Classification of Precipitation Types Detected in Malaysia

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Abstract The occurrences of precipitation, also commonly known as rain, in the form of “convective” and “stratiform” have been identified to exist worldwide. In this study, radar return echo or known as reflectivity have been exploited in the process of classifying the type of rain endured. The Malaysian meteorology radar data is used in this investigation. It is possible to discriminate the types of rain experienced in such tropical environment by observing the vertical characteristics of the rain structure. Heavy rain in tropical region profoundly affect microwave and milimetre wave signals, causing interference on transmission and signal fading. Required fade margin for wireless system largely depends on the type of rain. Information relating to the two most prevalent types of rain are 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 1 year period of 2009.

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1 Introduction

According to the literatures [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]. Convective rain is being characterised by severe rainfall that occurs for duration of limited periods and typically covers a small or localised area. “Stratiform” 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 will furnish information pertaining to both horizontal and vertical structure of rain. It is also practical for studying rain scatter and signal interference [4]. The evaluation of rain events using radar data is realistic. This is due to the fact that there are large numbers of space-based and ground-based radar around. There are two 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 analysis 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, precipitation rain height and the rain cell size can be ascertained. Rain attenuates wireless communication link both terrestrial and satellite links especially for those with operating frequency higher than 10 GHz. The access attenuation of a radio wave due to precipitation 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 radio wave. It is important to examine the variation of the scattering and/or absorption contributions to extinction, for water spheres of various radii.

2 Classification of Rain Types

Among previously proposed method to classify whether the precipitation is 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 of 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

Table 1 Criteria to differentiate rain types using radar data [5–9]

Stratiform	Convective
1. Reflectivity ranges (2–37 dBz)	1. Reflectivity ranges >38 dBz)
2. Rainfall intensity values (0–9.9 mm/h)	2. Rainfall intensity values (>10 mm/h)
3. Clear melting height	3. No melting height
4. Rain height between 4 and 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

overturning. In this investigation, precipitation 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. 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 [5–9] also utilised similar rain classification technique for investigation in Bangalore, India, Milan, Italy and Changi, Singapore. Table 1 shows the criteria used to differentiate the stratiform and convective rain types based on the RHI radar views.

3 System Configuration and Measurement Setup

3.1 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). The 8.5 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 3 µs 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° and 40°. The radar bin size is 238.3 × 23.8 m square. Figure 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

Fig. 1 Meteorological Radar

240 km from its station. The location of interest for the precipitation types analysis is carried out for area within the vicinity of Cyberjaya (2.945262°/101.667976°) where MEASAT ground stations are located. It is hoped that the findings are able to facilitate the greater understanding of milimetre wave propagation characteristics.

4 Correlation of Rainfall Rate with Reflectivity and Attenuation

Rain types can be determined from the rainfall rate values as highlighted in Table 1. 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 collocated 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 the 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. The rainfall rate, *R* is inferred from the value of the measured reflectivity according to the formulation;

$$R = \sqrt[[b]]{\frac{Z}{a}} \tag{1}$$

where a = 200 and b = 1.6 are the values proposed by Marshal Palmer [17].

The reflectivity Z can be expressed on a logarithmic scale in unit dBZ, which can be calculated from (1):

$$dBZ = 10 \log Z \tag{2}$$

5 Result and Discussion

The preliminary stage of the research only involve the investigations of the first 3 criterion identified in Table 1 shown in Fig. 7 is one of the RHI scans that portray 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 square in the figure.

Figures 3 and 4 shows convective and stratiform events time series derived from radar data. It has been identified during the convective rain event the rainfall rate is higher than 10 mm/h. Figures 5 and 6 shows the same time interval showing the values in radar reflectivity, dBz. The convective event ranges more than 37 dBz.

The radar data can then classified into two groups. Figure 7 below depict displays of Z vertical scan recorded on selected days during stratiform events within the period of campaign. It is apparent in the presented figures, that each exhibits clear melting height of approximately 6.5 km with approximate layer thickness between 200 and 500 m. Examples of convective events can be observed in labelled as in Fig. 8. Even though the reflectivity measurements do not exhibit existence of a

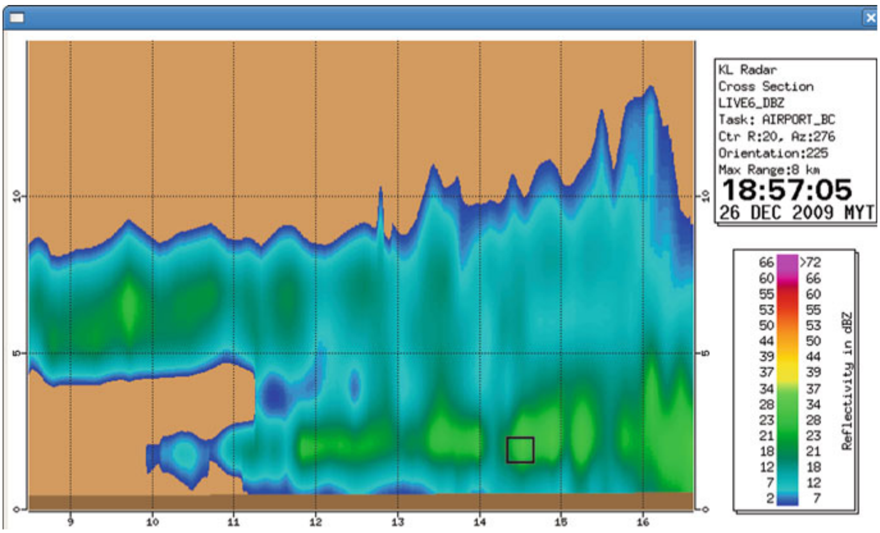

Fig. 2 RHI scan example that will be converted to reflectivity values

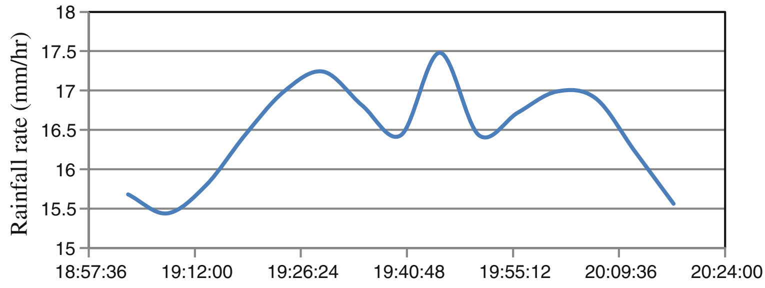

Fig. 3 Convective rain events on 12/08/2009 (Rainfall rates Values)

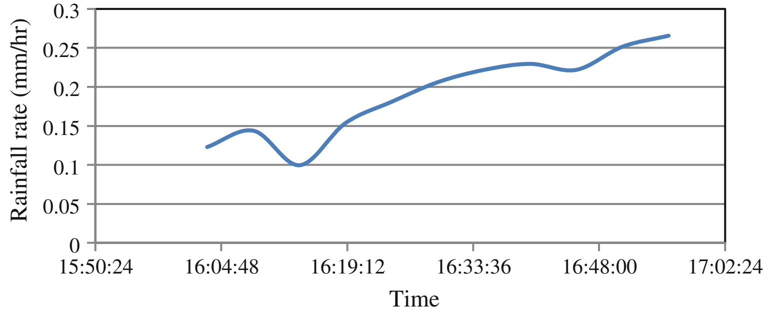

Fig. 4 Stratiform events on 28/8/2009 (Rainfall rates Values)

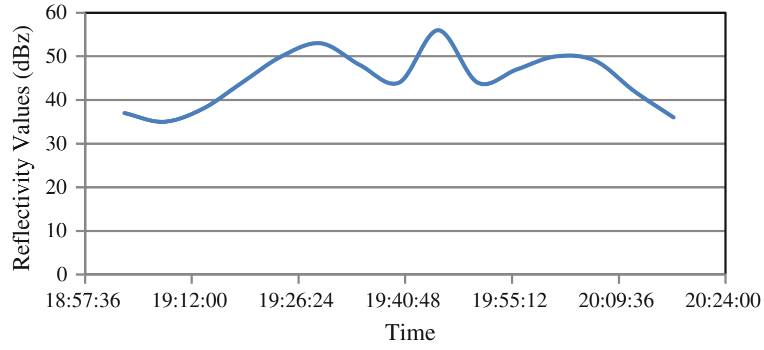

Fig. 5 Convective rain events on 12/08/2009 (Reflectivity Values)

melting layer, such enhancement can be seen in the cross-polar reflectivity that indicative of the melting process.

Based on the 1 year data, the radar scans were inspected and rain events are identified and recorded. Table 2 shows the number of occurrences of stratiform and

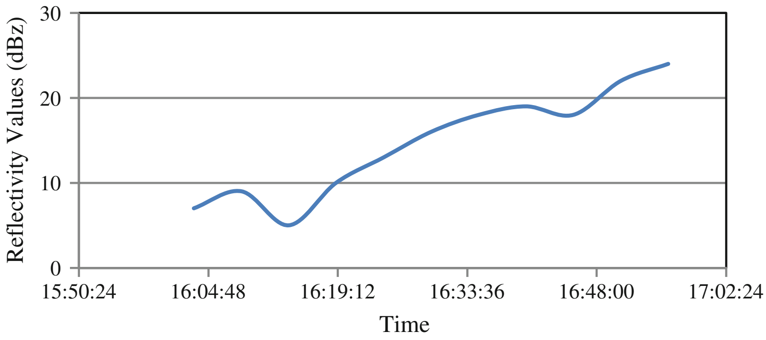

Fig. 6 Stratiform events on 28/8/2009 (Reflectivity Values)

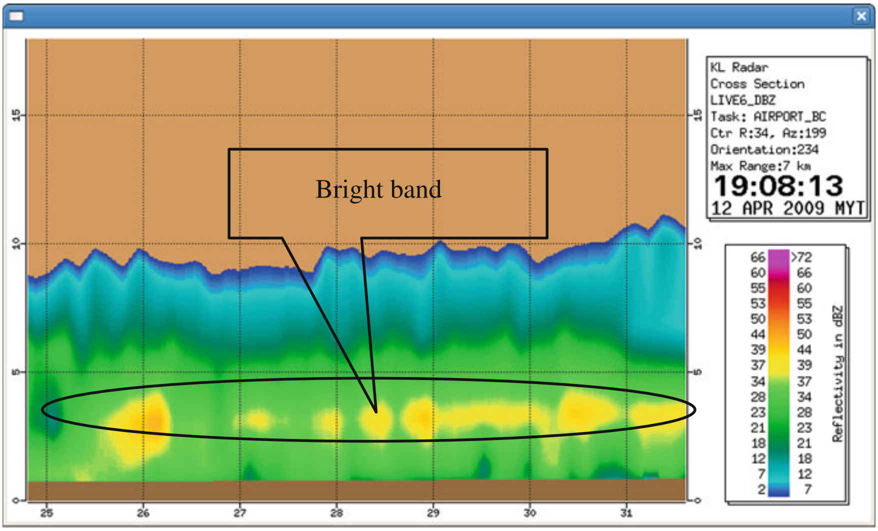

Fig. 7 Stratiform events on 19/08/2009

convective events identified from the radar data in the year 2009. It appears that in 2009 the numbers of occurrences of the two types are about equal. This might signifies typical characteristics of tropical country such as Malaysia. Meanwhile in temperate region convective rain are rare occurrences.

The tropical region are having dense rainfall rate and mostly convective compared to temperate region. The satellite links with operating frequency higher than 10 GHz will definitely experience severe attenuation if proper 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.

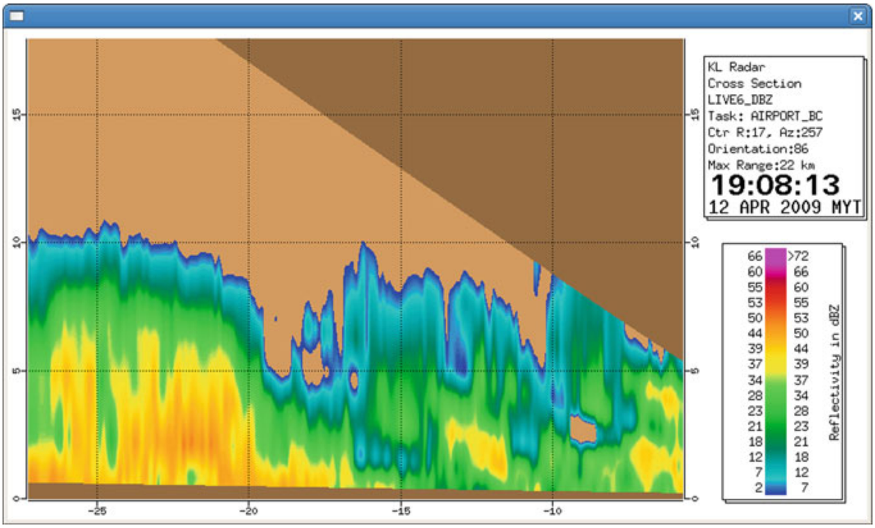

Fig. 8 Convective events on 19/08/2009

Table 2 Rain types based on radar data

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

6 Conclusion

High reflectivity values, high rainfall rates and non existence of melting height 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, satellite link margin would be best predicted if the characteristics of the rain can be studied profoundly at each location.

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