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CLASSIFICATION OF RAIN TYPES FOR RAIN ATTENUATION PREDICTION METHOD IMPROVEMENT BASED ON RADAR INFORMATION IN TROPICS

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ABSTRACT

An investigation has been embarked in classifying the rain types. The Terminal Doppler Weather Radar (TDWR) and rain gauge system are currently installed in Bukit Tampoi, Malaysia, and their data are used in this study. Sampled radar data and rain gauge data collected from January to December 2009 were analyzed. The research methodology involves 2 steps. The first step is the identification of precipitation events within the said period. The second step is "separation" process based on the column reflectivity value at desired location. From our analysis, 32 event data are classified as convective and 175 event data are classified as stratiform.

Keywords: rain attenuation, terminal doppler weather radar (tdwr), rain gauge system.

INTRODUCTION

Advancement of current Earth-to-satellite communication links including future high altitude platforms (HAPs) has pushed researcher to use higher frequency bands (10 GHz and above). However, higher operating frequency implicates larger attenuation due to rain as raindrops scatter and absorb energy from incident electromagnetic wave. In the study of rain attenuation, rain classification has become a major concerned as different rain types produce different effect on electromagnetic wave. It is important to understand the rain structure for different rain types as it indicates the effectiveness of rain attenuation modeling [1]. Many researchers have shown that by including the individual contribution of each rain types may increase the accuracy of the prediction model [2-4]. There have been numerous methods devised in discriminating the rain event into several types. Earliest studies of rain types classification using rain gauge data suggested that classification was assigned whenever the rain rate exceeded some background level by a certain threshold [5]. As radar data were made available, researchers have extended the technique by using radar reflectivity [6-10]. Nevertheless, some of the develop methods were only tested with the data in temperate region and further validation need to be done in tropical climate region. This study is an attempt to improve the rain attenuation prediction method by including the rain types classification. Only the rain types classification process is presented in this paper. The organization of the paper will be as follow: Section 2 outlines the previous proposed method and currently used method in this study. Section 3 highlights experimental setup and data collection. Section 4 underlines the results and analyses. Last but not least, conclusion and future work is presented in section 5.

Background Studies & Current Methodology

The advancement of radar has allowed researchers to easily study the rain structure. As mentioned by previous researchers [11-12], this is the only feasible technique of collecting data that will furnish both the horizontal and vertical structure of rain in a way that is practical for studying rain scatter and interference. Commonly, rain can be classified into two types, namely stratiform and convective. Stratiform rain produces from stratus cloud, consists of light rainfall intensity that typically shows stratified horizontal. It extends of hundred kilometers and the duration of time typically exceed one hour period. Where else, convective rain produces from cumulus cloud, consists of high rainfall intensity. It usually extents only several kilometers and duration of time exceeding several minutes.

Churchill and Houze did one of the earliest studies of rain types classification using radar data back in 1984. They proposed a method by assigning a fixed radius of influenced to identify core of convective. In 1995, Steiner *et al* proposed an improved method in identifying core of convective by assigning radius of influence in variable size. Their method often called as "peakedness method" in finding convective core is by finding average area background reflectivity. In the same year, DeMott *et al* extended the Steiner *et al* method by identifying cores of convective at different level height. Their method extends up to the echo top in order to avoid misclassification convective cells that tilted strongly with height. In 2000, Biggerstaff and Listemaa extended the Steiner *et al* method by adding additional criteria to classify rain types. They use the results from Steiner *et al* and further analyzed using more reflectivity radar information. Three parameters are required to calculate at each grid point namely, vertical lapse rate of reflectivity, bright band fraction and magnitude of two-dimensional horizontal gradient of radar reflectivity. Zhang *et al* proposed a more computational efficient method in distinguishing rain types in 2008. They apply a threshold value at vertical profile reflectivity (VPR) structure to identify convective rain type. They believed that this method is more computational efficient than Steiner *et al* as their scheme is directly applied to each pixel column and does not require repetitive computation at area background reflectivity.

In this study, we emulated the same methods as Zhang *et al* but with inclusion of proposed modifications. The Zhang *et al* method is chosen in this study due to its computational efficiency. The classification of rain types begins by removing the non-precipitating events where reflectivity value is below than 0 dBZ using IRIS Vaisala software. Then, VPR computational was carried out by taking reflectivity value at each pixel column at desired location. Next step is called "separation" step. In this step, a radar bin column is identified as convective if all of the following conditions are met:

a) Average reflectivity value in the column from lowest elevation scan height to 5.5 km height is greater than 36 dBZ
b) Average reflectivity value in the column from 4.5 km to 5.5 km height is greater than 36 dBZ
c) Average reflectivity value in the column from lowest elevation scan height to 2 km height and near to the condition (a) column is greater than 36 dBZ

(Note: Only reflectivity values (dBZ) are analyzed in this method)

Any non-zero reflectivity that are not identified as convective from the above two conditions will be classified as stratiform. The first condition is applied to the average reflectivity value of VPR. The average reflectivity value is calculated from the lowest column height to 5.5 km height. The 5.5 km height is chosen as the convective cells often exceed high reflectivity value beyond the 0°C isotherm height [13]. The second condition is almost similar to Smyth and Illingworth method [14] but with different height. In Smyth and Illingworth method, they applied the threshold value of 30 dBZ at -10°C height or above where else in our method, we applied the threshold average value of 36 dBZ from 4.5 km to 5.5 km. This condition is applied to include any initial convective cell. The third condition is applied to include any neighboring convective cell. The 36 dBZ threshold reflectivity value is chosen for all conditions after analyzing 1 year radar data samples. The analyses of threshold were done by calculate the mean value for each samples of radar scan. Figure-1 illustrates the current method proposed.

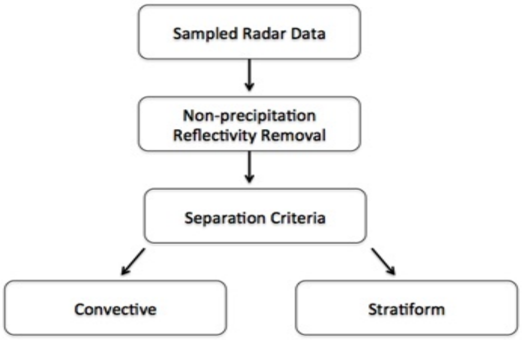

Figure-1. Proposed classification of rain types.

Data Collection

Radar reflectivity data from Terminal Doppler Weather Radar (TDWR) at Bukit Tampoi, Malaysia were obtained from Malaysia Meteorological Department as part of the Razak Satellite measurement campaign that lasted for 1 year [15]. The TDWR is located at 2° 50.8' N latitude and 101° 40.3' E. TDWR is a 10.43 cm wavelength Doppler radar with 125 m beam spacing. The radar data consist of volume scans of radar reflectivity, radial velocity, and spectrum width collected in polar coordinates at increasing elevation angles. The elevation angle steps of the radar are from 0.7° to 40° during periods of rain in a 360° azimuthal volume scan mode. The temporal resolution and number of elevation steps of the data depend on the operational mode of the radar. 1-year data from January 2009 until December 2009 are acquired. Data were collected using 10 elevations angle scan strategy (1° to 40°). Each volume scan took 5 minutes to complete.

Rain gauge data also were obtained from Malaysia Meteorological Department. The data are used to distinguish between rain and non-rainy day. The rain gauge measurement system is located at 2° 44' N latitude and 101° 42' E, within 13 km vicinity of TDWR. The acquired data are for a period of 1 year from January 2009 until December 2009. The rain intensity data were collected every 60 minutes using standard tipping bucket type rain gauge. Table-1 & 2 lists the specification of the TDWR and rain gauge. Only radar data directly above the rain gauge were analyzed in this study. Figure-2 shows the illustration of measurement setup. IRIS Vaisala Software is used to produce the reflectivity data and to remove any non-precipitation target. The 0°C height is taken from the annual estimated value from radiosonde data at Kuala Lumpur [16].

Table-1. TDWR specifications.

	Specifications
(Lat , Lon) Radome Round Parabolic Reflector Wavelength Frequency Bin Spacing Pulse Repetition Frequency Data Types	(2° 50.8' N , 101° 40.3' E) 12 m diameter 8.5 m diameter 10.43 cm 2.7845 GHz 125 m 1000 Hz 300 Hz Z, V, W

Table-2. Tipping bucket specifications.

	Specifications
(Lat , Lon)	(2° 44' N , 101° 42' E)
Receiving Collector	203±0.2mm
Accuracy	±1% to 200mm/hr
Bucket Capacity	0.2 mm
Dimension	5.5kg

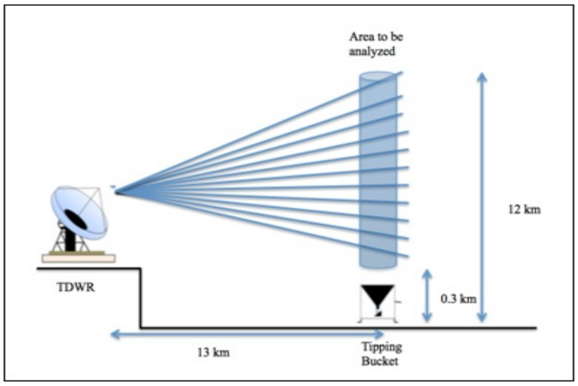

Figure-2. Measurement system setup.

RESULT AND ANALYSIS

Figure-3 shows one of the convective precipitation events. The display involves sample that occurred on 5 April 2009 at 13:40:54. The convective event shows a very high reflectivity (more than 34 dBZ) up until 6 km height. The echo top extends more than 9 km height. Figure-4 shows one of samples of stratiform precipitation event, which occurred on 8 January 2009 at 17:48:15. The stratiform event shows a very low reflectivity value (less than 34 dBZ) with estimated echo top less than 8 km height. From the analysis, we found out that 175 events are stratiform and 32 events are convective.

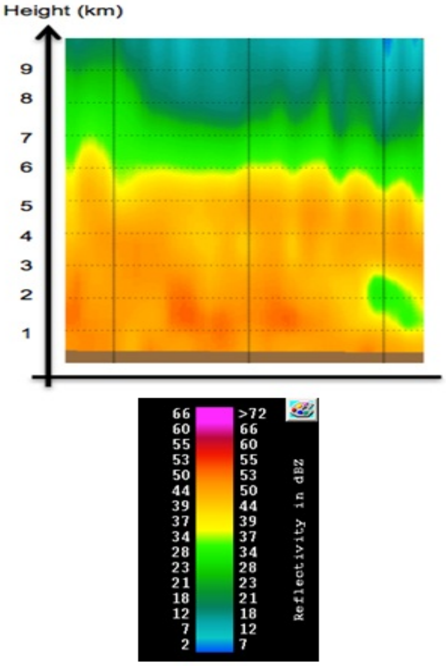

Figure-3. Radar reflectivity for convective event as shown in IRIS Vaisala software on 5th April 2009 at 13:40:54.

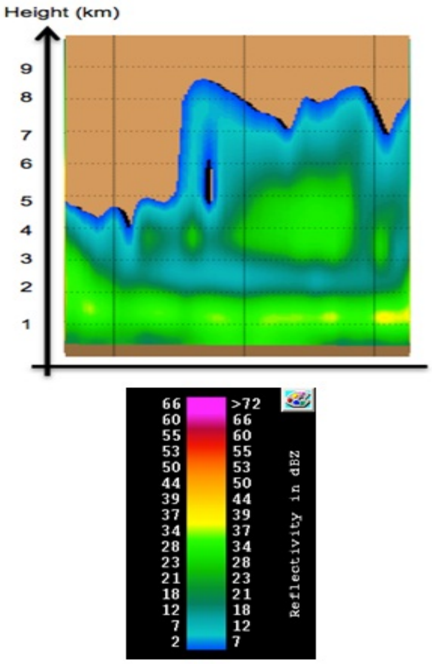

Figure-4. Radar reflectivity for stratiform event as shown in IRIS Vaisala software on 8th January 2009 at 17:48:15.

CONCLUSIONS

In the study it is preliminary concluded that based on our analysis of 1-year radar data, 32 events are classify as convective and 175 events are classified as stratiform. Subsequent research work will embark on the finding the rain height for both convective and stratiform rain types, which will be later, used to develop an improve rain attenuation model.

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