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Determination of Bright Band in Malaysia through Radar Data Analysis

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Abstract**—** Restrained usages of X-band and below is mostly due to commercial operations along the slant-path. In tropical regions, signal degradations are often due to hydrometeors such as rain, hail, cloud, and the melting layer. In addition, these can cause several problems, such as signal fading, depolarization and co-channel polarization due to scattering along the satellite link. Inadequate availability of database along the slant-path in tropical regions for use in rain propagation studies at microwave frequencies required more studies to be carried out. This work concerns the characterization of bright band in a tropical station. The effects of seasonal variations on rain height can give the information that are valuable for designing and planning of satellite link in a tropical region like Malaysia. The meteorological radar data for this work was obtained from the Meteorological Department of Malaysia. The result of the analysis of the processed radar data and the obtained parameters for the bright band showed good agreement with works carried out by other researchers in the tropical region.

Index Terms**—** Bright band, Stratiform, Convective, freezing height, 0^0 C isotherm, RAPIC, PPI, RHI.

I. INTRODUCTION

For the study of melting layer characteristics, rainfall types are grouped into stratiform and convective. In simple terms, stratiform rains comprise light intensity widespread rainfalls within limited vertical extent of rain height, and are produced by stratus clouds. On the contrary, convective rainfalls are produced by cumulus clouds; with narrow horizontal area and associated with extensive rainfall rates and height [1]. Rain height is generally known to be highly correlated with signal attenuation and co-channel interference due to scattering. The rain height distribution is important because it can be used to investigate the mechanisms responsible for variations in the attenuation distributions at any station. The prediction methods being used to estimate the degree of signal attenuation encompasses the various location-specific meteorological factors, and rain height is one such factor. The rain height, H_R is also directly related to the zero degree Celsius isotherm height, H_0. Rain height information can be indirectly obtained by studying the melting layer height in stratiform rain type. One major source of slant-path attenuation prediction errors is the complex nature of the rainfall structure along this path. Another reason is the uncertainty in the estimation of attenuation due to the melting layer. The difficulties in relating H_R to H_0 in the tropics had also been attributed to insufficient database and peculiar rainfall types existing in the tropical regions [2].

The rain height is being employed in ITU-R Rec. P.618-10 (for slant-path attenuation prediction), ITU-R Rec. P.452-14 (for co-channel interference estimation), ITU-R Rec. P.620-6 (for coordination distances), and ITU-R Radio Regulations Appendix 7 (for regulatory issues of coordination) [3]. The ITU-R Rec. P.618-10 uses the rain height as the boundary below which the slant-path attenuation is integrated while the ITU-R Rec. P.452-10 uses it to discriminate rain scatter from ice scatter, incorporating variability into the mean freezing height. It uses an effective rain cell model with rain height parameterized vertical dimension, adopting the effective rain height rather than the melting layer's height. The rain height can be considered to represent the boundary between the rain region and the snow region and it often correspond to the 0^0C isotherm (mostly during stratiform rain events). In the vertical dimension, the rainfall rate is assumed to be constant up to the point that represents the top of the rain height and attenuation beyond the height is considered insignificant, and thus neglected [3].

However, recent research has shown that the effect of melting layer on signal attenuation is not after all negligible, especially for weak rain rates [4].

At the H_0, hydrometeors changes from solid to liquid in the melting layer, leading to increase in their reflectivity; manifesting in the bright band signature seen in radar measurements. This band identification is made possible because of its sharp peak of reflectivity in high frequency domain [5-7]. Furthermore, if the bright-band was not recognized, it can result in serious over-estimation of precipitation reaching the ground by a factor as high as five [8].

The melting layer is a major factor responsible for the problems being encountered in characterization and modelling of microwave signal propagation. In the absence of actual attenuation measurement data, System Designers are usually compel to rely on rain attenuation models, either for terrestrial or slant-path propagation. This, unquestionably accentuate the importance of modelling in both link budget analysis and equipment designs.

Radar Meteorologists define the melting layer as the region where melting occurs, and it lie just below the 0^0C isotherm height. The 0^0C isotherm is that height at which the ice-to-water transition begins. The variances in the propagation characteristics of ice and water presents an effective boundary referred to as the bright band.

The height of the bright band is close to that 0^0C isotherm, depending on the season and location of the station of interest [3, 9-12]. The 0^0C isotherm, rain and bright band heights most times lie close to each other (see Figure 1), although they represent different parameters [3]. The difference between the effective rain height and the freezing height is taking to be 360 meters according to [13], and is expressed as:

$$H_R = H_0 + 0.36km \qquad (1)$$

Where H_R represents the mean rain height above mean sea level and H_0 is the mean 0^0C isotherm height above mean sea level.

The frozen hydrometeors were observed to show a typical enhancement of radar bistatic reflectivity (dBZ) as they fall through the melting layer, followed by a sharper decrease in reflectivity during the following stages of the melting process [10]. To this effect, several researchers have developed and proposed quite a handful of models for predicting attenuation in the melting layer [4, 14-17].

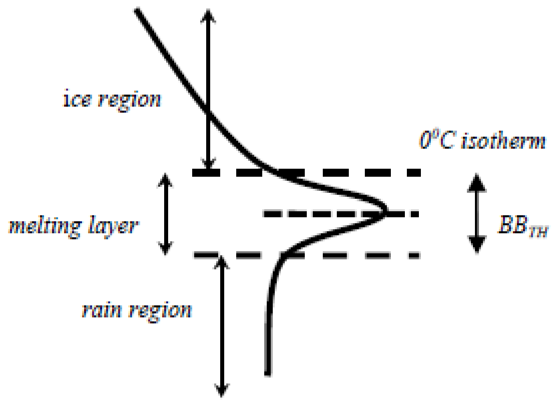

Figure 1. Bright band Conceptual Model.

II. METHODOLOGY

The meteorological radar data for this work was obtained from the Meteorological Department of Malaysia. The analysis undertaken here is for a 62 km range from Kluang radar station (lat. 2.02^0N, long. 103.38^0E) to Faculty of Electrical Engineering (FKE), Universiti Teknologi Malaysia (lat. 1.56^0N, long. 103.64^0E). The azimuth from Kluang to FKE was evaluated to be 169^0. The data duration spans thirteen months (November 2006 to November 2007). However, this preliminary data analysis is based on data samples from January to March 2007. The classification of the rain events is evaluated with the minimum amount of the rain rate that the radar can detect; confirmed by using the widely accepted empirical relationship of the radar reflectivity factor Z, and rainfall rate R, that is given by

$$Z = aR^b \quad (mm^6m^{-3}) \qquad (2)$$

Where the most common values for a and b are 200 and 1.6 respectively, according to Marshall-Palmer [18]. These are also the values used by the radar operators at the Malaysian Meteorological Department of Malaysia.

This system uses the 3D RAPIC system and two modes of scans - The plan position indicator (PPI) and range height indicator (RHI). The specification of the Kluang radar is given in Table I.

TABLE I. KLUANG RADAR SPECIFICATIONS [11]

Meteorological Radar MR 781 S Kajicuaca, Kluang With RAPIC Transmitter EH663 v.8.00	
Station ID	3
Station Position	Latitude: 2.02°, Longitude: 103.320°, Height: 88.1m above MSL
Reflector	12 Feet parabolic (3.66m)
Frequency	2800 MHz
Polarization	Vertical
Gain	38 dB
Coverage	Elevation: -2° to +90°, Azimuth: 360°
Beam width	2.0°
Pulse duration	2.2μs
PRF	278 pps
Peak power	389 kW
STC range	230 km

For PPI scan there are 15 volumetric elevation angles, 0.5°, 1.2°, 1.9°, 2.7°, 3.5°, 4.6°, 6.0°, 7.5°, 9.2°, 11.0°, 13.0°, 16.0°, 20.0°, 25.0°, and 32.0°. The radar image of each of these selected angles was recorded through the full RHI's azimuthal scan range of 360°. The elevations angles used in this work are 1.1°, 1.9°, 3.3°, 5.8°, 7.7°, 10.3°, 13.6°, and 18.1°.

The parameters of the melting layer are obtained from the detected bright band signature, after series of processing that include, but not limited to, various levels of sorting, filtering and decoding to build the vertical profile of reflectivity of the bright band.

III. RESULTS AND DISCUSSIONS

The vertical profile of reflectivity for the months of January, February and March 2007 are displayed in Figures 1-3 respectively.

Table II compares the results of measurements with those obtained by other researchers that were also carried out in other tropical stations and the ITU-Rec. P. 839-3. The ITU-Rec. P. 839-3 largely over-estimated the measurements for the rain heights.

Significant changes were observed in the month-to-month data for the freezing heights, from 5.815 km, 4.327 km, to 7.742 km for the months of January, February and March respectively.

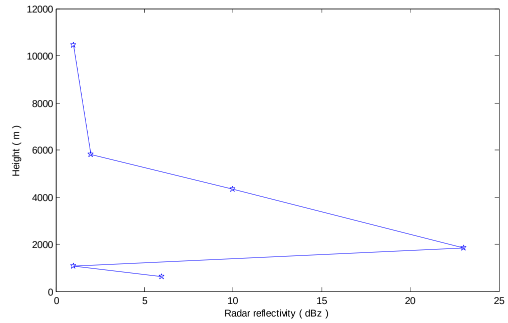

Figure 2. VRP plot for January 2007 for Kluang, Malaysia.

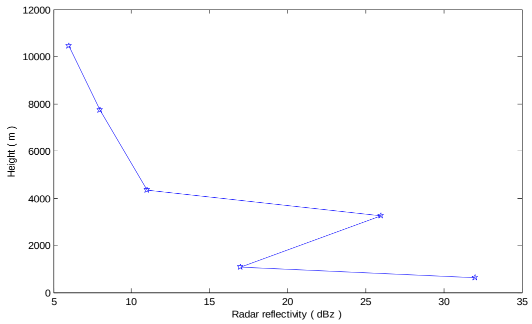

Figure 3. VRP plot for February 2007 for Kluang, Malaysia.

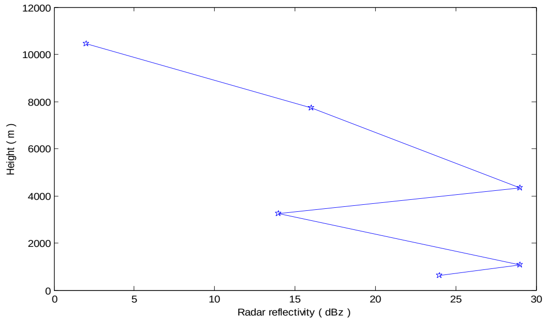

Figure 4. VRP plot for March 2007 for Kluang, Malaysia.

The month-to-month variations in freezing heights, bright band heights, bright band thickness and rain heights are shown in Figures 6-9 respectively.

Malaysia experiences two monsoon events yearly. These are the North-East (October to March) from the South China Sea and South-West monsoon (April to September) from the Indian Ocean. This results in two rainy and two dry seasons.

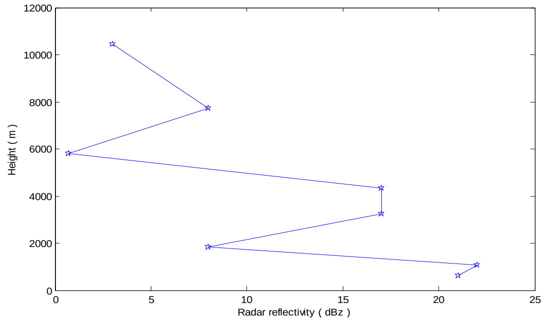

Figure 5. Mean VRP plot for January - March 2007 for Kluang, Malaysia.

January is the end month of the North-East monsoon rain and the start of the dry season, while March is the end of the North-East monsoon dry season and the beginning of the South-West monsoon rainy season.

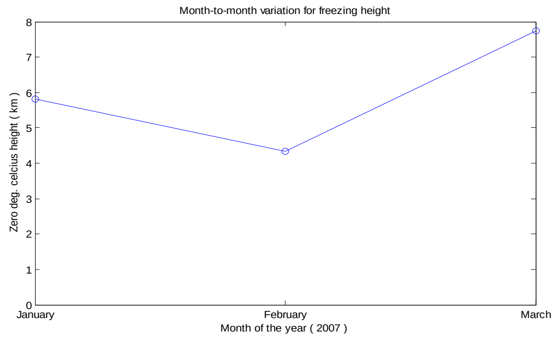

Figure 6. Month-to-month variation for H_0 .

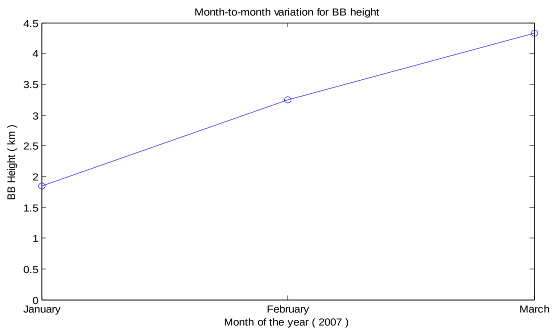

Figure 7. Month-to-month variation for BB_H .

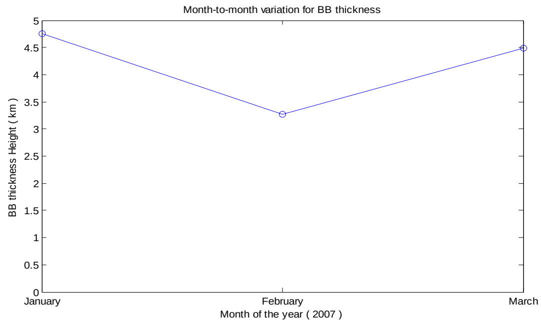

Figure 8. Month-to-month variation for BB_{TH} .

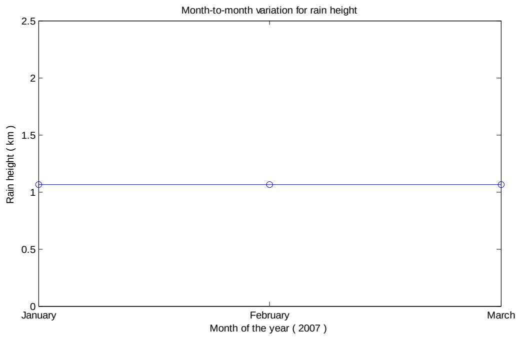

Figure 9. Month-to-month variation for H_R .

These values are in contrast to a constant value of 4.50 km as recommended by ITU-Rec. P. 839-3. The melting layer heights were observed to steadily increase over the months (1.845 km, 3.250 km, and 4.327 km for January, February and March respectively). Additionally, the rain heights were found to the fixed at 1.062 km over the three-month period. Results of this work showed good degree of agreement with some other results obtained in some other tropical regions.

TABLE II. COMPARISON WITH RESULTS OBTAINED FROM SIMILAR WORKS IN THE TROPICS

	Freezing height (H_0) km	BB bot Height km	BB height km	BB thickness km	Rain height (H_R) km
ITU-R P. 839-3 [13]	4.50				4.86
TRMM-PR [9]	5.00	3.75	4.4	1.25	3.75
Singapore [19]	5.00	2.00	3.50	3.00	2.00
Kluang 2007 [11]	2.952	2.00	3.961	1.827	1.976
Current work	5.961	1.845	3.789	3.970	1.062

IV. CONCLUSIONS

The results of the comparison of the evaluation of this processed ground radar data with other similar work showed a good degree of agreement with most of the measured parameters.

However, the ITU-Rec. P. 839-3 seems to over-estimate the measurements for the mean rain height above sea level, H_R . This may be due to the assumed constant value for the mean 0^0C isotherm height above mean sea level, H_0 .

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