o}34’ N, 91^{o}53’ E, 1050 m).

2. Experimental Setup and Methodology

Different meteorological instruments are installed at two different geographic locations- Trivandrum (08^{o}29’ N, 76^{o}57’ E, 4 m) and Shillong (25^{o}34’ N, 91^{o}53’ E, 1050 m). Micro Rain Radar (MRR), Disdrometer and tipping bucket raingauge are used to measure different rain parameters. In this work, rain observations of 3 years by MRR have been used.

The MRR is a vertically pointing FM-CW (Frequency Modulated Continuous Wave) Doppler radar which operates at 24.1 GHz. The vertical profile of drop size distribution (DSD) has been calculated from the Doppler spectra. Once DSD has been measured with Doppler principle, other rain integral parameters can be obtained. Retrieval of Doppler spectra and different micro physical parameters can be found in details by Atlas et al, 1993 [7], Strauch, 1976 [8] and Peters et.al.2002 [9]. The MRR has a temporal resolution of 30 seconds and spatial resolution of 200 m.

The rain height information can be obtained indirectly by studying the melting layer height in Stratiform rain type. The Stratiform type of rain is characterized by low rain rate and higher spatial and temporal coverage. It is normally associated with the melting layer, the region where ice crystals starts melting into liquid water. So effectively, the melting layer indicates the limit of rain region in stratiform rain type. Conventionally, the zero degree isotherm height is used for such rain height estimation, which usually matches with the top of melting layer height.

The vertical profile of radar reflectivity can detect the melting layer by bright band signature. The melting layer can be easily identified from the vertical radar reflectivity profile as a sharp peak, called bright band [10], due to the presence of water coated ice crystal in this region which has different dielectric constant.

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It is found in an earlier study that the vertical profile of rain rate is more sensitive than radar reflectivity in MRR data product to identify the bright band height [9, 10]. The melting layer top is identified as the height with maximum negative gradient in rain rate [12, 13]. An example of melting layer observations by MRR is shown in Fig. 1.

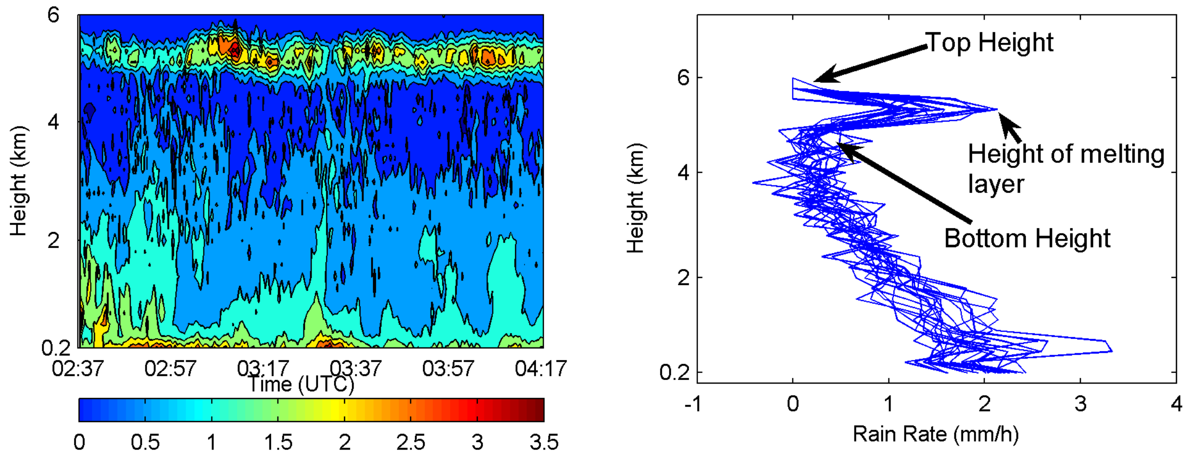

Fig. 1: *(a) MRR vertical rain rate profile indicating the melting layer around 5 km height, (b) the different parameters calculated from instantaneous melting layer information on 9 July 2009.*

3. Analysis and Results

From the 3 years MRR measurements, data corresponds to rain rate value less than 0.1 mm/h at ground has been discarded because it may contain ground echo. Also, rain rate above 10 mm/h is not taken in to account to consider only the certain cases of stratiform rain type [14]. Data have also been discarded if vertical profile of rain rate is found to be discontinuous at some height as a precautionary measure. Afterward, bright band top height has been determined as the maximum negative gradient of rain rate from the processed data set.

3.1 Comparison of MRR and Radiosonde Observations

In Fig. 2, comparison of monthly average melting layer top height with zero degree isotherm height measured from Radiosonde observations of 5 years is shown.

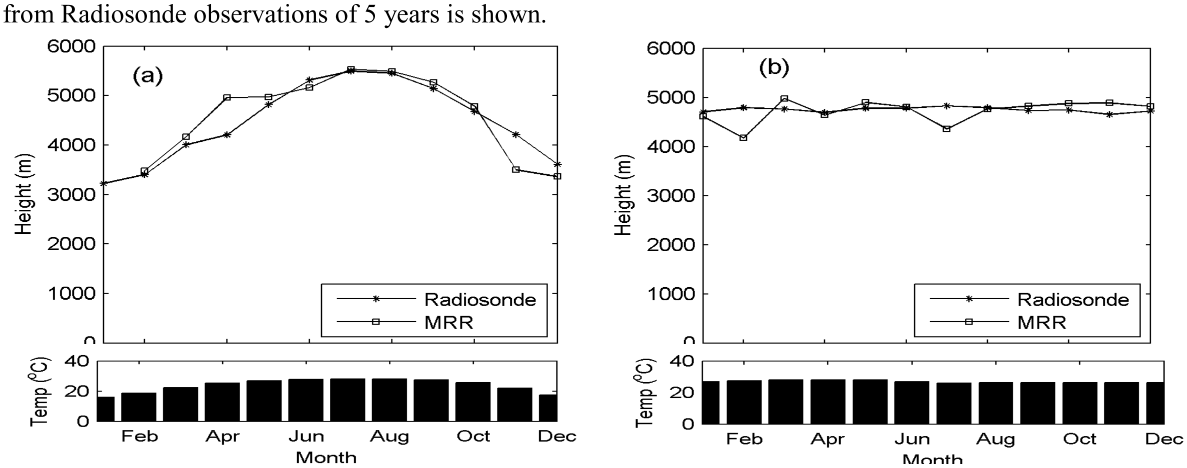

Fig. 2: *Comparison of monthly mean melting layer top height measured by MRR (2005-2007) and long term Radiosonde observation (1994-1999) of zero degree isotherm height at (a) Shillong and (b) Trivandrum. Lower subplots shows the monthly mean temperatures at respective locations. The vertical bar indicates the standard deviation values of MRR data.*

The zero degree isotherm height is found to be well indicated by MRR for both the location. This shows the validity of rain height calculation by MRR. It also indicates the possibility of using MRR effectively for monitoring the zero degree isotherm height in rainy conditions, considering that the Radiosonde launches are not possible in rainy condition.

It can be seen that the rain height has higher seasonal variability in Shillong than Trivandrum. This is due to the fact that Shillong, being located at higher latitude, has greater variability in surface temperature as shown in lower subplots. This suggests that the constant rain height assumption in ITU-R model for higher latitudes may not be adequate.

3.2 Variation of Rain Height with Rain Rate

To study the variation of melting layer top height with rain rate, the data is categorized in to 0.5 mm/h rain rate bins observed at 200 m height of MRR and averaged over for all 3 years.

The variation of top of the melting layer height for these two locations has been shown in Fig 3. It shows that the variation in rain height (H^0) is quite significant for stratiform rain in India for both the locations. The decreasing pattern of both the curves also implies that it may be a general feature for tropical rains.

The variation is then modeled as linear function of rain rate. The model equations with the coefficient values are given below

$$H^0_{Trivandrum} = -125.7R + 5042 \quad \text{m.} \qquad (1)$$

$$H^0_{Shillong} = -144.7R + 5161 \quad \text{m.} \qquad (2)$$

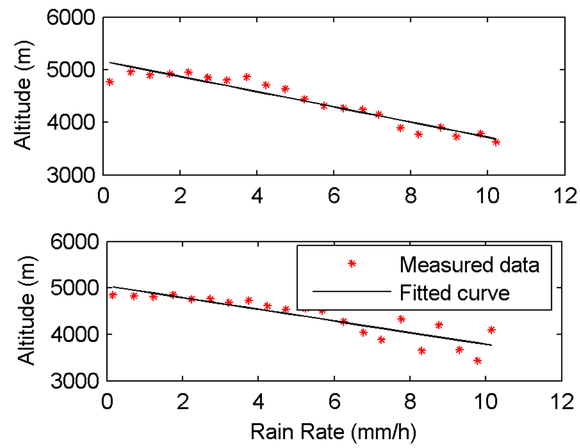

Fig. 3: *variation of rain height with rain rate for (a) Shillong and (b) Trivandrum*

3.3 Implication on ITU-R Model

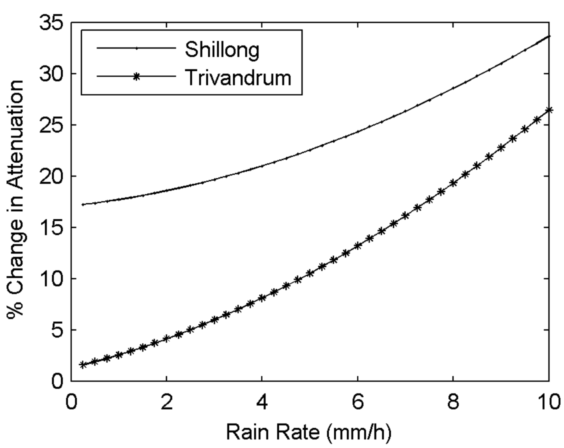

Fig. 4: *Percentage change in rain attenuation calculated from ITU-R model with fixed rain height and variable rain height.*

The ITU-R model for rain attenuation calculation uses the simple notion of a constant rain height for all rain rate and need to be revised for tropical region. ITU-R P. 618-9 is normally used to calculate the rain attenuation (A) from rain rate as follows:

$$A = \gamma L_E \qquad (3)$$

Where, L_E is the path length through rain and γ is the specific rain attenuation. The constant rain height assumption leads to a fixed value of L_E whereas a rain rate dependent rain height leads to variable path length.

Fig. 4 shows the percentage change in attenuation calculation with formal ITU-R model and with the proposed modification for the two locations. The percentage change is quite significant with the increase in rain rate, which suggest a possible modification in the ITU-R model.

4. Conclusion

This paper reports the characteristics of rain height measured by MRR data in tropical Indian region. It is observed that the melting layer top height measured by MRR is a good indicator of the zero degree isotherm height in rainy condition. The results also highlight the possibility of using MRR for studying the variation of zero degree isotherm in rainy condition when Radiosonde launches are not possible.

Rain height for higher latitude region shows significant variation than for the lower latitude regions. The study also shows that the rain height decreases with the rain rate at both the locations for stratiform rain for tropical region.

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