Conference Paper

Estimation of Rainfall Rate Cumulative Distribution in Indonesia Using Global Satellite Mapping of Precipitation Data

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Abstract

Accurate estimation of cumulative distribution of rain rate with 1-minute integration time is required to predict the attenuation of electromagnetic wave in rain medium. The model which is provided by the International Telecommunication Union-Radiocommunication Sector (ITU-R) is the most commonly used model to estimate 1-min integrated rain rate statistics. This model needs mean yearly rainfall accumulation (Mt) and the probability of rain (P_0) as input which are originally derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-40 Re-Analysis (ERA-40) data. In the current work, the use of Global Satellite Mapping of Precipitation (GSMaP) data as input of ITU-R P.837-6 model was examined. The GSMaP data have better spatial and temporal resolutions than ERA-40. It was found that Mt and P_0 values from GSMaP data are closer to Mt and P_0 obtained from rain gauge than that of ITU-R model. One-min rain rate estimated by modified ITU-R model was compared with the rain gauge data at Kototabang, and DBSG3 data for Bandung and with the value reported by previous studies. The use of Mt and P_0 derived from GSMaP data for the ITU-R model input provides similar distribution of 1-min rain rate with the rain gauge data at Kototabang especially for percentage times of less than 0.01%, while for percentage times more than 0.01%, ITU-R with default input provides closer distribution to rain gauge data.

Keywords: rain rate cumulative distribution, GSMaP, ITU-R P.837-6, Indonesia

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1. Introduction

Rain is a problem in telecommunication system. Raindrops cause significant attenuation of electromagnetic wave for the frequencies above 5GHz [1-4]. Attenuation is the function of rain rate and the operating frequency in which higher rain rates lead to the high attenuation. Therefore, accurate rain rate prediction is necessary for modeling the specific attenuation of rain.

International Telecommunication Union-Radiocommunication Sector (ITU-R) provides mathematical model to predict the rain rate. The ITU-R uses 40-year ECMWF re-analysis (ERA40) data as input. ERA40 data have low spatial and temporal resolutions, namely, 1.125° x 1.125° and 6 hours, respectively. In this work, the use of ERA40 data was replaced with Global Satellite Mapping of Precipitation (GSMaP) data with better spatial and temporal resolutions. Replacing ERA40 data with Tropical Rainfall Measuring Mission (TRMM) PR 3A25 and TMPA 3B43 have been conducted for Malaysia [2]. The result shows that the use of TRMM data as input of ITU-R P.837 model provide better estimation of rain rate. In Indonesia, replacing ERA40 data with TRMM data have been also conducted particularly using TRMM 3B42 and 3B43 data [5].

2. Methods

The main data used in this work are GSMaP reanalysis gauge data. GSMaP reanalysis gauge data contain rainfall data for tropical and subtropical areas (60°N - 60°S and 180°E - 180°W). Ten years GSMaP data were used in this work. The data have high spatial and temporal resolutions, i.e., 0.1° x 0.1° and 1 hour, respectively. GSMaP data are developed from several satellite observations that carry microwave radiometers with specified sensors. These sensors are in low earth orbit. The characteristics of microwave radiometers used in GSMaP data are given in Table 1 [6] and in GSMaP Data Format Description [7].

Table 1: Characteristics of satellites involved in GSMaP data.

Satellite	Altitude (km)	Sensor	Frequncies (GHz)
TRMM	402	TMI	10,19,21,37,85
AQUA	705	AMSR-E	7,10,19,24,37,89
DMSP-F11	803	SSM/I	19,37,85
DMSP-F13	803	SSM/I	19,37,85

To calculate 1-min integrated rain rate, ITU-R P.837-6 required Mt and P_0, which are respectively mean yearly rain accumulaltion (mm) and average probability to have rain. In this work, those parameters are extracted from GSMaP data and compared with the TRMM and rain gauge data. The following equation is the way to calculate 1-min rain rate available in the Annex 1 of the ITU-R P.837-6 [8], as in Azlan et al. [2], which is given by:

$$P(R)_1 = P_0 \exp\left(-1.09R\frac{1+bR}{1+cR}\right) \quad (1)$$

$$P_0 = P_{r6h}\left(1 - \exp\left(-0.0079\frac{M_t(1-\beta)}{P_{r6h}}\right)\right) \quad (2)$$

$$b = \frac{M_t}{21797P_0} \quad (3)$$

$$c = 26.03b \quad (4)$$

Nevertheless, P_{r6h} and β are no longer needed, because P_0 was simply calculated by [2]:

$$P_0 = \frac{N_R}{N_T} \quad (5)$$

where NR is the number of rainy pixel and NT is the number of total pixel. To validate the results, 7 years (2003, 2004, 2005, 2008, 2009, 2010, 2011) Optical Rain Gauge (ORG) data from Kototabang, West Sumatera, Indonesia (0.20°S, 100.32°E; 864 m above sea level) were used. Those data have availability more than 80% [1]. In addition to ORG data, the DBSG3 data also used to validate 1-min rain rate. DBSG3 data contain radiowave propagation measurement data that have been submitted to and accepted by ITU-R Study Groups 3. DBSG3 data are used by ITU-R for testing related prediction methods contained in the P-series of ITU-R Recommendation – Radiowave Propagation such as ITU-R P.837-6 which is used in this work.

The accuracy of the rain rate of each model is examined using root mean square error (RMSE). The smaller the value of RMSE, the higher the accuracy of the method. RMSE-1 denotes the accuracy between GSMaP data and the ORG, RMSE-2 denotes the accuracy between TRMM and the ORG, and the RMSE-3 denotes the accuracy between ITU-R and the ORG.

3. Results

Fig. 1 shows the comparison of 1-min rain rate derived using yearly Mt and P_0 from GSMaP, TRMM data, ITU-R model and ORG at Kototabang. It can be observed that the ITU-R provides better 1-min rain rate especially for percentage of time > 0.01%. On the other hand, for percentage of time ≤ 0.01% GSMaP provides better 1-min rain rate, while ITU-R with default input underestimates the rain rate.

Fig. 2 shows the comparison of 1-min rain rate derived from average Mt and P_0 from GSMaP data (10 years), TRMM data (17 years), ITU-R, and the ORG (7 years) at Kototabang. It was found that 1-min rain rate obtained from GSMaP data show the best performance for percentage of time ≤ 0.01%. For percentage of time > 0.01%, ITU-R shows better

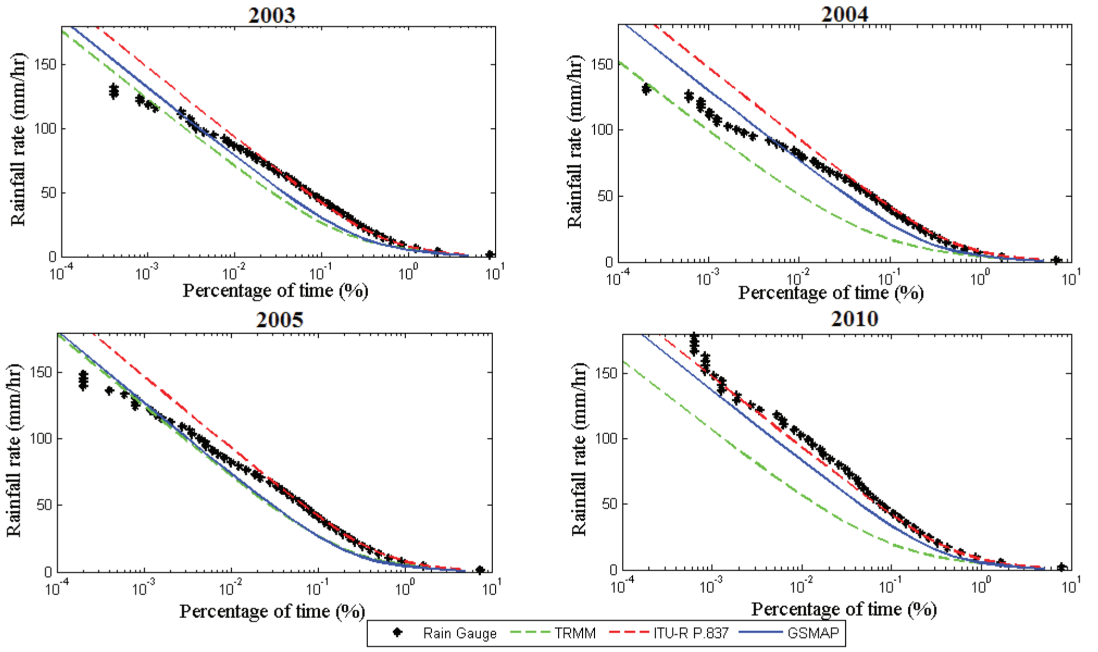

Figure 1: Comparison of 1-min rain rate estimated using yearly Mt and P_0 of TRMM and GSMaP along with the result of ITU-R model with default input and rain gauge data at Kototabang.

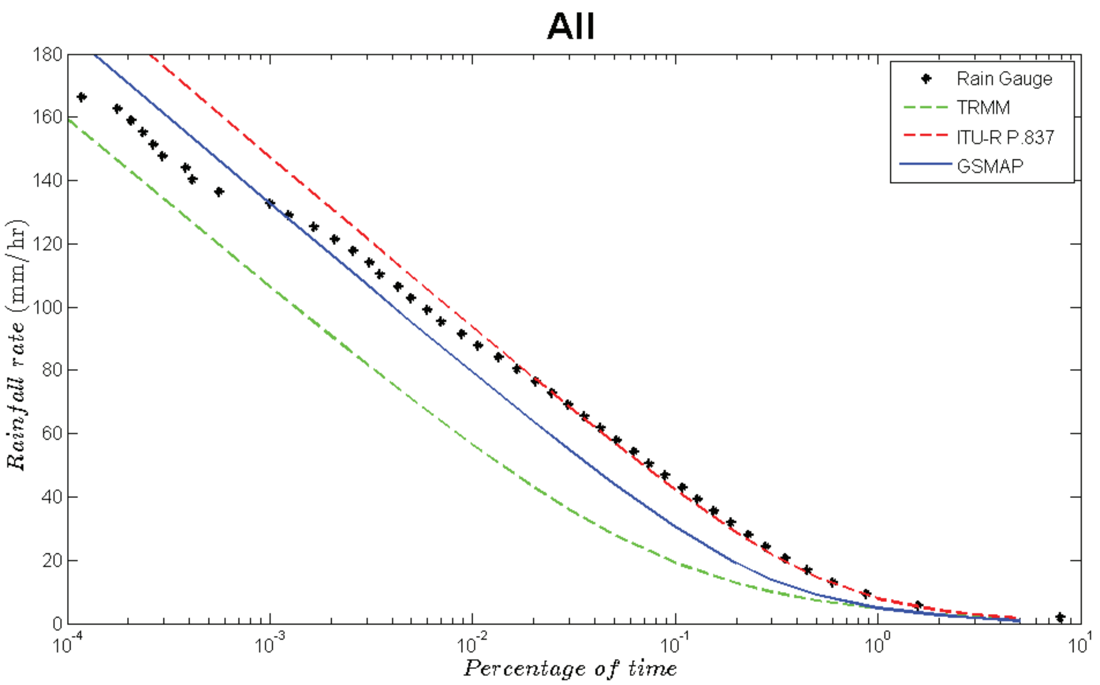

Figure 2: Same as Fig.1 but for average Mt and P_0.

performance in calculating the rain rate. However, for the entire data, GSMaP provides the best performance in calculating the rain rate, indicated by smaller RMSE (Fig. 2).

Fig. 3 shows 1-min rain rate estimated by using average Mt and P_0 from GSMaP (blue line) and TRMM (green line), ITU-R (red line), and the DBSG3 (cross) data for Bandung.

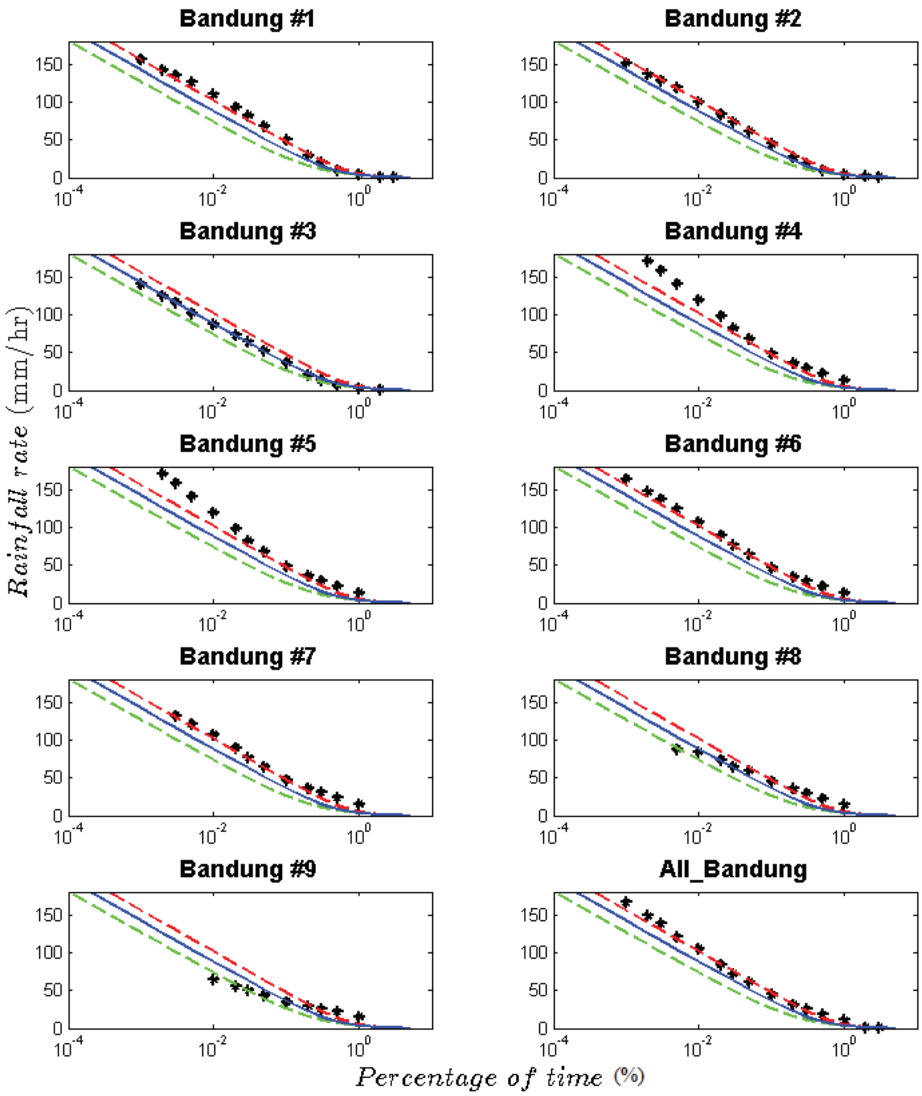

Figure 3: Same as Fig. 2 but the comparison with DBSG3 data for Bandung.

Bandung #1, Bandung #2 and Bandung #3 are data from 1992 to 1994, the rest are data with unknown year period. It is found that the accuracy of model for all data vary from year to year. For Bandung#3, one-minute rain rate estimated by ITU-R model with GSMaP input is in good agreement with DBSG3. However, for Bandung#2, one-minute rain rate estimated by ITU-R model with default input is in good agreement with DBSG3.

In general, for GSMaP data the best accuracy is obtained for percentage of time ≤ 0.01%, while for percentage of time > 0.01% default ITU-R model shows the best rain rate estimation. This condition may be due to the original data of ITU-R to estimate rain rate. The ITU-R data mostly come from middle and high latitudes such as Europe, North America and Japan which are dominated by light rain (high percentage of time) [9].

4. Conclusions

In general, the use of yearly and average Mt and P_0 derived from GSMaP data as input of ITU-R model show better performance to calculate 1-min rain rate than the original ITU-R model, indicated by a smaller RMSE. However, the accuracy of 1-min rain rate estimates from yearly data varies from year to year, as observed from the result which is validated using the DBSG3 data. An overall, the use of GSMaP data to calculate 1-min rain rate shows the best performance for percentage of time $\leq$ 0.01%, while the ITU-R model provides the best result for the percentage of time $>$ 0.01%.

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