GEOACTA, 24, 1-18, 1999

MONTHLY FREQUENCY DISTRIBUTIONS OF BOTH DRY SPELLS AND THE NUMBER OF DAYS WITH PRECIPITATION GREATER THAN 25 MM OVER PENINSULAR MALAYSIA

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ABSTRACT

The study of both the monthly distribution of the number of rain-days greater than 25 mm and the re-evaluation of the dry spell monthly distribution in Peninsular Malaysia is made. It is shown that: (a) the dry spell distribution of the east coast is more regular than both the one in the opposite coast and the one in the central part of the peninsula, (b) different dry spell distributions may be defined at the west coast, (c) a dry spell distribution for the central part of the peninsula is well established, (d) Kuala Lumpur is the area where the largest annual number of rain-days greater than 25 mm is observed, and (e) the monthly number of rain-days greater than 25 mm does not follow its respective monthly (average) distribution of rainfall.

RESUMEN

En este trabajo se analiza la distribución mensual del numero de días de precipitación mayor que 25 mm. Asimismo, se reevalúa la distribución mensual de días consecutivos sin lluvia en la península malaya. Las principales conclusiones de este trabajo son: (a) la distribución mensual de días consecutivos sin lluvia es más regular en la costa este que en la costa opuesta o en la parte central de la península, (c) se pueden definir hasta tres regímenes distintos de días consecutivos sin lluvias en la costa oeste y uno (diferente) en la parte central, (c) Kuala Lumpur registra el mayor número de días de precipitación mayor que 25 mm, y (d) generalmente, la distribución mensual de días con precipitación mayor que 25 mm no es similar a la respectiva distribución mensual de precipitación.

1. INTRODUCTION

It has been observed that the monthly distribution of the number of rainy days approximately follows the monthly distribution of precipitation in Peninsular Malaysia (Dale, 1959a; Camerlengo and Somchit, 1998a). The quantification of the daily amount of rainfall due to: (a) both the southwest (SW) and the northeast (NE) monsoon wind and (b) the two inter-monsoon periods is addressed. For this purpose, the study of the frequency of the monthly distribution of the number of days with precipitation larger than 25 mm in Peninsular Malaysia is analyzed. To the author' s knowledge, no similar study has been undertaken.

The single study on dry spells in Peninsular Malaysia has been conducted forty years ago (Dale, 1959a). In that particular study, non-similar number of years was considered. A different approach has been taken in this manuscript. 17 stations for fifteen years, from 1982-1996, have been scrutinized. In doing so, the rainfall data of the (analyzed) stations is affected by the same inter-annual variability (that occurred within this particular period).

An increase of 0.5°C, attributed to global warming, has been observed in Peninsular Malaysia in the last fifty years (Camerlengo *et al.*, 1997). It is expected that such an increase in temperature could change the dry spell distribution. These are two sufficient reasons to re-evaluate the monthly distribution of the dry-spell distribution. In this regard, one of the results of this study shows no major differences in the dry spell distribution between neighboring stations. This is in sharp contrast with Dale' s (1959a) findings.

The above mentioned result of this study may largely be attributable to the homogeneity induced by global warming as well as to the fact that all stations are affected by the same ENSO events. The aim of this investigation is two-folded. On one hand, it is intended to investigate the distribution of the number of days with rain larger than 25 mm; and on the other hand, to re-evaluate using a different approach than in a previous study the dry-spell distribution pattern in Peninsular Malaysia.

2. DATA

Rainfall data from 17 stations in Peninsular Malaysia has been obtained from the "Monthly Summary of Meteorological Observations" published by the Malaysian Meteorological Service (1982-96). Therefore, all stations are affected by the same ENSO events. This approach is different than the one taken previously were the analyzed stations had dissimilar number of years (Dale, 1959a). Both the location and the name of the stations are shown in figure 1 and Table 1, respectively.

The number of continuous days with precipitation less than 0.1 mm is known as *dry spells*. In this study dry spells of 5 days and above are considered. In doing so, all dry spells within the fifteen years are added.

3. RESULTS AND DISCUSSION

3. 1. Dry spells

Given the particular location of the stations five types of dry spell distribution may be defined. These are: northwestern region, Titiwangsa mountain region, central west coast region, central region, and eastern region.

3.1.1. Northwestern region

Taking into consideration the fifteen years of record, from 1982 to 1996, the largest number of consecutive days without rain in the northwestern sector of the peninsula occurs from December to March. In particular, Alor Setar, Cuping, Penang and Ipoh experience the largest dry spells within this period (Tables 2 and 3). A secondary maximum dry spell is observed in June/ July in this same region. As noted by Dale

(1959a), it is confirmed that dry spells are largely dependent on latitude, increasing towards the north.

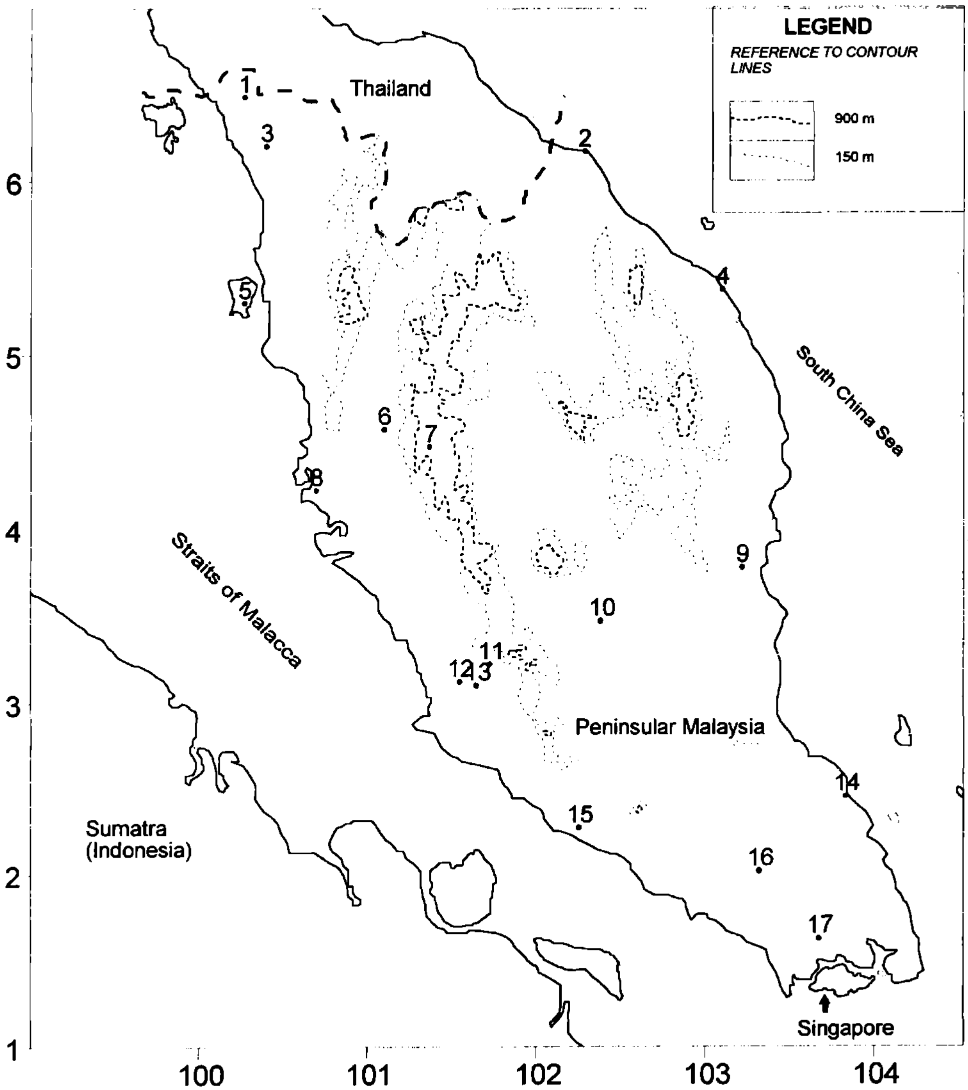

Figure 1. Location of stations:

Quantitatively, the results for Penang are similar to the ones obtained previously (Dale, 1959a). However, this is not the case for Alor Setar were considerable larger dry spells were reported in the latter study. Shorter dry spells observed in the northwestern sector of the country from May to September may be explained by the southwest (SW) monsoon winds. Nieuwolt (1981) suggests that during the boreal summer a deep vertical column of 8,000 m is affected by the light southwesterly winds. In his perception, the combination of these two factors favors convective activity.

Lesser dry spells are recorded at the west coast during May and October; respectively, as these two months represent the two particular inter-monsoon periods where the largest amount of rainfall is observed (during these two particular months) (Nieuwolt, 1981).

TABLE 1. Name of the stations.

No	Station	Latitude (N)	Longitude (E)	Height (m)
1	Cuping	6 29'	100 16'	22
2	Kota Baharu Airport	6 10'	102 17'	5
3	Alor Setar Airport	6 12'	100 24'	4
4	Kuala Terengganu Airport	5 23'	103 06'	5
5	Penang International Airport	5 18'	100 16'	2
6	Ipoh Airport	4 34'	101 06'	40
7	Cameron Highlands (Tanah Rata)	4 28'	101 22'	1545
8	Setiawan	4 13'	100 42'	7
9	Kuantan Airport	3 47'	103 13'	15
10	Temerloh	3 28'	102 23'	39
11	Universiti Malaya	3 13'	101 44'	104
12	KL International Airport(Subang)	3 07'	101 33'	17
13	Petaling Jaya	3 06'	101 39'	46
14	Mersing	2 27'	103 50'	44
15	Malacca Airport	2 16'	102 15'	9
16	Kluang	2 01'	103 19'	88
17	Johor Bahru International Airport	1 38'	103 40'	38

3.1.2. Titiwangsa mountain region

Two maximum dry spells, of approximately similar magnitude, are noticed in Cameron Highlands during the periods ranging from: (a) January to February and (b) from June to August. However, the first maximum is of a lesser magnitude than the one observed in a neighboring station, Ipoh, during this same period. This may be attributable to the altitude of the former station. Camerlengo and Somchit (1998b) estimated that the maximum belt of precipitation is at an approximate height of 1000 m in Peninsular Malaysia.

TABLE 2. Monthly dry spell distribution of the following stations: (a) Cuping, (b) Alor Setar and (c) Penang, located in the northwestern sector of the peninsula.

Number Of Events

Number of continuous days with no precipitation

30	1											
29	1											
28	1	1										
27	1	2										
26	1	2										
25	1	3										
24	1	3										
23	1	3										
22	2	3										
21	3	4										
20	4	4										
19	5	4										
18	5	6										
17	6	6										1
16	8	7										1
15	8	7				1						2
14	8	7	1			1						2
13	9	8	1	1		1						2
12	9	8	1	1		2	1					4
11	10	8	1	1		2	1					5
10	10	9	2	1		2	2					7
9	10	10	4	3		2	2	1			2	9
8	13	10	6	3		2	2	1			2	11
7	17	10	9	3		3	3	1			2	12
6	20	12	12	4		4	4	2	1		3	14
5	23	16	18	6	2	9	8	3	2	1	4	18

(A)

30	1											
29	1											
28	1	1										
27	1	2										
26	1	2										
25	1	2										
24	2	2										
23	2	2										
22	4	2										
21	4	2										1
20	5	3										1
19	6	3										1
18	6	5										1
17	6	6										2
16	9	6				1						3
15	9	6		1		1						3
14	9	6		1		1						3
13	9	6		1		1	1					3
12	9	6		1		1	1					3
11	9	6	1	1		1	1					6
10	10	6	1	1		1	2				1	6
9	11	7	2	2		1	3				2	7
8	13	10	4	2		2	3				2	8
7	16	10	5	2		2	3				2	11
6	19	12	11	3		3	4	2			3	13
5	20	17	16	5	2	6	6	4		1	5	16

(B)

continue

Continuation of Table 2

Number of continuous days with no precipitation	J	F	M	A	M	J	J	A	S	O	N	D
27		1										
26		1										
25		1										
24		1										
23		1										
22		1										
21		1										
20		1										
19		1										
18		1										
17		2				1						
16		2				1						
15	1	3				1						
14	3	3		1		1						1
13	3	3		1		1						1
12	3	4		1		2						1
11	4	4	1	1		2						2
10	5	4	2	1		2						3
9	7	4	2	1		2	1				1	4
8	9	5	3	2		4	2	1			1	5
7	10	9	5	2		5	2	1			1	7
6	16	10	6	2	1	6	3	2			3	10
5	20	11	10	2	3	6	4	4	1		4	12

(C)

3.1.3. Central west coast region

Lesser dry spells are observed in Malacca as compared to both Setiawan (further to the north at the west coast) and Petaling Jaya (in the central part) during the boreal summer (Tables 4 and 5). This is due to the fact that the former station is affected by convective activity during the early hours of the day. Ramage (1964) attributes this phenomenon to the convergence of the two land breezes, one from the peninsula and the other one from Sumatra.

The largest dry spell in Setiawan occurs both in June and in July, which in turn is larger than the ones observed in Petaling Jaya and in Malacca; repectively, for these same months. It is interesting to notice that the secondary maximum dry spell recorded in Setiawan during the first three months of the year is lesser than the ones noticed in the northwestern sector of the peninsular.

TABLE 3. Monthly dry spell distribution of: (a) Ipoh and (b) Cameron Highlands. The latter station is located on the Titiwangsa mountain range. Ipoh is located at the western side of the Titiwangsa mountain range, quite close to Cameron Highlands.

Number Of Events

Number of continuous days with no precipitation

30	1											
29	1											
28	1	1										
27	1	2										
26	1	2										
25	1	2										
24	2	2										
23	2	2										
22	4	2										
21	4	2										1
20	5	3										1
19	6	3										1
18	6	5										1
17	6	6										2
16	9	6				1						3
15	9	6		1		1						3
14	9	6		1		1						3
13	9	6		1		1	1					3
12	9	6		1		1	1					3
11	9	6	1	1		1	1					6
10	10	6	1	1		1	2				1	6
9	11	7	2	2		1	3				2	7
8	13	10	4	2		2	3				2	8
7	16	10	5	2		2	3				2	11
6	19	12	11	3		3	4	2			3	13
5	20	17	16	5	2	6	6	4		1	5	16

(A)

	J	F	M	A	M	J	J	A	S	O	N	D
16	1											
15	1											
14	2	1				1						
13	2	1		1		2		1				
12	3	1	1	1		2		2				
11	3	1	1	1		3	2	2				
10	3	2	1	1		4	2	2				
9	4	3	1	1		5	2	2				1
8	5	7	1	1		5	2	2				2
7	6	8	3	2		5	2	3				2
6	7	11	4	3	1	6	3	6				4
5	10	14	11	4	1	10	8	8			2	4

(B)

TABLE 4. Monthly dry spell pattern of the following stations: (a) Setiawan, and (b) Malacca, located in the central part of the west coast of the peninsula.

Number Of Events

Number of continuous days with no precipitation	J	F	M	A	M	J	J	A	S	O	N	D
(A)												
15						2						
14						3						
13				1		3						
12				1		3		2				1
11	1	1		1		3	1	2				1
10	1	2		1	1	3	1	3				1
9	1	2	1	1	1	4	1	3				1
8	1	4	2	1	1	8	2	3	1			1
7	3	5	3	1	2	8	4	5	1			1
6	5	8	5	1	4	10	9	5	2			1
5	10	10	12	3	8	13	14	11	2		1	2
(B)												
18		1										
17		1										
16		2										
15	1	2										1
14	1	3				1						1
13	1	3	2			1						1
12	1	3	2			1		1				1
11	1	4	2			1		1				1
10	2	4	2			1		2				1
9	4	4	2			3	1	2				1
8	6	5	4			3	1	2		2		2
7	7	7	6			5	3	2		2	1	3
6	10	8	10	2	1	6	4	5	1	2	1	4
5	17	12	10	5	3	7	5	6	3	3	4	7

3.1.4. Central region

Further to the south and closer to the west coast, Malacca, Kluang and Johor Bahru, exhibit their largest dry spell period during the first two months of the year. However, the magnitude of these dry spells is somewhat attenuated in regards to the ones observed in the northwestern part of the peninsula during this same period.

Setiawan, at the west coast; Temerloh, and Petaling Jaya, in the central part of the peninsula exhibit a dry spell of a lesser magnitude than the stations located further to the north during the first three months of the year. The reverse is true in June and in July.

TABLE 5. Monthly dry spell pattern of the following stations: (a) Petaling Jaya, (b) Temerloh, (c) Kluang and (d) Johor Bahru, located in the central sector of the peninsula.

Number Of Events

Number of continuous days with no precipitation

15						1						
14	1					1						
13	1					1						
12	1					1						
11	2					2						
10	2					3						
9	2					3						
8	4	2				3	1	1	1			
7	5	2				8	2	2	1			1
6	5	4		1	2	8	4	5	1	1		2
5	9	7	1	1	3	10	9	6	1	2	2	3

(A)

22		1										
21		1										
20		1										
19		1										
18		1	1			1						
17		1	1			1						
16		2	1			1						
15		2	1			1		1				
14	1	5	1			2		1				
13	1	5	2			2		1				
12	1	6	2			2		2				
11	1	7	2			3	1	3				
10	1	7	2			4	1	3				
9	1	7	5	1	1	5	1	3				
8	2	7	7	1	1	6	5	4				2
7	2	8	10	3	1	8	8	5	1	1	1	2
6	5	9	11	6	4	9	9	8	1	1	2	2
5	8	10	13	8	5	13	12	8	5	2	3	2

(B)

17		1										
16		1										
15	1	2										
14	1	2	1									
13	1	2	1									
12	2	2	2					1				1
11	2	3	2					1				1
10	2	3	2			1		1				1
9	4	4	3			1		1			1	1
8	4	6	3			1	1	2			1	1
7	6	8	4	1	1	2	2	2	1	2	1	1
6	10	13	7	1	1	2	3	2	1	3	2	2
5	11	17	8	1	1	4	5	4	2	4	5	6

(C)

continue

Continuation of Table 5

Number of continuous days with no precipitation	J	F	M	A	M	J	J	A	S	O	N	D
18	1											
17	1	1										
16	2	1										
15	2	1										
14	2	1										
13	2	1										
12	2	1										
11	2	1	2									
10	3	1	2			2						
9	4	1	2			2				1		
8	6	4	3			5	1	1		1		
7	6	5	4		1	5	2	3		1		
6	9	10	6	1	1	5	5	3		3		1
5	11	13	7	1	2	8	5	6	1	4		2

(D)

3.1.5. East coast region

Larger dry spells observed from February to May are observed at the east coast (Table 6). This may largely be attributable to the fact that the dry period (defined here as the mean monthly rainfall lesser than 150 mm) extends from February to July (Camerlengo *et al.*, 1996). In particular, the largest dry spell is noticed in the period February/March with a gradual decrease of the magnitude (of the dry spells) towards October.

On the other hand, with the single exception of Kota Bahru, no dry spell has been observed during the last two months of the year. That is, during the wettest months of the year in that particular area. Further inland from the east coast, both the frequency and the duration of the dry spells increase during November and December. In particular, such a growth is noticeable both in Kluang and Temerloh during these two months.

The dry spell monthly distribution of both Kota Bahru and Mersing are quite similar (This should largely be attributable to the fact that all the (analyzed) stations are affected by the same ENSO events). However, larger dry spells in the former station as compared with the latter one were reported in Dale (1959a)

Further inland, in Johor Bahru, Temerloh and Kluang, a principal maximum dry spell is recorded in January/March while a secondary maximum is observed in June/August. This may be attributable to the fact that both February and June (in this particular order) are the driest month in the peninsula (Dale 1959b).

Kuantan and Mersing, at the east coast; register shorter dry spells than Kota Bahru and Kuala Trengganu, This confirms the fact that dry spells are largely dependant on latitude, as they tend to decrease towards the Equator.

TABLE 6. Monthly dry spell pattern of the following stations: (a) Kota Bahru, (b) Kuala Terengganu, (c) Kuantan and (d) Mersing, located in the east coast of the peninsula.

Number of continuous days with no precipitation	Number Of Events												
29				1									
28				1									
27				1									
26				1									
25				1									
24				1									
23				1									
22				1									
21				1									
20			1	1									
19		1	1	1									
18		1	1	1									
17		1	1	1									
16		1	1	2									
15		1	2	3									
14		2	4	3			1						
13		2	4	4			1		1				
12		3	6	4	1		1		1				
11		4	6	4	2		1		1				
10	2	6	7	8	3	1	1	1	1				
9	4	6	7	8	3	1	1	1	1				
8	5	6	11	9	4	1	1	1	1	1	1		
7	7	9	12	12	8	3	1	4	1	1	1	2	
6	7	11	16	14	9	5	1	6	2	2	1	3	
5	9	14	19	17	16	8	3	9	4	4	1	5	(A)
25				1									
24				1									
23				1									
22				1									
21		1		1									
20		1		1									
19		1	2	1									
18		1	3	1									
17		2	5	1									
16		2	5	1									
15		2	5	2	2								
14		3	5	2	4								
13		4	5	3	4								
12	1	5	7	3	5								
11	1	8	7	5	6	1	1	1					
10	1	9	7	6	6	1	1	1					
9	2	9	8	6	6	2	3	1		1			
8	2	11	10	7	7	3	4	1	2	1			
7	3	13	14	8	9	6	6	2	2	1			
6	3	15	18	11	11	8	9	4	3	1			
5	5	18	21	12	14	11	13	5	4	2	(B		continue

Continuation of Table 6

Number of continuous days with no precipitation

	J	F	M	A	M	J	J	A	S	O	N	D	
19		1											
18		2											
17		2											
16		2		1									
15		2		1		1							
14		2		2		1							
13		2		2		1							
12		2	2	4		1		1					
11		2	2	4		1		1					
10		2	2	4		1		1					
9		3	3	4		1	1	1					
8	1	5	5	4	1	3	1	2					
7	1	10	8	4	3	6	2	2			1		
6	4	10	10	4	3	6	4	2	1		1		
5	8	12	14	4	3	8	5	4	1		1	1	(C)
18								1					
17								1					
16		3		1				1					
15		4		1				1					
14		5		1				1					
13		6		3				1					
12		6	1	4				1					
11		6	1	4				1					
10		7	2	4				1		1			
9	1	8	4	4	2	1	1	2		1			
8	1	10	7	4	2	2	2	2	1	1			
7	2	12	10	4	3	3	5	2	1	1			
6	3	14	11	6	9	3	6	3	2	1			
5	5	16	15	7	11	5	6	4	5	3			(D)

3.2. Number of days with rainfall larger than 25 mm

Largest number of days of rain greater than 25 mm is observed at the southeastern sector of the peninsula while a secondary maximum is recorded in the central part of the west coast in January (figure 2). The first maximum may be attributable to the southward migration of the area of convergence associated with the NE monsoon. For the same reason, lesser number of days of rain greater than 25 mm is noticed in the northwestern sector of the peninsula.

A principal maximum is observed in Kuala Lumpur while a minimum is recorded in the fourth northernmost part of the peninsula in February (figure 2). A similar pattern is noticed in the following month, where a secondary maximum is recorded in the southern part of the peninsula.

Due to the fact that the sea breeze has a larger horizontal length scale than in extra-tropical latitudes, a principal maximum is observed at the western side of the Titiwangsa mountain range while a secondary maximum is noticed in both Kuantan and Johor Bahru in April (Hastenrath, 1990). On the other hand, a minimum is recorded in the northern part of the east coast in this same month (figure 2).

In May the passage towards the north of the broad area of convergence ahead of the SW monsoon takes place. As a consequence of this, larger precipitation values are recorded in the western side of the Titiwangsa mountain range (Camerlengo and Somchit, 1998c). In spite of this, the maximum of days of rain greater than 25 mm in this same region is somewhat lesser than in the previous.

June represents the second driest month, after February, in Peninsular Malaysia. In contrast with previous months a uniform field of raindays greater than 25 mm is observed (figure 2). For the same reason given in the previous section, the maximum observed in Cameron Highlands may be explained by its higher altitude.

Larger values are noticed in both the southernmost and the northernmost sectors of the peninsula and in Kuantan in July. In contrast to previous months, lesser values are observed in the central part in this particular month. Specially, in the Kuala Lumpur area. Larger values are noted in Penang, Cameron Highlands, Kuala Lumpur and the southernmost part of the peninsula in August, while lesser values are recorded in Kuala Terengganu. The southward migration of the area of convergence ahead of the retreating SW monsoon may be attributable for the largest values in the northwestern sector of the country in September. On the other hand, a minimum value is recorded in Kluang.

October, representing one of the inter-monsoon seasons, is noted for largest monthly values of rainfall in the western half of the peninsula (Nieuwolt, 1981) . Larger values of rain-days greater than 25 mm observed in the north half west of the Titiwangsa mountain may be attributable to this effect.

In concordance with the November rainfall pattern largest values of rain-days greater than 25 mm are recorded in the northern half of the east coast. Secondary maximums are noted both in Kuala Lumpur and in Mersing. On the other hand, minimum values are recorded in the northwestern sector of the peninsula.

The December pattern of the number of rain-days greater than 25 mm shows a principal (secondary) maximum in the southern (northern) part of the east coast, and somewhat lesser values at the western side of the Titiwangsa mountain range. Conversely, minimum values are recorded in the northwestern sector of the country during this particular month. In this regard, a similar pattern is observed for the December average rainfall pattern (Camerlengo and Somchit, 1998c).

Larger of number of rain-days greater than 25 mm are observed in Cameron Highlands in comparison with its closest station, Ipoh, in October and November. This should largely be attributable to both the altitude of the former station as well as to the discharge of humidity of the air mass that is driven by the NE monsoon winds. The situation is completely reversed in December. This may be explained by the combined effect of both the southward migration of the area of convergence ahead of the NE monsoon and the discharge of humidity (due to the elevation) of the air mass, driven by the sea breeze, at the western side of the Titiwangsa mountain range.

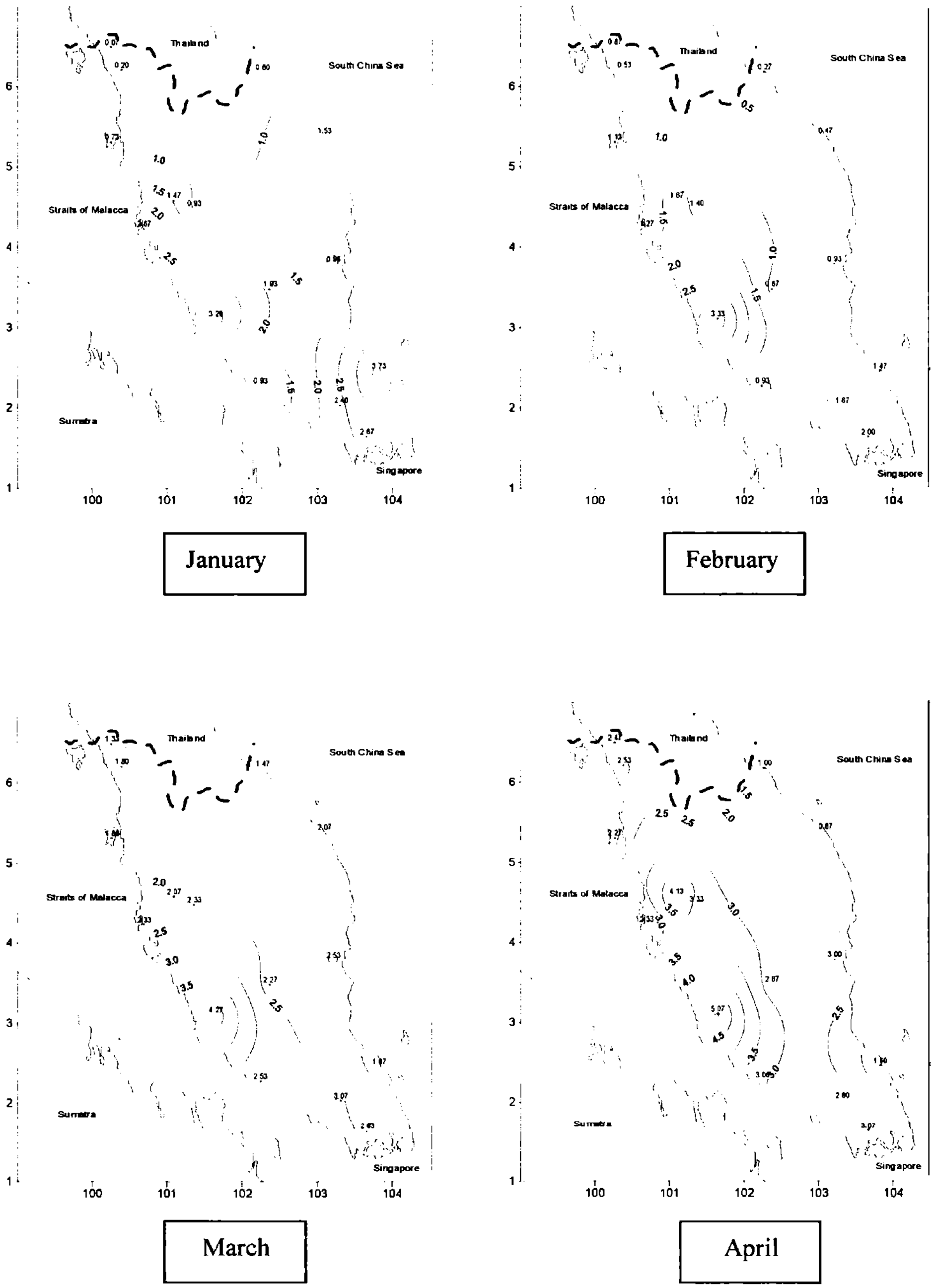

Figure 2. Monthly distribution of number of days with precipitation larger than 25 mm.

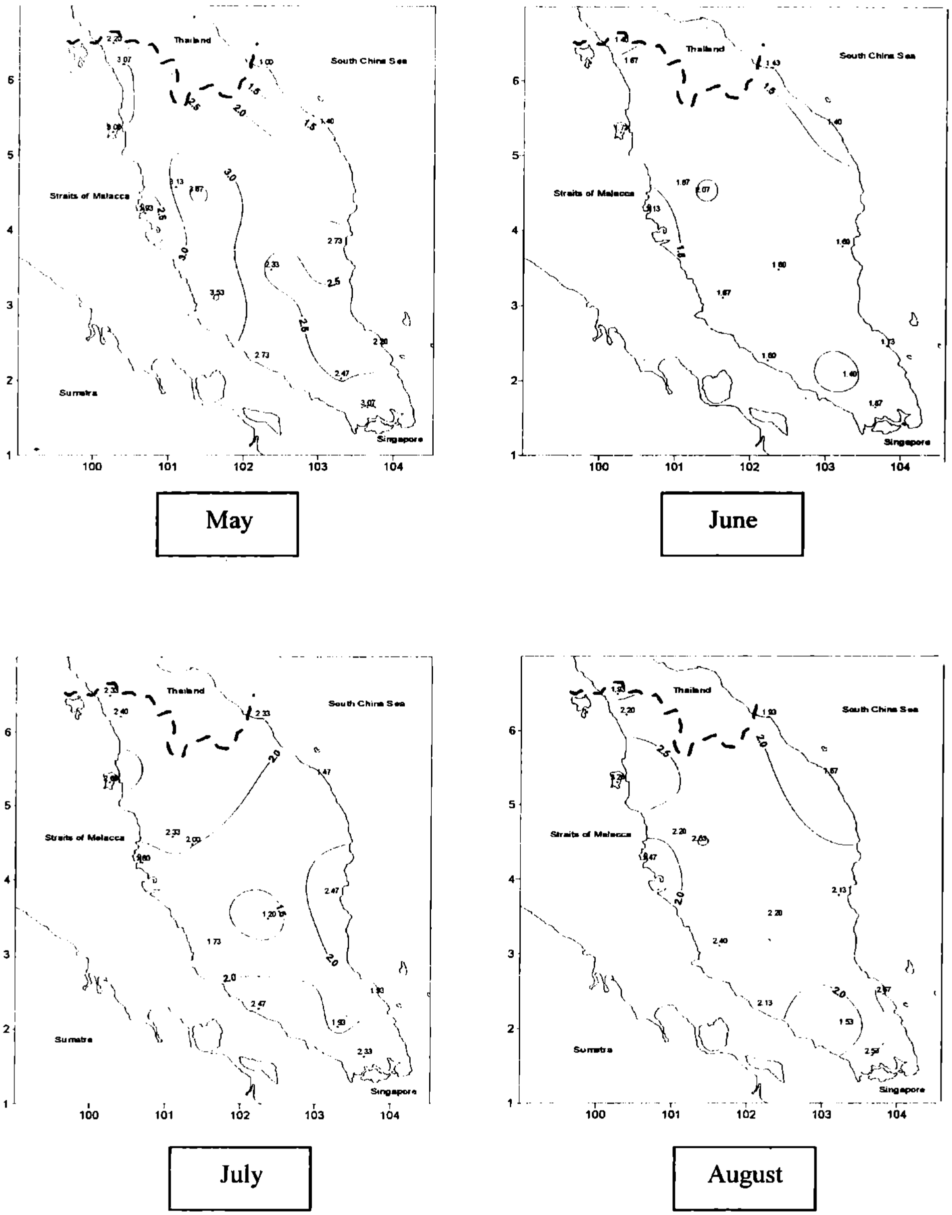

Figure 2 (Continuation)

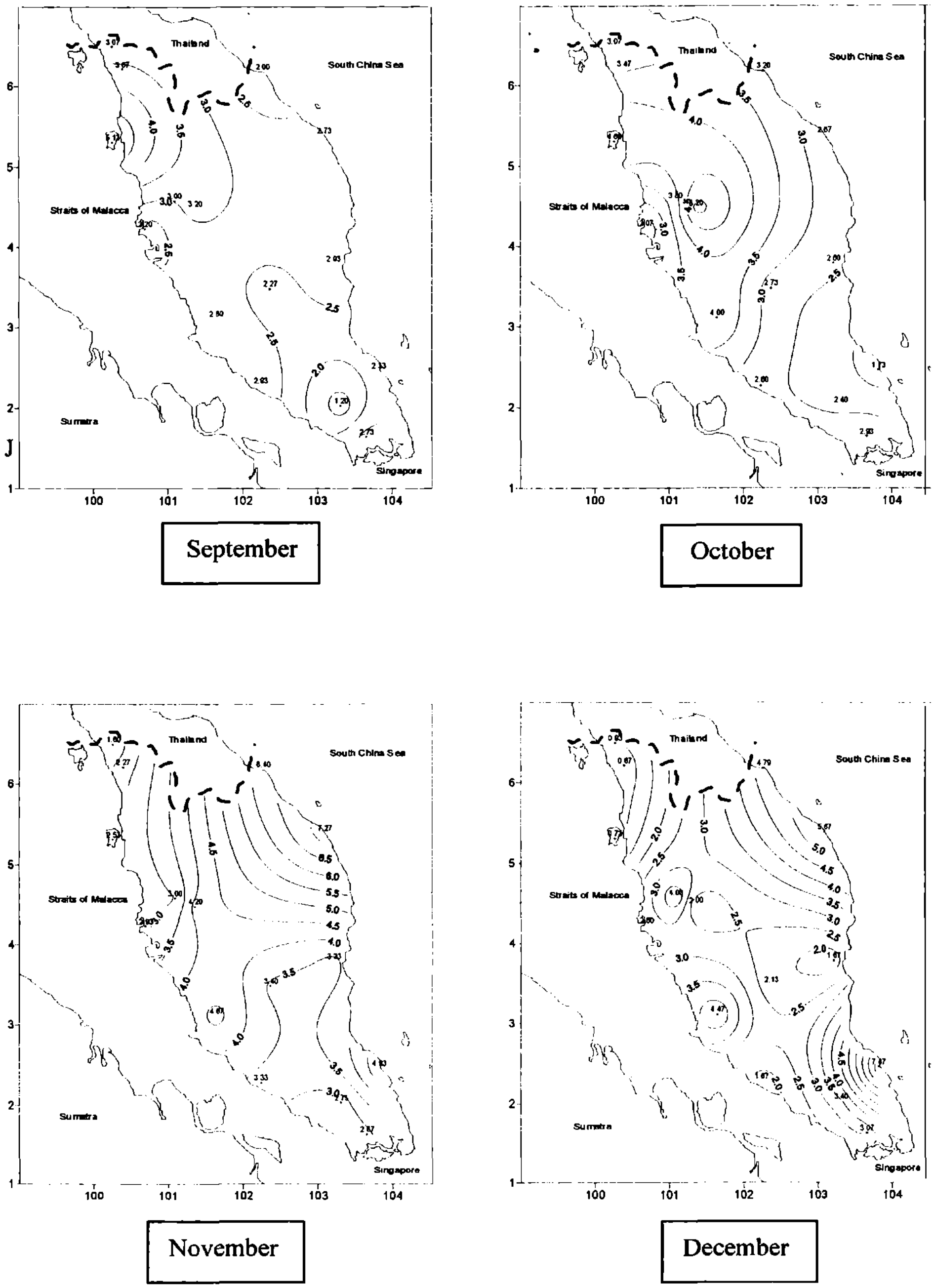

Figure 2 (Continuation)

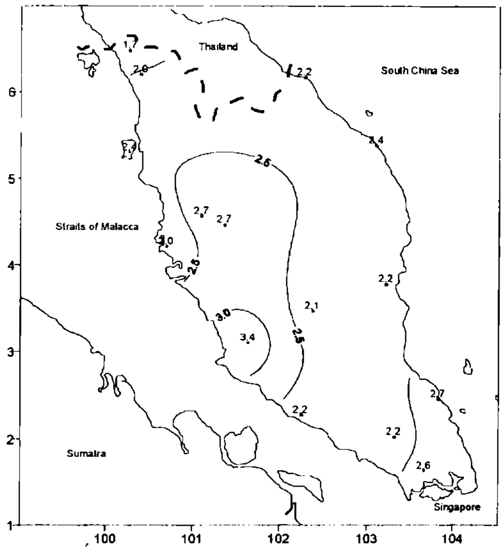

Figure 3. Annual distribution of number of days with precipitation larger than 25 mm.

Annually Kuala Lumpur represents the area with the largest number of rain-days greater than 25 mm, while Chuping represents the area of lesser number of rain-days greater than 25 mm (figure 3). The most significant feature of mean annual distribution of the analyzed field is its uniformity.

4. CONCLUSIONS

The monthly distribution of rain-days greater than 25 mm is analyzed and the dry spell monthly distribution in Peninsular Malaysia is re-evaluated.

The main conclusions of this study are:

1) The monthly dry spell distribution of the east coast has lower values in the last four months of the year. This is largely due to the combined effect of the NE monsoon season and the September/October (transitional) inter-monsoon period. Greater dry spell values, on the other hand, are noticed from February to June, in coincidence with the dry period observed at that coast. However, both in the central and the western part of the peninsula larger values are noticed in February and June, the two driest months of the year (Dale, 1959).

2) Diverse monthly dry spell distributions are noticed at the west coast. As such, the dry spell distribution pattern of the northwestern sector of the peninsula is different than the one of Setiawan. On the other hand, these two dry spell distribution patterns are somewhat different than the ones further to the south.

3) A dry spell pattern for the central part of the peninsula may be defined.
4) Major differences in the dry spell distribution of neighboring stations were reported in Dale (1959a). However, the results of the present study do not show such discrepancies (in the dry spell distribution of closer stations). This should be attributable to the fact that: (a) all stations analyzed in this investigation are affected by similar inter-annual variability, and (b) to the homogeneity induced by the global warming (that has taken place in the last forty years).
5) Practically all year around, Kuala Lumpur represents the area where the largest number of rain-days greater than 25 mm is observed.
6) The monthly distribution of rain-days follows quite closely the monthly rainfall distribution (Dale, 1959a). This investigation shows that with the exception of the last two months of the year, the monthly distribution of rain-days greater than 25 mm is substantially different than the monthly rainfall distribution.

Acknowledgments: This investigation was supported by an IRPA grant. The authors gratefully acknowledge this support. Our thanks are extended to the Malaysian Meteorological Service for providing us the necessary data to carry out this investigation. Comments made by anonymous reviewers helped to improve this manuscript in a considerable manner.

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