

# Conversion of 60-, 30-, 10-, and 5-Minute Rain Rates to 1-Minute Rates in Tropical Rain Rate Measurement

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*ABSTRACT*—In this study, several methods to convert rain rate data for various time intervals to one-minute rates are compared. High-resolution tipping bucket precipitation records for seven locations in a tropical region are analyzed and compared using these conversion models. The Segal, Chebil, and Burgueno methods give the smallest average errors below 10% at different integration times.

*Keywords*—Rain rate, microwave, attenuation.

## I. Introduction

Obtaining one-minute rain rate data is necessary for the prediction of rain attenuation at any location [1]. Due to the rapidly changing nature of rainfall at a given point, the cumulative rainfall intensity distribution which has been observed will actually depend on the effective sampling time of the rain gauge. Since hourly rain rate data is more easily obtained than short integration time data (1, 5, and 10 minutes) in some countries, methods to convert hourly time integration to equivalent one-minute rain rates would be very useful. Several methods were proposed in [2]–[5], which we tested in seven locations in the tropical and equatorial regions.

## II. Measurement

Five types of rain rate data are used in this analysis, including rain rate data for intervals of 1, 5, 10, 30, and 60 minutes. The

measurement sites were at Universiti Sains Malaysia (USM), Institute Technology Bandung (ITB) in Indonesia, King Mongkut's Institute of Technology Ladkrabang (KMITL) in Bangkok, Ateneo de Manila University (ADMU) in the Philippines, Bukit Timah in Singapore, University of Technology (UNITECH) in Papua New Guinea, and University of the South Pacific (USP). The rain gauges were the tipping bucket type with a built in aperture of 400 cm<sup>2</sup> and a sensitivity of 0.5 mm/tip for all sites except for USP, where the gauge used had a sensitivity of 0.2 mm/tip. The rain gauge data logger samples the data at one-second intervals and averages the data over intervals of 1, 5, 10, 30, and 60 minutes. The availability of each set of 1-minute rain rate data is greater than 90%. The 60-minute values were obtained from 60 successive 1-minute values for all the measurement sites, except for Bukit Timah where the data was obtained from the Singapore Meteorological Service (SMS). This method was repeated to obtain data at intervals of 30, 10, and 5 minutes. Data was unavailable for intervals of 5, 10, and 30 minutes at ADMU and UNITECH. The measured data at ADMU and UNITECH is from one year only, whereas the data for other sites is from four years.

## III. Results Analysis

The rain rate and conversion factor distributions for integration times of 1, 5, 10, 30, and 60 minutes are shown in Figs. 1 and 2. The transformation of  $\tau$ -min rainfall distributions into equivalent 1-min distributions is expressed in terms of the ratio of equiprobable rain rates:

$$\rho\tau(R) = R1(P) / R\tau(P), \quad (1)$$

where  $R1$  and  $R\tau$  denote a given rainfall rate exceeded with

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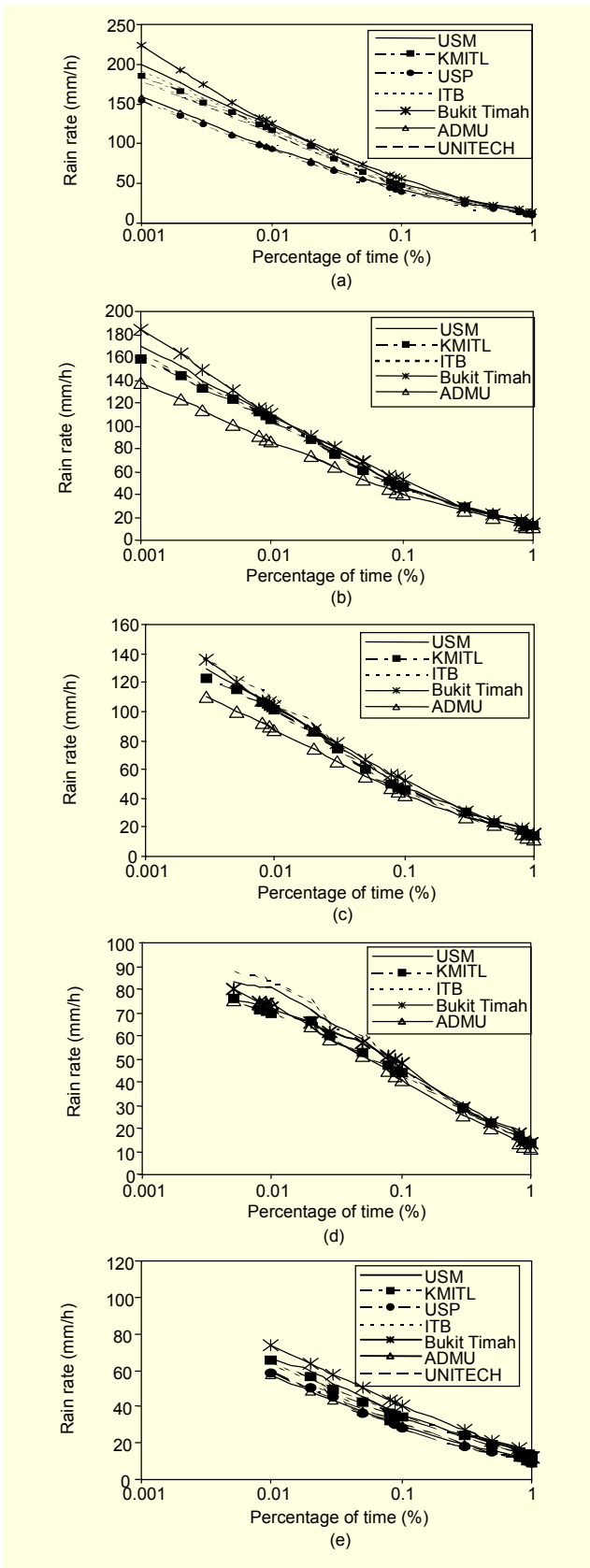


Fig. 1. Rain rate distributions for (a) 1-min, (b) 5-min, (c) 10-min, (d) 30-min, and (e) 60-min intervals.

equal probability  $P$  for two integration times. Figure 1 shows that as the integration time increases, the rain rate is reduced. The rain rate distribution is a function of the rain gauge sampling interval because the intensity of rain is neither spatially nor temporally constant during an event. A precipitation measuring system having a relatively long integration time will always fail to record the short term peaks in rain intensity and thus will tend to underestimate the rain rate,

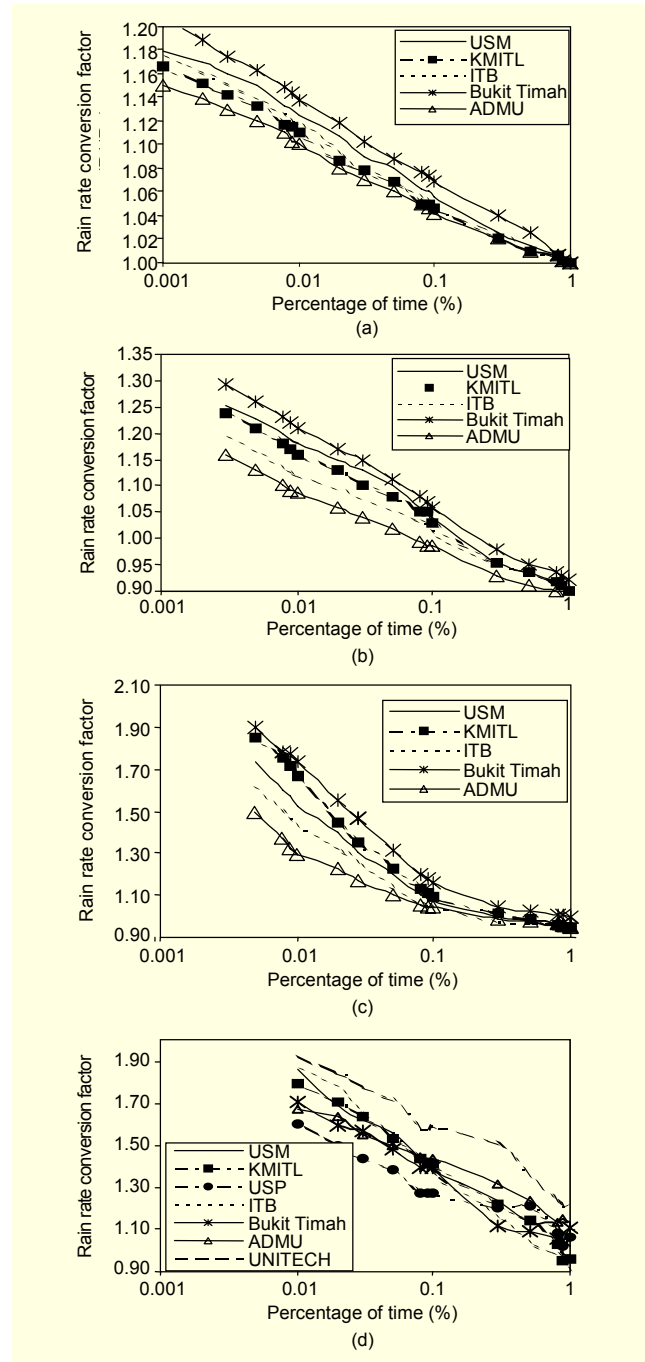


Fig. 2. Rain rate conversions to 1 min from (a) 5-min, (b) 10-min, (c) 30-min, and (d) 60-min intervals.

at least in the moderate and high-intensity region.

The most important prediction is hourly rainfall, because most meteorological stations provide only hourly data. Table 1 shows the average error rates for the conversion of rain rates for intervals of 5, 10, 30, and 60 minutes to 1-minute rain rates using different conversion models. The converted rain rates for different integration times were compared with the measured 1-minute rain rate exceeded at various percentages of time to produce the average errors. Segal's method provides a reasonable estimate of 1-minute rain rate cumulative distributions. The model considers important effects on distribution caused by varying the integration time of the rain gauge, the annual probability distribution of rain rates, and the percent of time specified rain rates are exceeded. Burgueno's method is suitable for conversion because the occurrence of precipitation and the relative proportions of convective to stratiform rain are considered. Joo's methods produce large errors because the measurement of the 1-minute rain rate is derived from standard recording tipping bucket gauges. Errors are due to poor resolution of the recording down to 1 minute and the large year-to-year variations in the distribution

of instantaneous rates. Chebil's method yields good predictions because the regression coefficients of the model are based on thunderstorm activities, whereas stratiform rainfall which results in higher prediction errors is not considered.

Table 1 shows the error rates given in percentages. They are calculated as follows:

$$\%error = (R_p - R_m) / R_m * 100, \quad (2)$$

where  $R_p$  is the predicted rainfall rate (mm/h) using the available models and  $R_m$  is the measured rainfall rate (mm/h).

#### IV. Conclusion

Segal's method for rainfall rate integration time conversion provided the best estimator with the lowest error rate for the 1-minute rainfall rate distribution in seven observation locations. This method can be used effectively to estimate the 1-minute rainfall rate distribution for tropical locations in South East Asia.

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Table 1. Average error rates for various rain rate conversions (%).

	USM	KMITL	USP	ITB	Bkt. Timah	AdMU	Unitech
5 minutes to 1 minute							
Burgueno	-3.2	-4.1	-4.0	-3.8	-4.3	-	-
Segal	-1.5	-1.8	-1.4	-0.5	-1.4	-	-
Joo	-25.0	-26.4	-27.4	-29.0	-28.0	-	-
Chebil	-3.1	-4.0	-4.8	-3.0	-2.0	-	-
10 minutes to 1 minute							
Burgueno	-3.5	-4.2	-3.5	-3.0	-4.0	-	-
Segal	-2.0	-1.9	-1.8	-0.4	-1.8	-	-
Joo	-26.0	-27.0	-29.0	-25.0	-29.0	-	-
Chebil	-3.2	-4.5	-3.0	-3.4	-2.7	-	-
30 minutes to 1 minute							
Burgueno	-3.7	-4.6	-5.0	-4.0	-3.2	-	-
Segal	-2.6	-2.0	-0.5	-2.6	-0.4	-	-
Joo	-27.0	-28.0	-28.0	-27.0	-27.0	-	-
Chebil	-3.4	-5.0	-3.6	-4.1	-2.4	-	-
60 minutes to 1 minute							
Burgueno	-3.7	-4.6	-5.3	-5.0	-4.0	-3.2	-5.6
Segal	-2.6	-2.0	-2.1	-0.5	-2.6	-0.4	-3.3
Joo	-27.0	-28.0	-31.4	-28.0	-27.0	-27.0	-37.3
Chebil	-3.4	-5.0	-6.3	-3.6	-4.1	-2.4	8.3