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Classification of Precipitation Types Detected in Malaysia

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***Abstract*—**The occurrences of precipitation, also commonly referred as rain, in the form of "convective" and "stratiform" have been identified to exist worldwide. In this study, the radar return echoes or known as reflectivity values acquired from radar scans have been exploited in the process of classifying the type of rain endured. The investigation use radar data from Malaysian Meteorology Department (MMD). It is possible to discriminate the types of rain experienced in tropical region by observing the vertical characteristics of the rain structure. .Heavy rain in tropical region profoundly affects radiowave signals, causing transmission interference and signal fading. Required wireless system fade margin depends on the type of rain. Information relating to the two mentioned types of rain is critical for the system engineers and researchers in their endeavour to improve the reliability of communication links. This paper highlights the quantification of percentage occurrences over one year period in 2009.

***Keywords*—**Stratiform, convective, tropical region, attenuation radar reflectivity.

I. Introduction

ACCORDING to the literature [1], [2] precipitation that occurs all over the world may be grouped into four different types. However, precipitation events are generally classified in only two broad classes namely "convective" and "stratiform". *Convective* type typically involves a very intense and relatively short-lived precipitation with variable rain heights that might go up to more than 13 km [3]. In other words, convective rain is generalised assevere rainfall that occurs for duration of limited periods and typically covers a small and localised area. "Stratiform" or “widespread” rain on the other hand can be characterised by medium and low rate events that occurs for a longer period of time. This type of rain comprises a very well developed "melting layer" at a constant height. The melting layers are the transition regions between snow and rain. They usually start at the 0° C and finish a few degrees above 0° C where the entire snow particles melted and become raindrops.

A radar system is an ideal tool for studying the climate conditions in the tropics. This is one of the feasible techniques of collecting data that can furnish detailed information pertaining toboth horizontal and vertical structure of rain. It is also practical for studying rain scatter and signal interference [4]. The attempt to evaluate and distinguish the type of rain event using radar data is realistic approach. This is due to the fact that there are large numbers of space-based and ground-based radar around. There are two essential types of radar display namely the constant altitude plan position indicator (CAPPI) and the range height indicator (RHI). The types of precipitation can be classified from the analyses carried out upon the RHI scans. The vertical variability of the rain at instantaneous time can be observed from RHI views. From the RHI raster scan, the reflectivity values, rain height and the rain cell size can be ascertained. Rain severely attenuates wireless communication link both terrestrial and satellite links especially for those with operating frequency higher than 10 GHz. The access attenuation of a radiowave signal due to rain is formed from two components. The components are described as absorption and scattering. The relative importance of scattering and absorption is a function of the complex refraction of the absorbing/scattering particle. The complex index of refraction itself is a function of signal wavelength, temperature, and the size of the particle, relative to the wavelength of the radiowave. It is important to examine the variation of the scattering and/or absorption contributions to extinction, for water spheres of various radii. Water spheres with larger radii are normally associated with convective rain event that causes higher signal fading than the widespread rain.

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II. Classification of Rain types

One previously proposed method to classify the precipitation as stratiform is by establishing existence of melting layers in radar reflectivity display [5], [6]. If there is no indication of melting layer, the rain will be usually regarded as convective type. The melting layer is associated with cumulus–scale convection in unstable air. During convective events, the bright band is entirely absent because of convective overturning. In this study, precipitation event is classified as convective or stratiform from the inspection upon the radar reflectivity. The inspection involved determination of melting layer signature up to 15 km height. Several literatures also proposed that the two rain types (convective and stratiform)can also be determined from their reflectivity values displayed on the radar scan. The convective rain type region can be modeled as an area with high reflectivity compared to its surrounding area. Steiner et al. [2] proposed this technique to distinguish the convective rain region from stratiform rain region using reflectivity values at certain height from ground.Previous studies [7]-[9]also utilised similar rain classification technique for investigation in Bangalore, India, Milan, Italy and Changi, Singapore. Table I shows the criteria of the stratiform and convective rain types based on the RHI radar views.

TABLE I
CRITERIA TO DIFFERENTIATE RAIN TYPES USING RADAR DATA [5]-[9]

Stratiform	Convective
1. Reflectivity Ranges (2 - 37dBz)	1. Reflectivity Ranges > 38 dBz)
2. Rainfall Intensity Values (0 - 9.9mm/hr)	2. Rainfall Intensity Values (>10 mm/hr)
3. Clear Melting Height	3. No Melting Height
4. Rain height between 4 -5 km	4. Rain height > 6 km
5. Slow differences in vertical profile	5. Rapid increase in vertical profile
6. Bright band height for each bin has to be approximated within the same height of the neighboring bins.	6. Bright band height for each bin is extremely different with the neighboring bins.
7. Low values of reflectivity gradient	7. High values of reflectivity gradient

III. SYSTEM CONFIGURATION AND MEASUREMENT SETUP

A. Description of the Radar System

The Malaysian Meteorology Department (MMD) installed a fixed Terminal Doppler Radar (TDR) at the Bukit Tampoi, Sepang, Selangor(2° 51' 0"N /101° 40' 0.0114"E). The8.5 m diameter parabolic reflector antenna operates at 2.8 GHz S-band frequency. It is a single polarisation system capable of measuring and recording reflectivity (*Z*), linear depolarisation ratio (*LDR*), radial velocity and velocity spectral width at 3µs sampling rate.The radar antenna rotates at the speed of 2 revolution per minute (RPM) with pulse repetition frequency (PRF) equals to 300 Hz for scanning elevation angles of less than 5°. The radar will rotate at faster speed of 4 revolution per minute (RPM) with PRF equals to 1000 Hz for angles of elevation between 5° to 40°. The radar bin size is 238.3 m x 23.8 m square. Fig. 1 shows the radar system being covered by a 12 m radome. Such system can be utilized in the process to obtain information regarding the vertical structure of precipitation in tropical climate [10], [11]. The radar can detect precipitation up to 480 km from its station.

Fig. 1 Meteorological Radar

IV. CORRELATION OF RAINFALL RATE WITH REFLECTIVITY AND ATTENUATION

Rain types can be determined from the rainfall rate values as pointed out in Table I. Conveniently, rainfall rate can be estimated using radar reflectivity values. The technique exploits the pre-determined rainfall rate versus reflectivity relationship (*R-Z* relationship) to convert radar reflectivity measurements to rainfall rates. Over the years, several different *R-Z* relationships have been developed and proposed [12], [13]. These are mostly empirical models that were developed using co-located rainfall rate measurements equipment (rain gauge) and radars. There has been significant variability in the suggested models for estimating the rainfall rate from radar reflectivity measurements [14]. It has been discussed that some models may be site-specific and that they do not apply universally to different locations around the world [15], [16]. In addition, the models after all might be dependent on the type of rainfall, which commonly accepted to deviate considerably as from one specific region of the world to another. According to proposed conversion formulae by Marshal Palmer [17], the rainfall rate, *R* can be inferred from the value of the measured reflectivity, Z as in (1);

$$R = \sqrt[b]{\frac{Z}{a}} \quad (1)$$

where a = 200 and b = 1.6 is the value.The reflectivity Z can be expressed on a logarithmic scale in unit dBZ, which can be calculated from (2):

$$dBZ = 10\log Z \quad (2)$$

The rain attenuation ,A of the satellite path can be configured from the deduced rainfall rates using the power law equation [18];

$$A = k\,R^{\alpha}.Le \quad (3)$$

where L_e is the effective length affected by rain. k and α are the coefficients given in the ITU-R recommendation [13] as;

$$k = [k_H + k_V + (k_H - k_V)\cos^2\theta\cos 2\tau]/2 \quad (4)$$

$$\alpha = [k_H\alpha_H + k_V\alpha_V + (k_H\alpha_H - k_V\alpha_V)\cos^2\theta\cos 2\tau]/2k \quad (5)$$

whereθ is the path elevation angle and τ is the polarization tilt angle relative to the horizontal

V. RESULTS AND DISCUSSION

This paper highlights the first 3 criterion identified in Table I. The investigations of the remaining criteria are in progress. Shown in **Error! Reference source not found.** is one of the RHI scans that portrays the vertical variation of rain where the radar reflectivity values can be analyzed. The raw values of radar reflectivity can be converted to rainfall rate according to (1). For example the RHI stratiform event on 26/12/2009 in Fig. **2** can be read as 34 dBZ or equal to 0.35 mm/hr at that particular bin marked as red square in the figure.

Figs. 3 and 4 show the corresponding events with particular attention towards the values of radar reflectivity, dBz. It is evident in Fig. 5 that reflectivity values are higher than 37 dBz hence qualifying it as a convective event and comply to criterion highlighted in Table I. Alternatively, **Error!**

Reference source not found. 5 shows derived rainfall rates for what might be considered as convective event. It has been identified during the convective rain event, the rainfall rate exceeded 10 mm/hr. **Error! Reference source not found.** portrays what can be considered as a stratiform even time series derived from radar data.

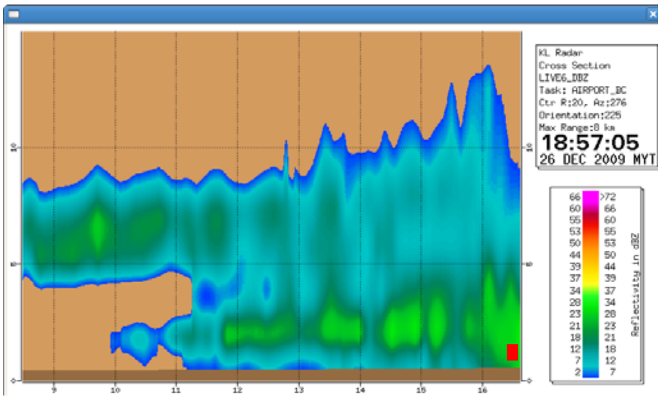

Fig. 2 RHI scan example that will be converted to reflectivity values

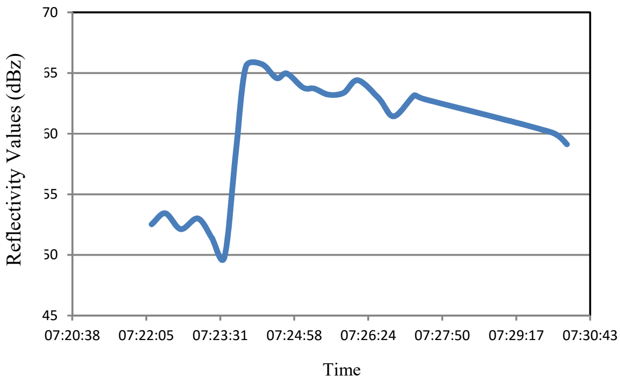

Fig. 3 Convective rain events on 05/08/2009 (Reflectivity Values)

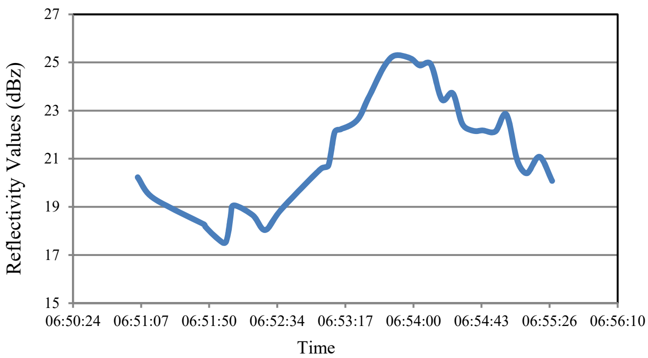

Fig. 4 Stratiform events on 28/8/2009 (Reflectivity Values)

From visual inspection for existence of melting layer, all rainevents are then classified into two groups. Fig. depicts a display of *Z* vertical scan recorded on a selected day during stratiform events within the period of campaign. It is apparent in the presented figure that it exhibits clear melting height of approximately 6.5 km with approximate layer thickness between 200-500 m. An example of a convective event can be observed in Fig. . The reflectivity measurements do not exhibit existence of a melting layer.

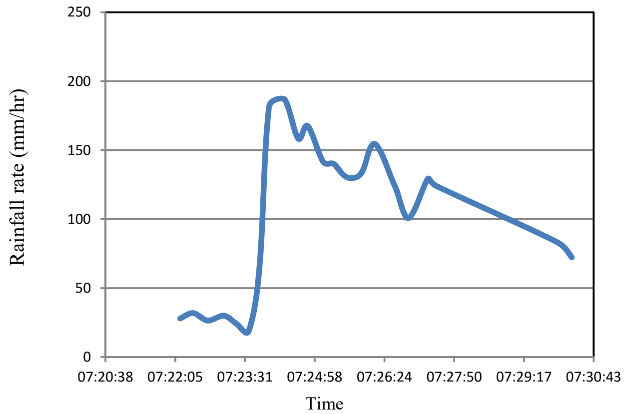

Fig. 5 Convective rain events on 05/08/2009 (Rainfall rates Values)

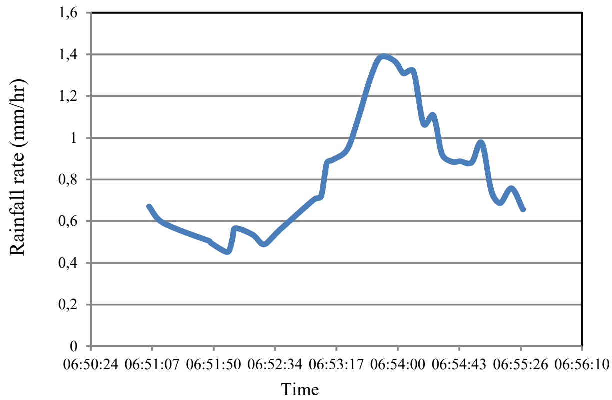

Fig. 6 Stratiform events on 28/8/2009 (Rainfall rates Values)

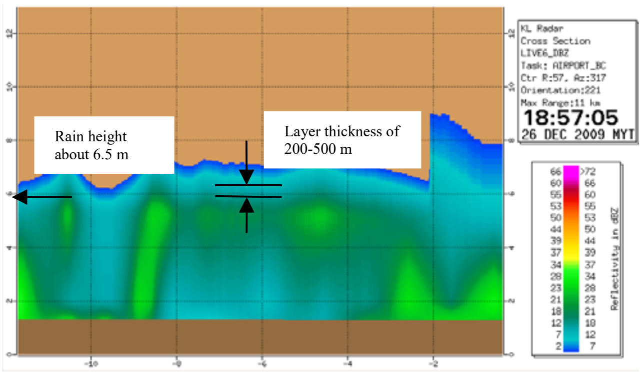

Fig. 7 Stratiform events on 26/12/2009

Based on the one year data, the radar scans were inspected and rain events are identified and recorded. Table II shows the number of occurrences of stratiform and convective events identified from the radar data. It appears that in 2009 the number of occurrences of the two types is about equal. This might signify a typical characteristic of tropical country such as Malaysia whereas in temperate region, convective rain events are of rare occurrences.

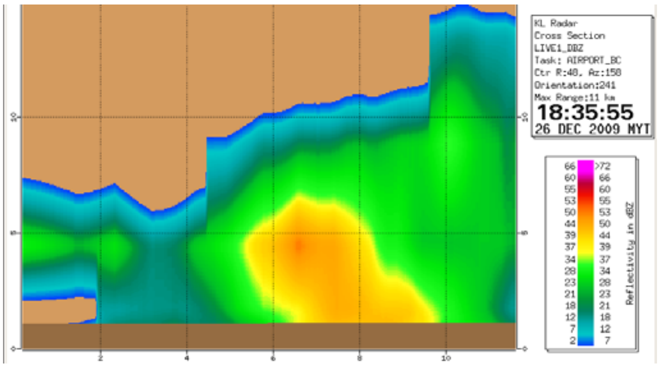

Fig. 8 Convective events on 26/12/2009

TABLE II
RAIN TYPES BASED ON RADAR DATA

Number of Events	Stratiform Events	Convective Events
486	226	220
100%	54.7%	45.3%

The tropical regions experience dense rainfall rate and base on the preliminary finding, about half of the time is convective as compared to what is being experienced by temperate region. On such note, any wireless link with operating frequencies higher that 10 GHZ will definitely suffer relentless attenuation if proper or adequate rain fade countermeasure is not being implemented. Engineers and researchers should take account these behavior in order to overcome such disadvantages and would be able to serve the communication services with better prediction.

VI. CONCLUSION

High reflectivity values, high rainfall rates and non-existence of melting height are often associated with the characteristics of convective precipitation. Low reflectivity values and lower rain rates on average reflect characteristics of stratiform precipitation. The presence of a bright band typically indicates stratiform region. In the future, wireless link margin would be best predicted if the characteristics of the rain can be studied profoundly at each location.

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REFERENCES

[1] Radiocommunication Bureau (1996) *Handbook on Radiometeorology*, Geneva
[2] S. Carolina, “On the Separation of Tropical Convective and Stratiform Rains,” pp. 188–195, 2002.
[3] B. J. Zafar, “Classification of Precipitation Type from Space Borne Precipitation Radar Data and 2D Wavelet Analysis,” vol. 00, no. V, pp. 3570–3573, 2004.
[4] H. E. T. Al, “Separation of Convective and Stratiform Precipitation Using Microwave Brightness Temperature,” pp. 1195–1213, 1999.
[5] S. Das, K. Ashish, and A. Maitra, “Classification of Convective and Stratiform Types of Rain and their Characteristics Features at a Tropical Location,” pp. 0–3, 2009.
[6] C. Separation, “5. Convective-Stratiform Separation,” 2000.
[7] S. Das, K. Ashish, and A. Maitra, “Classification of Convective and Stratiform Types of Rain and their Characteristics Features at a Tropical Location,” pp. 0–3, 2009.
[8] E. Matricciani, “from Radar Measurements Useful to Design Satellite Communication Systems for Mobile Terminals,” vol. 49, no. 5, pp. 1534–1546, 2000.
[9] “Progress In Electromagnetics Research B, Vol. 32, 107–127, 2011,” vol. 32, no. July, pp. 107–127, 2011.
[10] K. Badron, A. F. Ismail, and H. A. M. Ramli, “Evaluation of RazakSAT’s S-band Link Signal Measurement with the Radar Derived Rain Attenuation,” no. July, pp. 1–3, 2013.
[11] J. D. Eastment, D. N. Ladd, and M. Thurai, “Rain Radar Measurements In Papua New Guinea And Their Implications For Slant Path Propagation,” pp. 1–6, 1996.
[12] L. Luini and N. Jeannin, “Use of Weather Radar Data for Site Diversity Predictions and Impact of Rain Field Advection,” *2008 4th Adv. Satell. Mob. Syst.*, pp. 116–121, Aug. 2008.
[13] S. Y. Matrosov, K. a. Clark, and D. E. Kingsmill, “A Polarimetric Radar Approach to Identify Rain, Melting-Layer, and Snow Regions for Applying Corrections to Vertical Profiles of Reflectivity,” *J. Appl. Meteorol. Climatol.*, vol. 46, no. 2, pp. 154–166, Feb. 2007.
[14] J. Bech, A. Magaldi, B. Codina, and J. Lorente, “Effects of Anomalous Propagation Conditions on Weather Radar Observations,” 2008.
[15] M. Akimoto and K. Watanabe, “Study on rain attenuation considering rainfall-intensity dependent spatial correlation characteristics,” *IEEE Glob. Telecommun. Conf. 2004. GLOBECOM ’04.*, vol. 5, pp. 2864–2868, 2004.
[16] N. Hisham, H. Khamis, J. Din, and T. A. Rahman, “Rainfall Rate from Meteorological Radar Data for Microwave Applications in Malaysia,” pp. 1008–1010.
[17] J. S. Marshall and W. K. Palmer, “The distribution of raindrops with size,” *J. Atmospheric Sci.*, vol. 5, no. 4, pp. 165-166, 1948.
[18] I. Introduction, “the Calculation of Rain Attenuation 7,” 1978.

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