VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ONE-MINUTE RAIN RATE STATISTICS PREDICTION USING ITO-HOSOYA MODEL IN MALAYSIA

N. A. M. Aris[1] and J. Din[2]
[1]Department of Telecommunication Engineering, Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia
[2]Department of Communication Engineering, Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM), Johor Bahru, Johor, Malaysia
E-Mail: norazlan@utem.edu.my

ABSTRACT

This paper investigates one-minute rain rate in Kuala Lumpur, Malaysia predicted based on Ito-Hosoya model. The model is categorized into meteorological based model as it receives as input local meteorological parameter. The best part about this model is it does not requires measured rain rate data to be converted into one-minute, instead it depends on long-term meteorological parameter values which widely available from various sources. In this paper, the local meteorological parameters are extracted from TRMM database which are average accumulation rainfall (from TMPA 3B43) and thunderstorm ratio (from TRMM PR 3A25 and TMI 3A12). The result shows that this model could be promising for use in Malaysia region as it produces better performance compared to the ITU-R model.

Keywords: one-minute rain rate, equatorial region, ITU-R, TRMM.

INTRODUCTION

Information of rain attenuation is one of the key knowledge required in order to design a satellite communication system with adequate Quality of Service (QoS), especially in equatorial/tropical regions which commonly characterized by heavy rainfall rates compared to temperate region. Such information could be retrieved through direct measurement of satellite beacon signal under rainy condition as shown by previous researchers (e.g. [1]). However, the measurement setup requires a number of outdoor and indoor equipment which are expensive. Therefore it can only be carried out at limited location and period.

Another method is through prediction model based on recommendation by International Telecommunication Union for Radiocommunication (ITU-R). In fact, besides the recommendation from ITU-R, there are number of rain attenuation models made available by researchers (e.g. [2, 3]). One important parameter that typically associated with the prediction of the rain attenuation is one-minute integrated Complementary Cumulative Distribution Function (CCDF) of the rain rate (henceforth $P(R)_1$). However, the $P(R)_1$ data are not easily retrievable as it also requires expensive measurement setup while most raingauges setup are meant for meteorological purposes [4].

To date, a variety of methods and approaches had already been proposed and developed to fulfil the needs for $P(R)_1$ that can be divided into two types based on their different principle which are conversion method and meteorology-based method [5]. The advantage of meteorology-based method compared to the conversion method is the worldwide applicability of the general meteorological information as input to the prediction model. One of the example of meteorology-based method is prediction model of the $P(R)_1$ by Ito and Hosoya [6]. From the review of available model in [5], prediction model by Ito and Hosoya [6] which incorporates the local thunderstorm ratio, β (or referred as convectivity ratio by ITU-R) is found to be applicable worldwide. The authors in [6] claimed that their model provides a good accuracy for any integration time and location. In fact, the earlier model by Ito and Hosoya [7] which does not rely on the longer integration time of $P(R)$ data seems to also provide good estimation of one-minute rain rate as shown by Omotosho and Oluwafemi [8] and Omotosho et al. [9] whose estimated the one-minute rain rate in Nigeria and Malaysia respectively.

This contribution presents an investigation of $P(R)_1$ in Malaysia equatorial area using Ito-Hosoya prediction model which receive as input local meteorological information derived from Tropical Rainfall Measutring Mission (TRMM) data. The TRMM data are used in this contribution due to its high resolution data compared to other global database as already been mentioned in [10].

Tropical Rainfall Measuring Mission (TRMM) in general is a joint project between National Aeronautics and Space Administration (NASA) and Japan Aerospace Exploration Agency (JAXA) to provide better understanding on the Tropical precipitation and was launched on November 1997. Although the TRMM operation has been discontinued, where its role has been replaced by more advanced Global Precipitation Measurement (GPM) satellite, it already fulfill its purpose to provides valuable data about tropical precipitation since November 1997.

ITO-HOSOYA PREDICTION MODEL

The Ito-Hosoya model is developed through multiple regression analyses of a databank of rain attenuation on satellite links of 290 data sets from 84 locations in 30 countries and a databank of different integration time rain rates that contains data sets from 54

VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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locations in 23 countries. The model requires information of average rainfall accumulation (M_t) and thunderstorm ratio (β) and is given in the following equation:

$$R_p = a_p M^{b_p} \beta^{c_p} \tag{1}$$

$$\log(a_p) = 0.1574155\ x^4 + 1.348171\ x^3 + 3.528175\ x^2 + 1.479566\ x - 2.302276 \tag{2}$$

$$b_p = -4.583266 \times 10^{-2} x^4 - 0.4098161\ x^3 - 1.162387\ x^2 - 0.826117\ x + 0.911857 \tag{3}$$

$$c_p = 2.574688 \times 10^{-2} x^4 + 0.1549031\ x^3 + 0.1747827\ x^2 - 0.2846313\ x + 1.255082 \times 10^{-2} \tag{4}$$

where R_p is the 1-minute rain rate at p% of an average year (typically between 0.001% - 1%), x is log(p) while a_p, b_p, and c_p are the coefficients required in the prediction model.

In fact, the use of Ito-Hosoya model for predicting one-minute rain rate in Malaysia had been carried out previously as in [9]. However, the works utilized Ito-Hosoya model in order to provide one-minute rain rate distribution over Malaysia while validation works were carried out only for TRMM data.

AVERAGE YEARLY RAINFALL ACCUMULATION

To get an accurate value of average yearly rainfall accumulation (M_t), data from TRMM Multi-satellite Precipitation Analysis (TMPA) 3B43 are extracted. The use of TMPA 3B43 data for obtaining local meteorological parameter has been widely established due to its high accuracy as deliberated in several research works [11, 12]. Furthermore, previous research in [10] shows that the use of TRMM data could lead to a more accurate prediction of one-minute rain rate. Table-1 provides average accumulation rainfall from TMPA at several locations in Malaysia and their respective measured value that depicts the accuracy of TMPA 3B43.

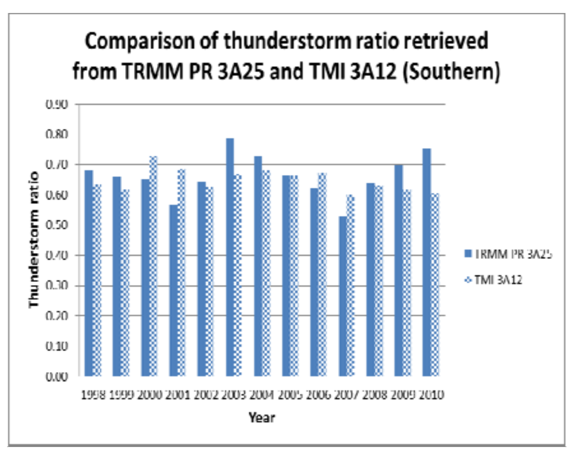
Table-1. Comparison of average yearly rainfall accumulation between TMPA and measured data at selected location.

Location	Latitude (N)	Longitude (E)	Measured (mm)	TMPA (mm)	Error (%)
Ladang Tebrau JB	1.55	103.74	2677.6	2698.5	-0.78055
Ladang Sg. Tiram	1.59	103.92	2442.4	2458.3	-0.651
Ladang Kulai Young	1.63	103.53	2822.8	2834.7	-0.42157
JPS Kemaman	4.23	103.42	2820.1	2775.4	1.58505
Kg. Ban Ho	4.13	103.18	3181.6	3080.1	3.190219
Jambatan Air Putih	4.27	103.2	3318.4	3070.5	7.470468

Another important parameter to be obtained is thunderstorm ratio. By definition it can be written as a ratio of thunderstorm rain accumulation ($M1$) over the total rain accumulation ($M2$) as follows:

$$\beta = M1\ /\ M2 \text{ (in unit mm)} \tag{5}$$

extracted which are TRMM Precipitation Radar and TRMM Microwave Imager (3A25 and 3A12 respectively). Two areas with spatial range of 0.5° by 0.5° from southern (103.5-104°E, 1.5-2.0°N) and eastern coast (103-103.5°E, 4-4.5°N) of peninsular Malaysia had been chosen to show the sample of thunderstorm ratio value extracted from both different sensors of TRMM satellite as shown in the following Figure-1.;



(a)

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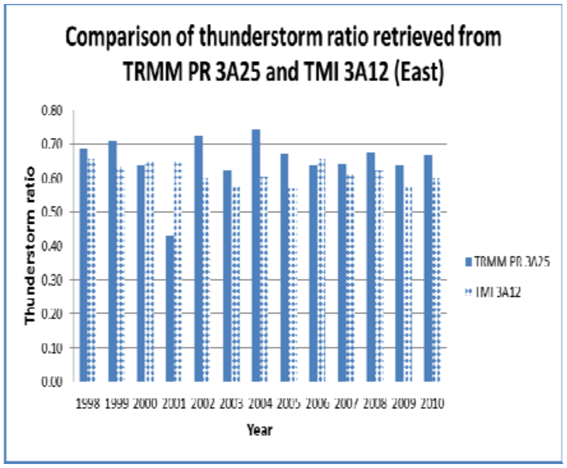

(b)

Figure-1. Thunderstorm ratio within (a) southern and (b) eastern coast area in Peninsular Malaysia.

Figure-1 shows the yearly comparison of thunderstorm ratio between TMI and TRMM PR for 13 years. The average value recorded by TMI for southern and eastern coast area are 0.65 and 0.61 respectively while the average value by TRMM PR for southern and eastern coast are 0.66 and 0.65 respectively. There might be inconsistency in the yearly reading; however it seems that the long term average values recorded are almost consistent between the two sensors.

PREDICTION MODEL'S PERFORMANCE

The prediction of one-minute rain rate using Ito-Hosoya model is carried out using the previously mentioned method whereby average accumulation rainfall is extracted from TMPA 3B43 while thunderstorm ratio is extracted from the average value given by TRMM PR 3A25 and TMI 3A12. While it is preferable to analyse the performance of the prediction model with local measured value, the challenge for validating one-minute rain rate is the lack of measured values.

By considering this limitation, it is decided to test the model's performance at one location only which is Kuala Lumpur whereby the measured one minute rain rate data is available for the year 1992, 1993 and 1994. In addition, as a gauge to the model's performance, prediction from ITU-R P.837-6 is used for comparison purpose. The following Figure-2. shows the comparison between Ito-Hosoya (TRMM extracted parameter as inputs), ITU-R model [13] and measured value at Kuala Lumpur.

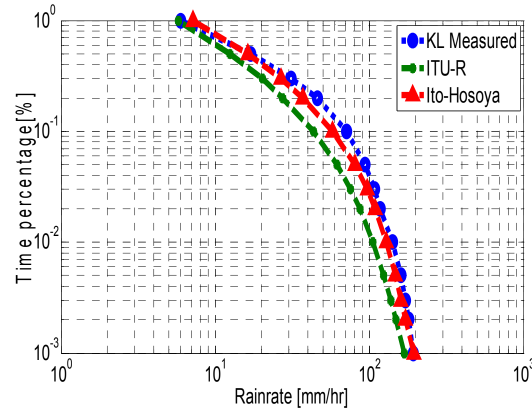

Figure-2. Comparison between Ito-Hosoya and ITU-R model with measured data at Kuala Lumpur.

From the result in Figure-2, the error performance at 0.01%, for ITU-R and Ito-Hosoya are -33.56% and -8.23% respectively. The curve of Ito-Hosoya if compared to the ITU-R shows qualitative indication on a better prediction performance. It seems that Ito-Hosoya model appear better in prediction compared to ITU-R model as ITU-R model seems to significantly underestimate one-minute rain rate in Kuala Lumpur.

CONCLUSIONS

Meteorology based method for predicting one-minute rain rate could become very useful especially when considering how easy it is to obtain the local meteorological parameter which made available from various sources; one of them is TRMM. By considering the Ito-Hosoya prediction model, it seems that the model could be more than just suitable for use in Malaysia. However, this work could only be used as initial reference as a lot of validation work should be carried out to determine the quality of Ito-Hosoya model for one-minute rain rate prediction especially for Tropical region. However, the result of this initial work could be viewed as opportunity for a lot of research to be carried out in the future.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) and Ministry of Higher Education, Malaysia for the financial supports given through Research Grant (RAGS/1/2014/TK03/FKEKK/B00064). Some data used in this study were acquired using the GES-DISC Interactive Online Visualization and Analysis Infrastructure (Giovanni) as part of the NASA's Goddard Earth Sciences (GES) Data and Information Services Center (DISC).

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