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TECHNICAL NOTE

HOURLY RAINFALL DISTRIBUTION IN EAST MALAYSIA DURING THE SOUTHWEST MONSOON SEASON.

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ABSTRACT

The hourly rainfall pattern during the southwest (SW) monsoon season is addressed. For this purpose, hourly rainfall data of nine selectedstations are analyzed. The study period was thirty-one years. The results of this investigation show that four main mechanisms are responsible for the daily rainfall distribution in East Malaysia. . These mechanisms are: (a) convergence of land breezes, (b) increase of the atmospheric lapse rate during the night, (c) convection and (d) sea breeze. For example, these four mechanisms may be important in a particular station in a given month and not in the following one or the precedent one. Or it may just be that one mechanism is important for a different station in a given month.
Keywords: Precipitation – Monsoon – Atmospheric flow

RESUMEN

Se presenta la distribución horaria de precipitación en nueve estaciones localizadas en el Este de Malasia durante el Monsoon del Sudeste. El período de estudios consta de 31 años. Los resultados de la investigación muestran cuatro factores que afectan la precipitación en esa zona, pero estos no afectan en la misma estación del año ni simultáneamente en las mismas estaciones. Estos factores son: a) convergencia ocasionada por la brisa de tierra, b) incremento de del gradiente vertical de temperatura.
Palabras claves: Precipitaciones – Monzón – Circulación atmosférica.

1. INTRODUCTION

The poleward advancement of the SW monsoon starts in early May in the southern part of Peninsular Malaysia. The SW monsoon season extends itself well into September. The hourly rainfall distribution during August in Peninsular Malaysia has been addressed (Ramage, 1964). To the authors' knowledge no other significant study regarding this matter has been conducted for that specific area. Taking into consideration global warming, it is expected that a substantially different result in the daily rainfall distribution may be obtained. Therefore, a new complete study with a larger number of stations than the previous one in Peninsular Malaysia is both pertinent and mandatory.

The Malaysian states of Sabah and Sarawak are also known as East Malaysia. These two states are located in the northern part of the island of Borneo. The network of meteorological stations in this specific region is quite recent. Therefore, the objective of this particular manuscript is to learn the hourly distribution of precipitation in East Malaysia during the SW monsoon season. Understandingly, this study focuses the daily rainfall distribution from the month of May through September.

2. DATA

Hourly rainfall data from Kuching, Sri Aman, Sibu, Bintulu, Miri, Kota Kinabalu, Kudat, Sandakan and Tawau has been obtained from the "Monthly Summary of Meteorological Observations" published by the Malaysian Meteorological Service (1964-95). The location of the stations is indicated in Table 1 and figure 1. Standard statistical methods were used.

Table 1. Name of the selected stations chosen for this study.

No	STATION:	Latitude	Longitude	Height(m)
1	Kuching	110° 20'	1° 29'	22
2	Sri Aman	111° 27'	1° 13'	10
3	Sibu	111° 58'	2° 15'	31
4	Bintulu	113° 02'	3° 12'	3
5	Miri	113° 59'	4° 20'	17
6	Kota Kinabalu	116° 03'	5° 56'	2
7	Kudat	116° 50'	6° 53'	4
8	Sandakan	118° 04'	5° 54'	10
9	Tawau	117° 53'	4° 16'	20

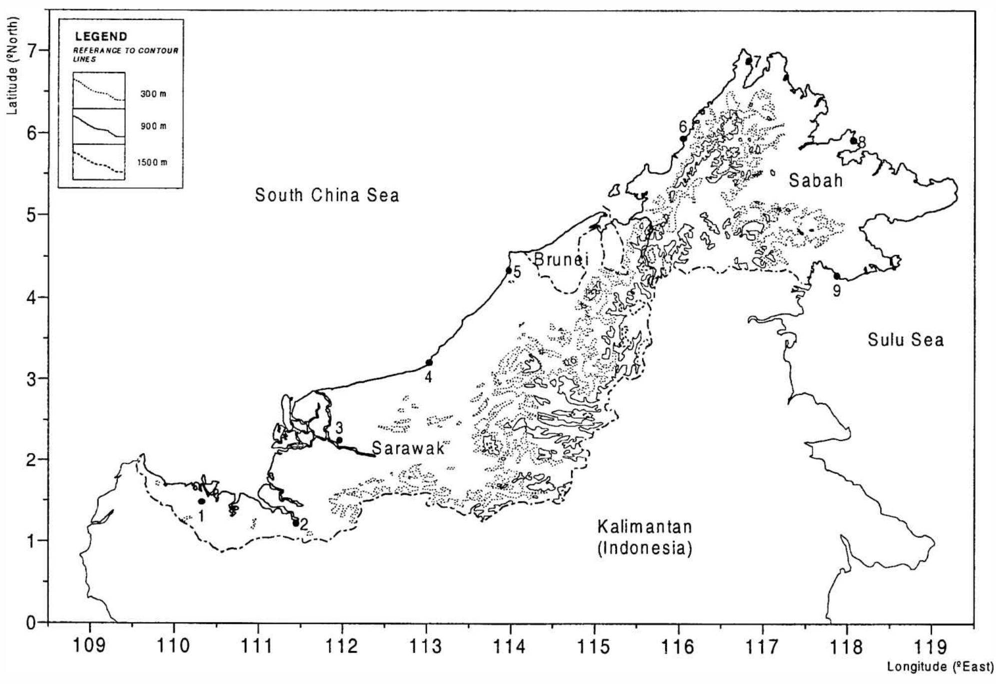

Figure 1. Location of the selected stations chosen for this study.

3. DISCUSSION AND RESULTS

May represent the passage of the Intertropical Convergence Zone (ITCZ) in East Malaysia. It may be viewed as the boundary zone in advance of the poleward migration of the Southwest (SW) monsoon. Heavy rainfall activity is observed within this boundary zone. A principal maximum of rainfall, attributable to both the sea breeze and convection, is observed in Kuching and Sri Aman at 16 h while in Sibu it is reported at 19 h (figure 2a). In all these three stations a secondary maximum, more significant in Sri Aman, is also noticed in the early hours of the day. This maximum is due to two factors: (a) the cooling due to outgoing longwave radiation (ORL) from the top of the clouds and (b) the warm sea surface. These two combined factors contribute to increase the lapse rate of the atmosphere. Thus, the air mass becomes increasingly unstable. Lesser precipitation is noticed in these stations in the early daylight hours where a minimum is recorded at midday.

Kota Kinabalu registers an outstanding maximum at 17 h, which is mainly due to convection and the sea breeze effect (figure 2b). On the other hand, at that same time, minimum rainfall is perceived both in Miri and in Bintulu where a secondary maximum, induced by convection, is observed at 13 h. Moreover, larger amount of precipitation is noticed in the early hours of the day in these two coastal stations where a principal maximum is recorded at 4 h. It may be stated that the daily rainfall distribution of Miri and Bintulu are quite similar. Thus, they are governed by the same dynamics.

Lesser rainfall is noticed in Kudat and in Sandakan in the early daylight hours where a minimum is recorded at 10 h (figure 2c). Convection is largely responsible for the principal maximum that is recorded in Kudat at 19 h and Sandakan at 21 h. Rainfall activity is also high during the night in Sandakan and Tawau. The principal maximum is more pronounced in Kuching in June than in the previous month (figure 3a). Convection also plays a larger role in Sri Aman than in the antecedent month. Precipitation in the early hours of the day is also significant in Sri Aman where a secondary maximum is observed at 6 h as well as in Sibu. It may be stated that in Sri Aman and in Sibu convection plays the major role in the hourly distribution of rainfall while the increase of the lapse rate of the atmosphere, during the night hours, plays the secondary role. No major differences are noticed in the daily rainfall pattern in Bintulu and in Miri in comparison with the antecedent month (figure 3b). It is also interesting to observe that convective activity is less significant in Kota Kinabalu as compared with previous months where an increase of rainfall activity during the night is noticeable.

The "build up" starting at 14 h leads to an absolute maximum observed in Sandakan, at 21 h, which is attributable to convection (figure 3c). Larger amounts of rainfall, during the night, in Tawau and Kudat, may be due to the convergence of their respective land breezes. In the first station the land breeze are the ones of Kalimantan and Sabah. This same convergence of land breezes has also been observed in Malacca[1]. Minimum rainfall noticed in the early daylight hours is attributable to the inverse correlation between wind and rainfall.

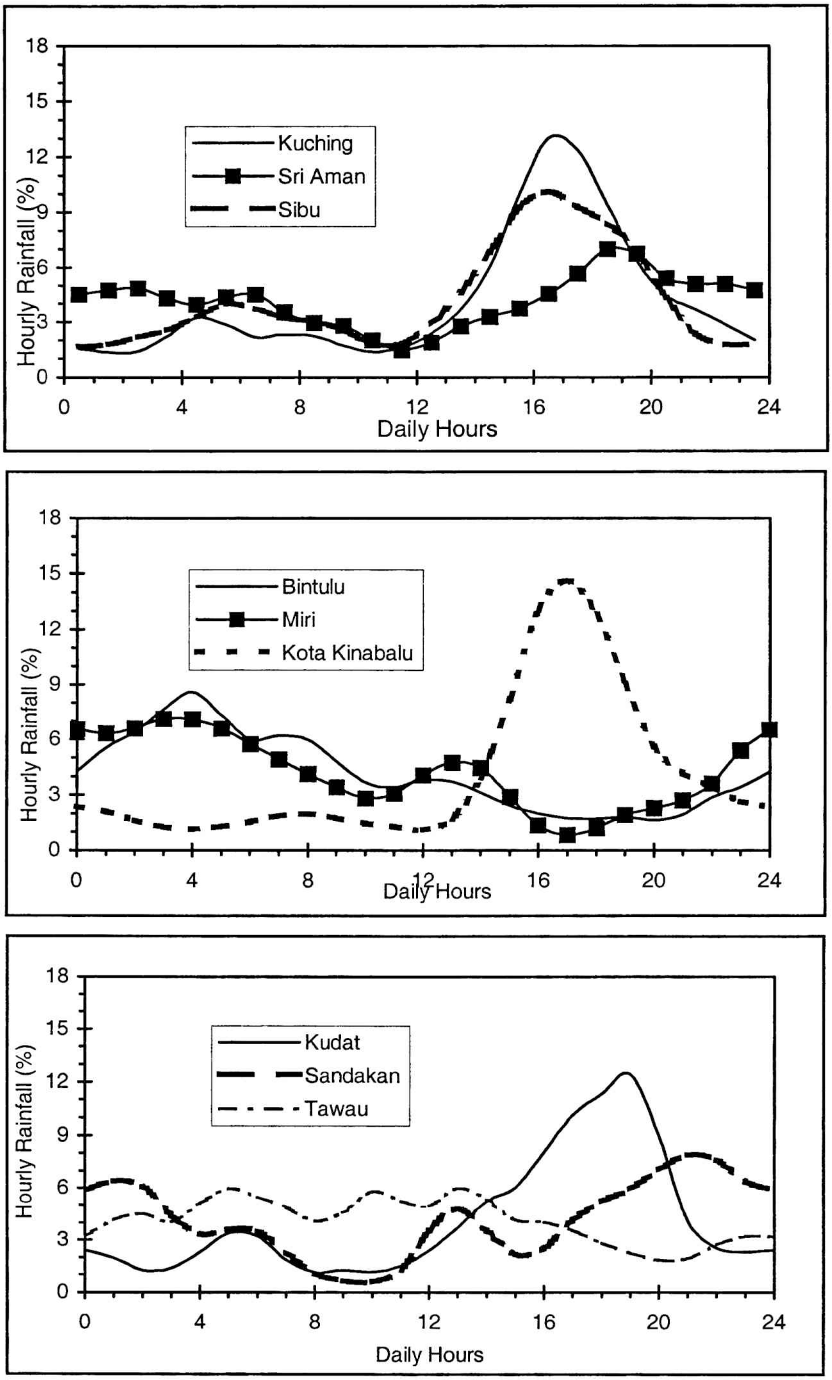

Figure 2. May hourly rainfall distribution of : (a) Kuching, Sri Aman and Sibu, (b) Bintulu, Miri and Kota Kinabalu, and (c) Kudat, Sandakan and Tawau.

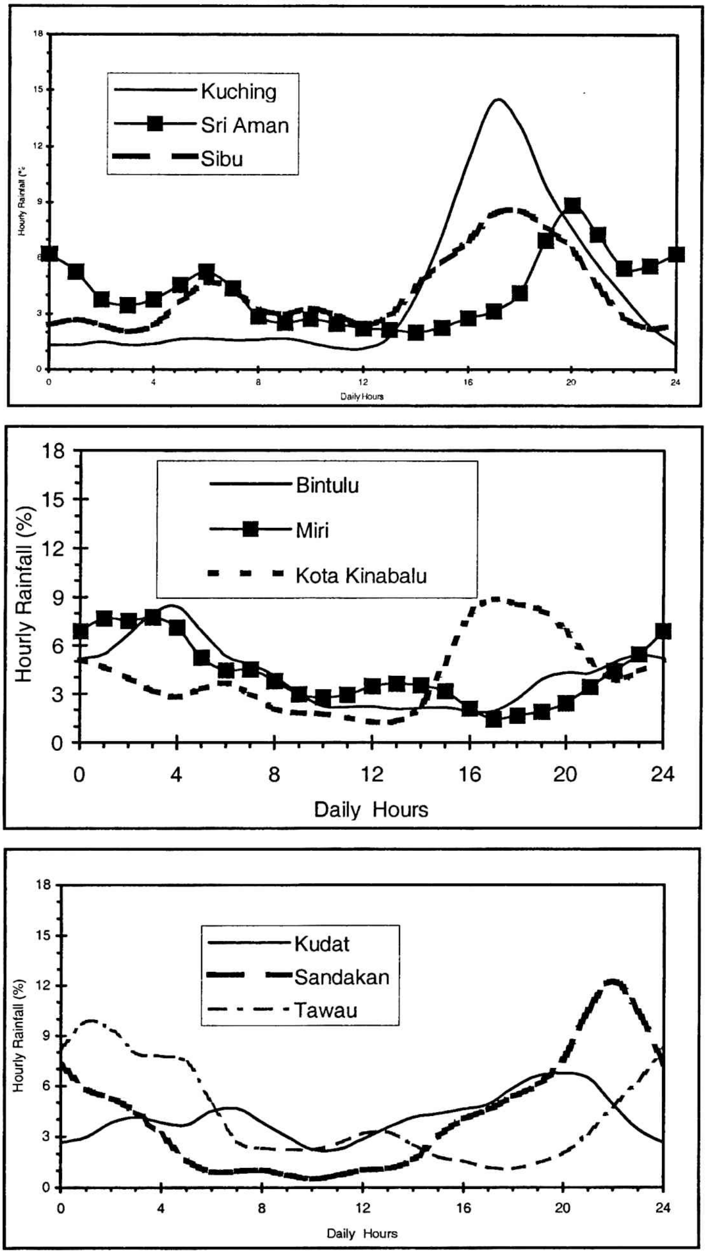

Figure 3. June hourly rainfall distribution of : (a) Kuching, Sri Aman and Sibu, (b) Bintulu, Miri and Kota Kinabalu, and (c) Kudat, Sandakan and Tawau.

The convective activity as well as the sea breeze effect is significant in the southernmost stations in July (figure 4a). However, the rainfall activity is somewhat equally relevant during the night in Sri Aman and in Sibu.

As in the previous month the hourly rainfall distribution of Bintulu and Miri are quite similar (figure 4b). It may be stated that the daily rainfall distribution of these two stations is out of phase with the one of Kota Kinabalu in the afternoon.

A sharp (slight) increase of rainfall activity is noticed in Sandakan (Kudat) starting at 16 h where a maximum is reached at 20 h (figure 4c). This attributable to convection. The rainfall activity in the coastal station of Tawau, attributable to both the convergence of land breezes of Sabah and Kalimantan and the instability due to the increase of the lapse rate of the atmosphere is only significant during the night. On the other hand, the daily rainfall distribution of Kudat is more uniform as compared with Tawau and Sandakan. The primary role of rainfall activity in the former station is given by convection while the secondary role is given by the atmospheric instability during the night (Dale, 1959, Nieuwolt, 1981).

A significant increase of rainfall is perceived during the night in Kuching and in Sri Aman in August in comparison with the previous months (Figure 5a). In particular, this instability is relatively more important than convective activity in Sri Aman. A similar situation is noticed in Miri and in Bintulu (figure 5b). (No major differences are recorded in both stations with respect to the antecedent month.) The main difference is that lesser values are perceived between 17 and 19 h in these two stations. A slight increase of rainfall activity during the night is observed in Kota Kinabalu. Therefore, the influence due to convection and the sea breeze is somewhat attenuated in contrast with the precedent month. The nightly rainfall activity in Tawau is completely determined by the convergence of the land breezes of Kalimantan and Sabah as well as the instability induced by the increase of the lapse rate of the atmosphere (figure 5c). Rainfall activity during daylight hours is insignificant at this particular station.

It is interesting to observe that the daily rainfall distribution of Tawau lags the one of Sandakan by four hours. However, both daily distributions are driven by different dynamics. In effect, precipitation increases due to convection and the sea breeze effect at 13 in the latter station. The instability observed during the night hours sustains the rainfall frequency at higher values where a sustained decreased is noticed to start at midnight. The rainfall activity of Kudat is determined, in first instance, by convection where a principal maximum is reached at 18 h. For the same reasons as explained above it is observed that the precipitation during the night is also of secondary importance.

The distribution of Kuching is somewhat similar in September as the precedent month (figure 6a). In a similar fashion as in the previous month the nightly precipitation of Sri Aman is more significant than its convective activity. Furthermore, the rainfall activity at night is larger in Sri Aman than in Kuching and in Sibu. In contrast with the previous month the daily rainfall distribution of Sibu approximately equally dominated by convection as well as by the precipitation during the night in September. The abatement of convective activity observed in Kota Kinabalu in the previous month is sustained in September (figure 6b). Furthermore, the atmospheric instability at night is still more significant in Miri and in Bintulu than convective activity.

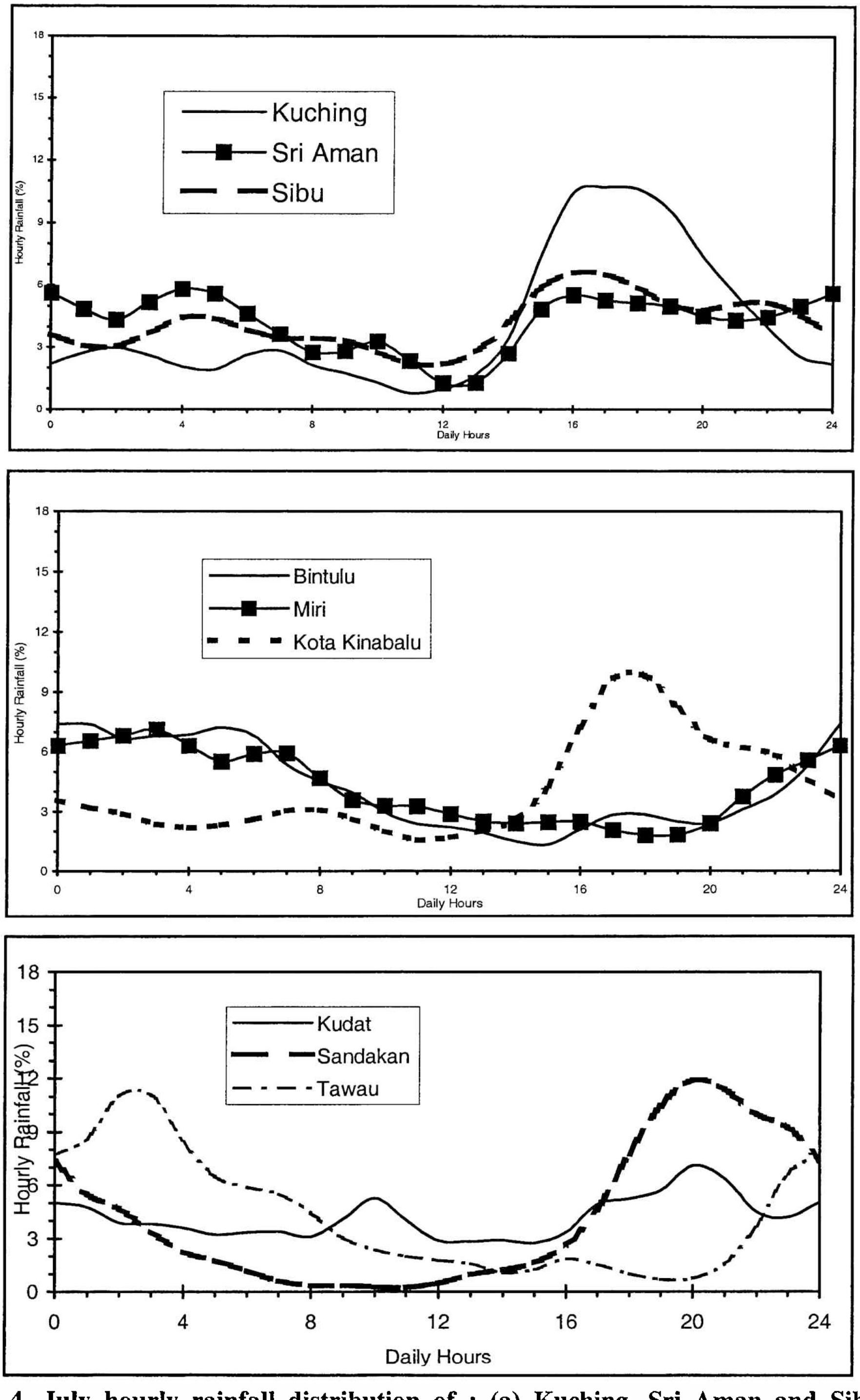

Figure 4. July hourly rainfall distribution of : (a) Kuching, Sri Aman and Sibu, (b) Bintulu, Miri and Kota Kinabalu, and (c) Kudat, Sandakan and Tawau.

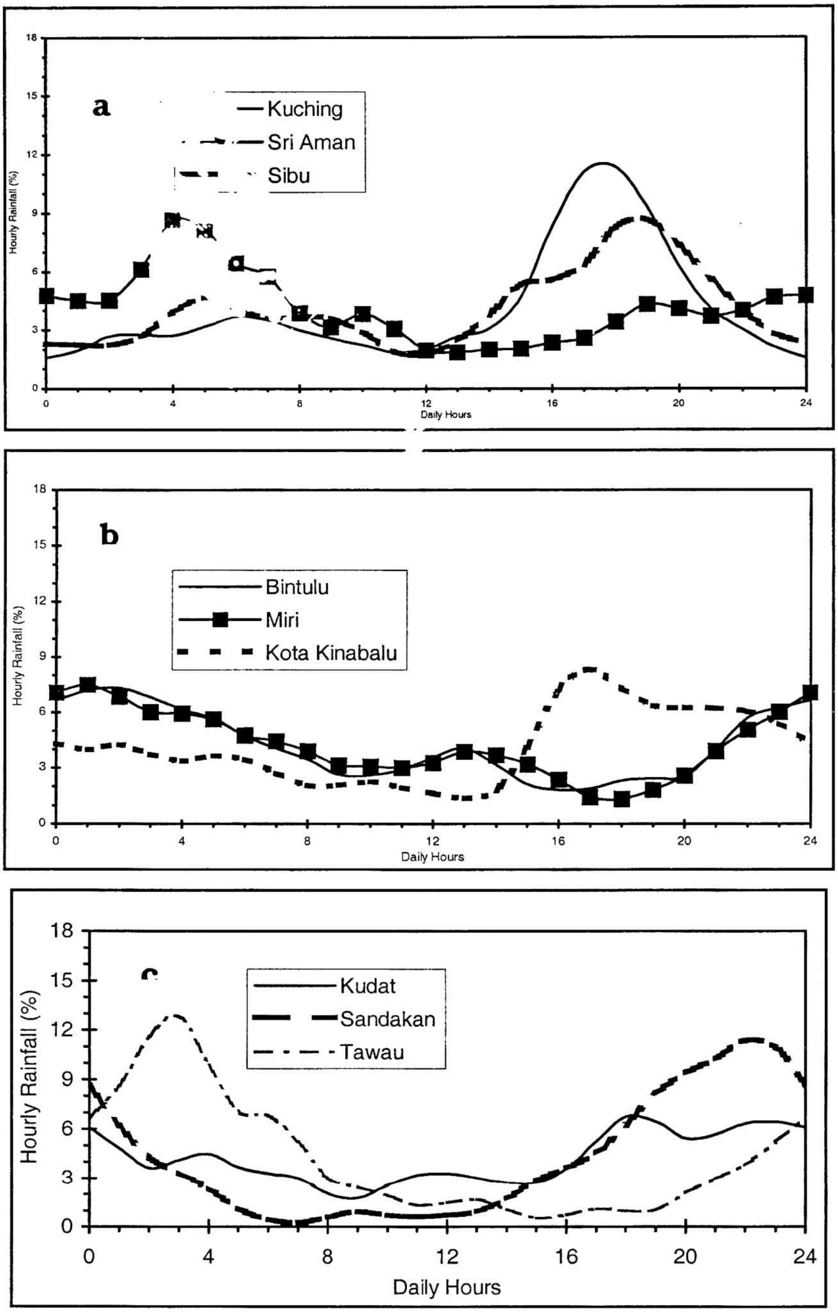

Figure 5. August hourly rainfall distribution of : (a) Kuching, Sri Aman and Sibu, (b) Bintulu, Miri and Kota Kinabalu, and (c) Kudat, Sandakan and Tawau.

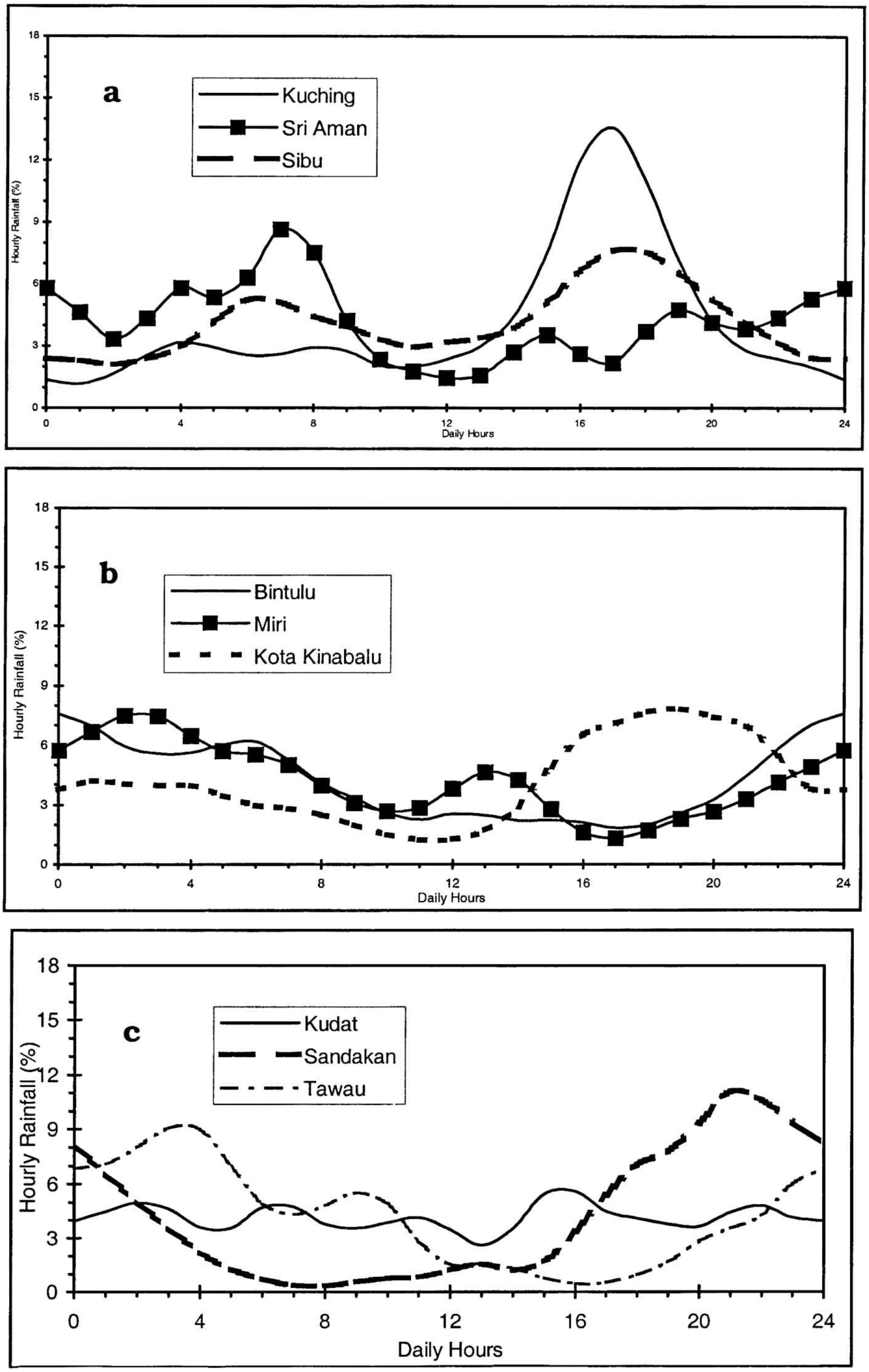

Figure 6. September hourly rainfall distribution of : (a) Kuching, Sri Aman and Sibu, (b) Bintulu, Miri and Kota Kinabalu, and (c) Kudat, Sandakan and Tawau.

Not a significant departure from the previous month is noticed in Sandakan in September (figure 6c). The only difference is that the maximum of rainfall is observed at 21 h. On the other hand, the rainfall activity during the night is as significant as the one due to convection in Kudat. In this respect, the daily rainfall distribution differs from the one of the previous month. It is also interesting to observe, in contrast with the precedent month, that a significant amount of rainfall is observed in the early daylight hours in Tawau. At the same time, the nightly principal maximum is not as relevant in September as in the previous month.

CONCLUSIONS

The aim of this paper is to shed some light into the hourly rainfall distribution of East Malaysia. For this purpose, thirty-one years of data of nine selected stations has been analyzed.

The results of this investigation show that there are four main mechanism that may trigger rainfall in our area of interest. These mechanisms are: (a) convergence of land breezes, (b) increase of the atmospheric lapse rate during the night, (c) convection and (d) sea breeze. It may happen that all four mechanisms are equally important in a single month for a particular station. Or it may just be that two or three are significant.

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