Trends in Peninsular Malaysia Rainfall Data During the Southwest Monsoon and Northeast Monsoon Seasons: 1975–2004

(Trend Hujan di Semenanjung Malaysia Ketika Monsun Barat Daya
dan Monsun Timur Laut: 1975–2004)

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ABSTRACT

This study investigated the spatial pattern and trends of the daily rainfall data in Peninsular Malaysia based on seasonal rainfall indices. Five rainfall indices which describe the main characteristics of rainfall, the total amount of rainfall, frequency of wet days, rainfall intensity, extreme frequency, and extreme intensity, were employed in this study. The statistics of rainfall indices were calculated in terms of their means for four regions in Peninsular Malaysia for the period 1975 to 2004. The findings indicate that the southwest monsoon had the greatest impact on the western part of the Peninsula, particularly in characterizing the rainfall pattern of the northwest region. During this season, the northwest region could be considered as the wettest region since all rainfall indices tested are higher than in other regions of the Peninsula. Otherwise, the northwest region is denoted as the driest part of the Peninsula during the northeast monsoon period. The northwest region is less influenced by the northeast monsoon because of the existence of the Titiwangsa Range, which blocks the region from receiving heavy rainfall. On the other hand, it is found that the lowlands areas such as the eastern part of the Peninsula are strongly characterized by the northeast monsoonal flow. Based on the results of the Mann-Kendall test, as the trend of the total amount of rainfall and the frequency of wet days during the southwest monsoon decrease at most of the stations, the rainfall intensity increases. In contrast, increasing trends in both the total amount of rainfall and the frequency of wet days were observed at several stations during the northeast monsoon, which give rise to the increasing trend of rainfall intensity. The results for both seasons indicate that there are significantly decreasing trends in the frequency of wet days during the extreme events for most of the stations on the peninsula. However, a smaller number of significant trends was found for extreme intensity.

Keywords: Extreme indices; frequency of wet days; Mann-Kendall test; rainfall intensity, total amount of rainfall

ABSTRAK

Kajian ini bertujuan menyelidiki pola taburan dan trend hujan di Semenanjung Malaysia berdasarkan indeks hujan mengikut musim. Lima indeks hujan yang menerangkan perlakuan hujan, amaun hujan, frekuensi hari basah, kelebatan hujan, frekuensi hari basah ekstrim dan frekuensi kelebatan ekstrim digunakan dalam kajian ini. Statistik indeks hujan dihitung berdasarkan nilai purata untuk empat rantau di Semenanjung Malaysia bagi tahun 1975 hingga 2004. Hasil kajian mendapati bahawa monsun barat daya mempunyai pengaruh yang besar dalam mempengaruhi pola taburan hujan di bahagian barat Semenanjung terutamanya rantau Barat Laut. Ketika monsun barat daya, rantau Barat Laut merupakan rantau yang paling basah kerana kesemua indeks kajian di rantau ini adalah lebih tinggi dari rantau lain di Semenanjung Malaysia. Sebaliknya, rantau Barat Laut merupakan rantau yang paling kering di Semenanjung Malaysia ketika monsun timur laut. Rantau Barat Laut kurang dipengaruhi oleh angin monsun timur laut disebabkan kehadiran Banjaran Titiwangsa yang menghalang rantau tersebut dari menerima hujan lebat. Di samping itu, keputusan turut mendapati bahawa kawasan kaki bukit di Timur Semenanjung lebih dipengaruhi oleh monsun timur laut. Berdasarkan keputusan ujian Mann-Kendall, trend amaun hujan dan hari basah di kebanyakan stesen didapati menurun ketika monsun barat daya seiring dengan peningkatan kelebatan hujan. Berlainan pula ketika monsun timur laut, di mana trend menaik diperolehi bagi indeks amaun hujan dan frekuensi hari basah di beberapa stesen, yang turut menyebabkan peningkatan trend kelebatan hujan. Keputusan kedua-dua monsun juga menunjukkan penurunan trend secara signifikan berlaku bagi indeks frekuensi hari basah ekstrim di kebanyakan stesen di Semenanjung. Walau bagaimanapun, hanya bilangan kecil trend signifikan diperolehi bagi kelebatan melampau.

Kata kunci: Amaun hujan; frekuensi hari basah; indeks ekstrim; kelebatan hujan; ujian Mann-Kendall

INTRODUCTION

Studies on rainfall behaviour have attracted a lot of attention from scientists throughout the world. Previous studies have been carried out to investigate the changes in rainfall pattern temporally and spatially. Some findings indicate significant positive trends in rainfall such as the analyses in the United States of America (Karl & Knight 1998), central Argentina (Lucero & Rozas 2002), northern and central Italy (Brunetti et al. 2000, 2001) and the central region of Australia (Gallant et al. 2007). In addition, a decrease in rainfall can also be found in some parts of the world such as in Nigeria (Hess et al. 1995), northern China (Gong et al. 2004), Kenya (Kipkorir 2002) and Sicily (Cannarozzo et al. 2006).

The annual rainfall was found to decrease in the Southeast Asia region between 1961 and 1998 and the number of rainy days has decreased significantly throughout most of the countries of Southeast Asia (Manton et al. 2001). In addition, the annual and monsoon rainfall data of the Ganga basin in India during the period 1901 to 1989 also showed a decreasing trend (Kothyari & Singh 1996). Recent studies conducted in the central mountainous region of Sri Lanka indicated that the annual rainfall decreased between 1964 and 1993 and the highest decrease in rainfall was recorded in March–April (Herath & Ratnayake 2004). Meanwhile the number of rainy days in this region has also decreased, giving rise to an increasing trend in rainfall intensity.

In recent years, several extreme and drought events have been reported in Malaysia. For example, an extreme rainfall event from 9 to 11 December 2004 caused severe floods over the east coast of Peninsular Malaysia (Juneng et al. 2007). In addition, due to the cold surges of the northeast monsoon, abnormally heavy rainfall occurred in the southern part of Peninsular Malaysia for several days in late December 2006 and in the middle of January 2007, causing massive floods in the region (Malaysian Met. Department 2006, 2007). Referring to Tangang et al. (2008), the influences from the Borneo vortex, the Madden-Julian Oscillation, and the Indian Ocean Dipole also play an important role in contributing to the massive floods during those periods. On the other hand, Malaysia also experienced numerous drought occurrences with the most significance one in the 1997/98 El Niño, which had an extensive impact on the environment and social activities across the whole nation. Some parts of the nation were threatened by extensive wild forest fire due to prolonged dry weather conditions. These events have raised concern in researches on the behaviour of daily rainfall such as the frequency of wet days, the mean intensity of rain during wet days, the mean amount for extreme events, and the mean lengths of wet and dry spells, which have gradually changed over the years, possibly due to global climatic change.

This present study intends to provide a trend analysis of the behaviour of seasonal rainfall in Peninsular Malaysia over the past 30 years. This includes giving details of the spatial description of several rainfall indices such as the total amount of rainfall, frequency of wet days, rainfall intensity, and the extreme indices that have been considered in the study.

MATERIALS AND METHODS

The climate of Peninsular Malaysia is described by four seasons, namely two monsoon seasons and two inter-monsoon seasons. In this study, the southwest monsoon (SWM) season occurs from May to August while the northeast monsoon (NEM) season from November to February. During the NEM, the exposed areas on the eastern part of the Peninsula receive heavy rainfall. On the other hand, the areas which are sheltered by the mountain ranges (the Titiwangsa Range) are more or less free from its influence. The period of the SWM is a drier period for the whole country, particularly for the other states of the west coast of the Peninsula. In contrast, the two inter-monsoon seasons often result in heavy rainfall that usually occurs in the form of convective rains. During these seasons, the west coast is generally wetter than the east coast.

The daily rainfall data from 30 rain gauge stations which have been classified into four regions, namely northwest, west, southwest, and east over Peninsular Malaysia were obtained from the Malaysian Meteorology Department and Drainage and Irrigation Department for the period 1975 to 2004. A list of the stations is given in Table 1 and the locations of the stations are mapped onto Figure 1.
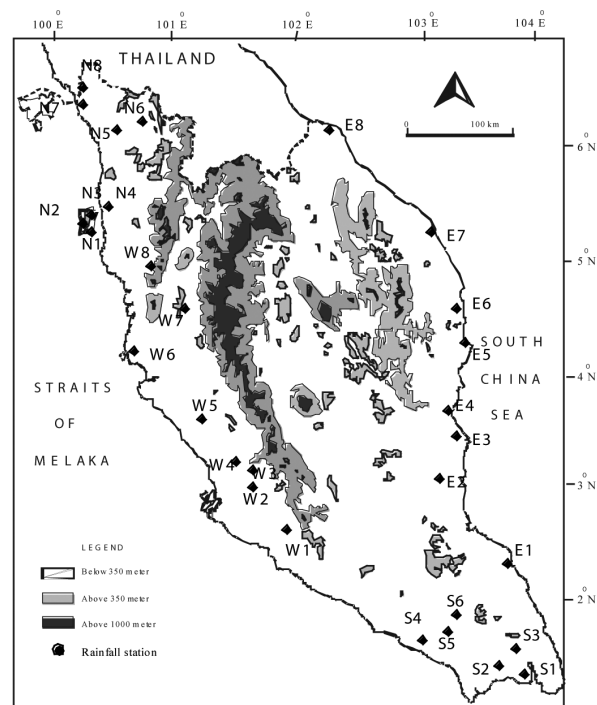

FIGURE 1.   Physical map indicating the thirty selected rainfall stations in Peninsular Malaysia

TABLE 1. List of the thirty stations according to the four regions

Code	Stations	Latitude	Longitude
	Southwest		
S1	Stor JPS Johor Bahru	1° 28′ N	103° 45′ E
S2	Senai	1° 37′ N	103° 40′ E
S3	Sek. Men. Bkt. Besar di Kota Tinggi	1° 45′ N	103° 43′ E
S4	Sek. Men. Ingg. Batu Pahat	1° 52′ N	102° 58′ E
S5	Pintu Kawalan Sembrong	1° 52′ N	103° 02′ E
S6	Kluang	2° 01′ N	103° 19′ E
	East		
E1	Mersing	2° 27′ N	103° 49′ E
E2	Bkt. Ibam	3° 10′ N	102° 58′ E
E3	Rumah Pam Pahang Tua, Pekan	3° 33′ N	103° 21′ E
E4	Kuantan	3° 46′ N	103° 13′ E
E5	JPS Kemaman	4° 13′ N	103° 25′ E
E6	Sek. Men Sultan Omar, Dungun	4° 45′ N	103° 25′ E
E7	Stor JPS, Kuala Trengganu	5° 19′ N	103° 07′ E
E8	Kota Bharu	6° 17′ N	102° 16′ E
	West		
W1	Setor JPS Sikamat Seremban	2° 44′ N	101° 57′ E
W2	Pusat Penyelidikan JPS Ampang	3° 09′ N	101° 45′ E
W3	Empangan Genting Kelang	3° 14′ N	101° 45′ E
W4	Gombak	3° 16′ N	101° 43′ E
W5	Rumah Pam JPS Bagan Terap	3° 43′ N	101° 04′ E
W6	Sitiawan	4° 13′ N	100° 42′ E
W7	Ipoh	4° 34′ N	101° 05′ E
W8	Pusat Kesihatan Bt. Kurau	4° 58′ N	100° 47′ E
	Northwest		
N1	Bayan Lepas	5° 17′ N	100° 16′ E
N2	Kolam Takongan Air Itam	5° 24′ N	100° 16′ E
N3	Klinik Bkt. Bendera	5° 25′ N	100° 16′ E
N4	Rumah Pam Bumbong Lima	5° 33′ N	100° 26′ E
N5	Alor Star	6° 12′ N	100° 24′ E
N6	Ampang Pedu	6° 14′ N	100° 46′ E
N7	Padang Katong Kangar	6° 27′ N	100° 11′ E
N8	Abi Kg. Bahru	6° 30′ N	100° 10′ E

DATA QUALITY

The homogeneity of the rainfall series in this study was checked by using the four approaches of Wijngaard et al. (2003). The standard normal homogeneity test, Buishand range test, Pettitt test, and Von Neumann ratio test are the four homogeneity tests that were applied. The data series from thirty stations that were used in this study were found to be homogeneous. Another important aspect of data quality is the completeness of the data series. The percentage of missing values was found to be less than 10% for the period 1975 to 2004. These missing values in the data series were estimated using various types of weighting methods such as the inverse distance, normal ratio, correlation, and several revised weighting methods (Eischeid et al. 2000; Teegavarapu & Chandramouli 2005; Suhaila et al. 2008).

RAINFALL INDICES

Indices used in this study as shown in Table 2 were designed to capture changes in a variety of aspects of the rainfall distribution. In this present study, a wet day is defined as a day with at least 1 mm of rainfall. This study used the 95th percentile threshold as in the studies of Haylock and Nicholls (2000), Manton et al. (2001) and Schmidli and Frei (2005) to represent the extreme events. The 95th percentile threshold represents long-term conditions and was determined from the base period 1975 to 2004. For example, if we have 365 days in a year then above 95th percentile corresponds to the 18th highest amount of rainfall on an annual time scale. Two indices of extreme rainfall were calculated for each year in the period during the SWM and NEM seasons. The number of events above the long-term 95th percentile is referred to as the extreme frequency while the intensity of rain falling in the highest intensity events is referred to as the extreme intensity.

TABLE 2. Rainfall indices

Description	Index Name
Total amount of rainfall	TAR
Frequency of wet days with at least 1mm of rain	FREQ
Mean rainfall amount on wet days or rainfall intensity	RI
Frequency of wet days exceeding the 95th percentile	XFREQ
Rainfall intensity exceeding the 95th percentile	XI

MANN-KENDALL TEST

The nonparametric Mann-Kendall (MK) statistical test, also called Kendall's tau test (Mann 1945; Kendall 1975), has been applied in many studies to identify whether monotonic trends exist in hydro-meteorological data such as temperature, rainfall and streamflow. This test is often used because of its property that no assumptions are needed about the data that need to be tested. In the trend test, the null hypothesis H_o is that there is no trend in the population from which the dataset is drawn and the sample of data $\{x_j, j = 1, 2, \ldots, n\}$ is independent and identically distributed. The alternative hypothesis H_1 is that a trend exists in the dataset. The test statistic, Kendall's S, is defined as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{Sign}\left(x_j - x_k\right), \qquad (1)$$

where x_j and x_k are the sequential data values, n is the length of the dataset, and

$$\text{Sign}(x) = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases} \qquad (2)$$

Under the null hypothesis, the statistic S is approximately normally distributed when $n \geq 8$ with zero mean and the variance is given as follows:

$$\text{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{t} t(t-1)(2t+5)}{18}, \qquad (3)$$

where t is the extent of any given tie and $\sum_{t}$ denotes the summation over all ties.

The standardized test statistic Z is computed by

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\text{Var}(S)}} & \text{for } S > 0 \\ 0 & \text{for } S = 0 \\ \dfrac{S+1}{\sqrt{\text{Var}(S)}} & \text{for } S < 0 \end{cases} \qquad (4)$$

It follows a standard normal distribution, . In a two sided test for trend, H_o should be accepted if $|Z| \leq 1.645$ at the 0.10 level of significance. A positive Z value indicates an upward trend, whereas a negative one indicates a downward trend.

RESULTS AND DISCUSSION

The two following sections will discuss the results for spatial patterns and trends of seasonal rainfall indices.

SOUTHWEST MONSOON (SWM)

Spatial pattern of mean values Figure 2(a) depicts the spatial distribution of the average amounts of SWM rainfall recorded during the period 1975 to 2004. A large TAR index during the SWM can be seen over the northwestern areas. The largest TAR is recorded at the N3 station with nearly 1000 mm, while the rest of the stations in the northwestern areas recorded amounts between 550 mm and 950 mm. The lowest TAR index, which is between 350 mm and 550 mm, is found at five stations in the eastern areas and three stations in the western areas. An average of between 550 mm and 750 mm is recorded at the rest of the stations. On average, the occurrence of rainfall in Peninsular Malaysia during the SWM as depicted in Figure 2(b) is between 46 and 54 rainy days per year. Large FREQ indices are observed in the southwestern and northwestern areas and at a few stations in western areas, with the largest at the W8 and N3 stations. However, most stations in the eastern part of the Peninsula have less than 38 rainy days per year.

In terms of RI index, most stations in the east, west, and southwest have less than 15 mm/day, while from 15 to 18 mm/day is observed at a few stations located at a latitude between 4° 30′ and 5° 35′ N in the north of the western areas as shown in Figure 2(c). Again the largest RI index is observed at the N3 station in the northwestern area. The W5 station is the only station that recorded an RI index of less than 12 mm/day. Based on Figure 2(d), the study again found that the largest XFREQ index is recorded by stations in the northwestern areas followed by a few stations in the western and southwestern areas. A smaller XFREQ index is observed at the stations along the eastern coast of Peninsular Malaysia. Figure 2(e) indicates that the largest XI index, which is between 75 and 85 mm/day, is found at two stations in the northwestern areas, namely the N1 station and the N3 station. The lowest XI index is observed at most of the stations in the eastern areas with an intensity of between 45 and 55 mm/day. Based on these results, it can be said that the stations in the northwestern areas can most likely be considered the wettest areas during the SWM period since all rainfall indices at these stations tend to be higher than those at the other stations,
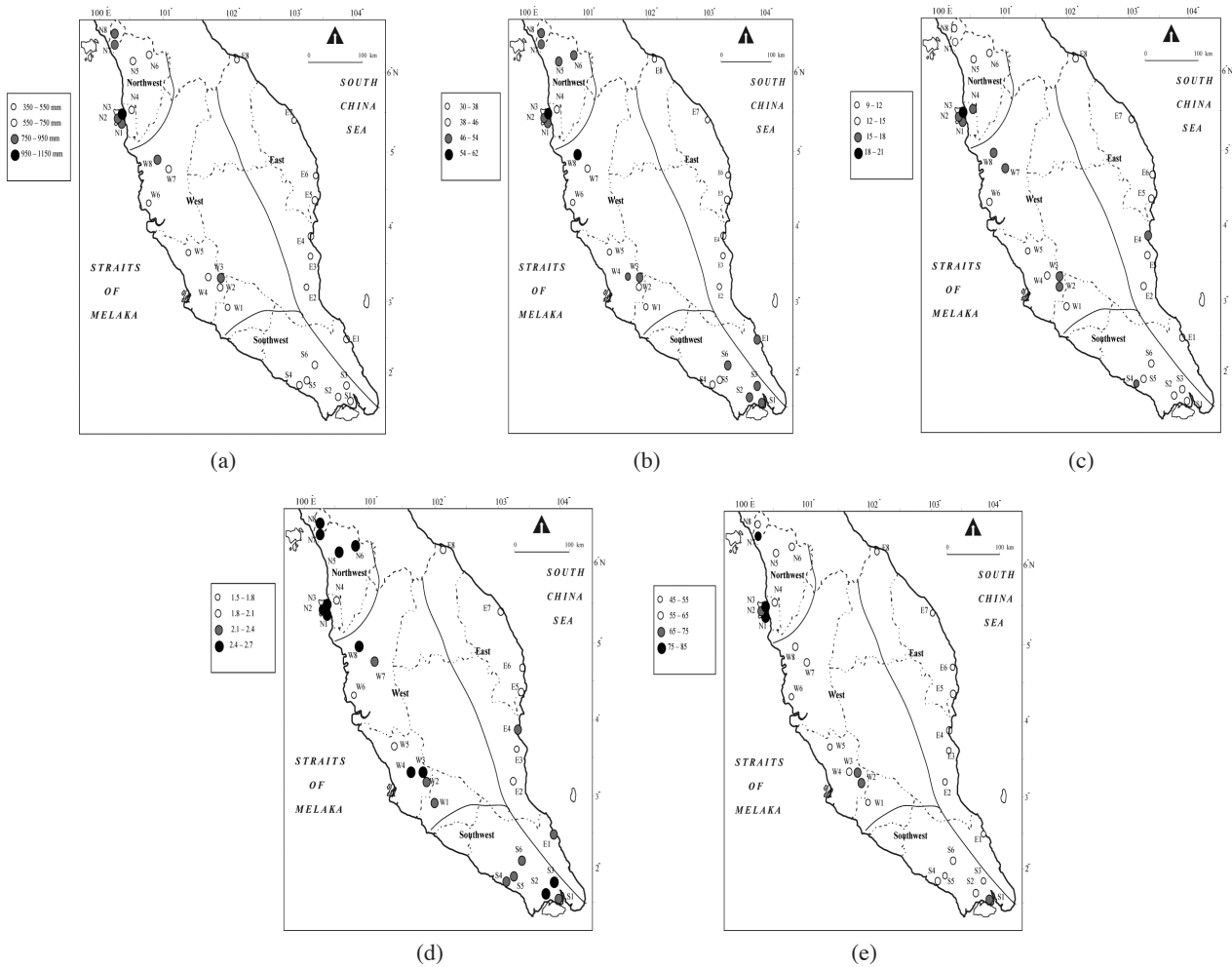
FIGURE 2. Spatial distributions of southwest monsoon rainfall indices: (a) TAR, (b) FREQ, (c) RI, (d) XFREQ, (e) XI

particularly in the eastern areas. Conversely, the eastern areas can be regarded as the driest during the SWM period. The presence of mountain ranges separating the eastern and western parts of the Peninsula could be the best reason explaining the differences between the averages of the rainfall indices of each region.

Changes During The Southwest Monsoon (SWM) Season
Figures 3(a) to 3(e) depict the trends of the TAR, FREQ, RI, XFREQ, and XI indices for the SWM season. The results of the MK test indicated that no significant trends in the TAR index were observed for almost all stations over the Peninsula. However, more than half of the stations indicated a decreasing trend in the TAR index during the SWM season, particularly in the eastern and southwestern areas, although it is not statistically significant. In addition, only the N8 station exhibits a significant declining trend of the TAR index, while the W3 station is the only station with a significant positive trend of the TAR index. In terms of the FREQ index, the SWM season showed a very clear decreasing trend for all stations over the eastern, western, and northwestern parts of the Peninsula. Almost all the stations in the northwestern areas, except the N5 and N8

stations, have statistically significant decreasing trends. A few significant decreasing trends in the FREQ index are also observed at the S4, S5, and S6 stations in the southwestern areas as well as at the E2 and E5 stations in the eastern areas. However, no indications of significant trends in the FREQ index were detected in the western areas.

The stations at latitudes between 2.70° and 3.30° N in the western areas as shown in Figure 3(c) indicated significant increasing trends in the RI index. In addition, the E2 and N4 stations also exhibit a significantly increasing trend in the RI index. Based on this figure, it can be said that no significant trends in the RI index were observed in the southwestern areas. In addition, there were also no significant decreasing trends in the RI index in any of the regions during this season. Combining these results with the previous results on the TAR and FREQ indices, it can be summarized that while both TAR and FREQ indices have decreased, the RI index has increased insignificantly at most of the stations.

XFREQ, which measures the frequency of wet days that exceed the 95th percentile, shows a significant decline in all regions during the SWM season. These significant negative trends in the XFREQ index have been observed in 11 stations
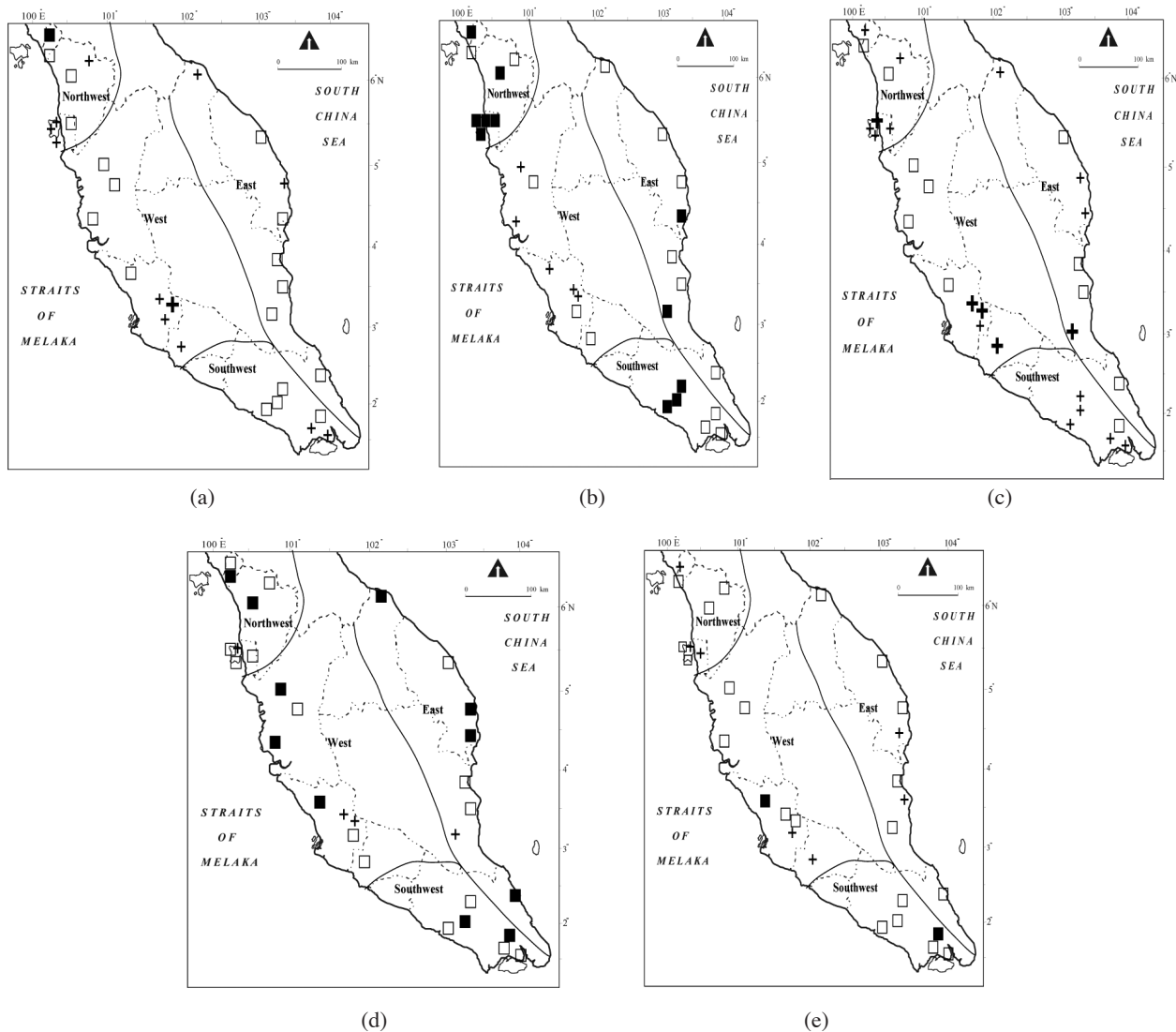
FIGURE 3. Trends in southwest monsoon rainfall indices: (a) TAR, (b) FREQ, (c) RI, (d) XFREQ (e) XI (□) negative trend, (■) significant negative trend, (＋) positive trend, and (✚) significant positive trend

over the regions. More significant trends were observed in the eastern areas compared to those in the other three areas. In the case of the XI index, decreasing trends can also be seen scattered throughout the region. However, only the S3 and the W5 stations exhibited a significantly declining trend in the XI index.

NORTHEAST MONSOON (NEM)

Spatial Pattern of Mean Values In general, the average TAR index is found to be higher during the NEM season than during the SWM season. As mentioned earlier, the coast that is exposed to the NEM flow tends to be wetter than that exposed to the SWM. As shown in Figure 4(a), the highest TAR index, which ranges between 1200 and 1500 mm, is observed in the eastern areas, while stations in the southwestern and western areas recorded between 600 and 900 mm during the NEM season. The lowest TAR index, ranging between 300 and 600 mm, was recorded

at all the northwestern stations. Between 50 and 60 rainy days are observed during the NEM at the eastern stations as shown in Figure 4(b). The values of the FREQ index tended to decrease with increases in latitude in the upper north of the western peninsula, where only 20 to 30 rainy days were observed during this season. As shown in Figure 4(c), more rainfall intense can be seen over the eastern areas compared to the other three areas. For instance, RI indices of a minimum of 17 mm/day at the E2 station and of 28 mm/day at the E8 station were observed over the eastern areas, while RI indices of less than 17 mm/day were observed in the western and the northwestern areas. Smaller XFREQ indices are also found in the northwestern areas as depicted in Figure 4(d), with an average of less than two rainy days per year. Similar patterns can be seen for the XI index in Figure 4(e). The largest rainfall intensity during the extreme event is observed in the eastern areas, with an average of between 135 and 165
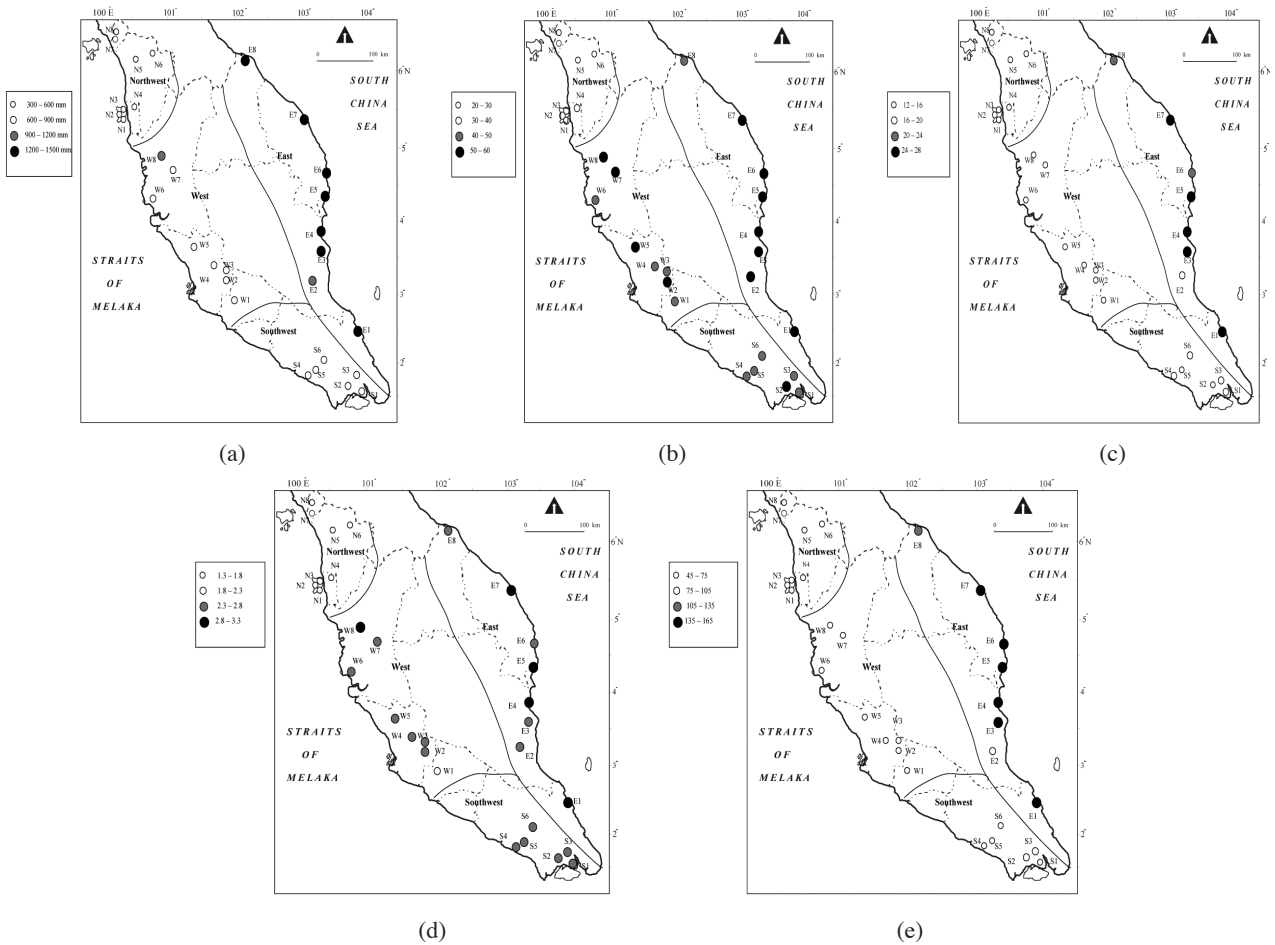
FIGURE 4. Spatial distributions of northeast monsoon rainfall indices: (a) TAR, (b) FREQ,
(c) RI, (d) XFREQ, (e) XI

mm/day compared to 45 and 75 mm/day recorded by most of the stations in the other three areas.

In general, the rainfall patterns for the stations in the eastern areas are strongly influenced by the NEM, while there is a lesser impact at stations in the western part of Peninsular Malaysia, especially those in the northwestern areas. This probably occurs because the northeasterly winds, which are known to bring heavy rainfall, are blocked by the Titiwangsa Range, which possibly affects most of the stations along the western part of the Peninsula. Therefore, the eastern part of the Peninsula is considered the wettest area during the NEM season.

Changes During the Northeast Monsoon (NEM) Season
In contrast with the SWM season as discussed earlier, the NEM season showed an increasing trend in the TAR index for most of the stations. From Figure 5(a) it can be seen that stations E2 and E4 in the eastern areas, W2 and W5 in the western areas, and N4 and N5 in the northwestern areas are the six stations that indicate a positive significant trend in the TAR index. Meanwhile, no significant decreasing trend is found in any of the areas and none of the stations in the southwestern areas has a statistically significant trend during the NEM season.

Figure 5(b) depicts the trend of the FREQ index at all 30 stations during the NEM season. A large number of positive trends was observed. However, only four stations in the western areas have positive significant trends for the FREQ index; they are followed by two stations in the eastern areas and one station in the southwestern areas. No significant trends in the FREQ index were observed in the northwestern areas. In general, more positive than negative trends in the RI index are observed in all regions during the NEM season, as shown in Figure 5(c). However, only four stations, one each from every region, show significant positive trends. In addition, a significant decreasing trend in the RI index can be seen only at the S6 station. An increase in the TAR and FREQ indices during the NEM season could also possibly give rise to the RI index for most of the stations.

Figures 5(d) and 5(e) map the results of trends in the extreme indices. The MK test showed a significantly decreasing trend in the XFREQ index at 11 stations throughout the region. But in the case of the XI index, the results indicate both decreasing and increasing non-significant trends for most of the stations. One station each from the northwestern, eastern, and southwestern areas

indicates a significant decreasing trend in the XI index while a significant increasing trend is found at the W4 station.

The results shown in Figure 5 indicate that during the NEM period most of the stations are mainly characterized by significantly decreasing trends in the XFREQ index. Similar conclusions are reached as for the SWM period.

CONCLUSION

Seasonal variations and trends have been assessed using five selected rainfall indices of four regions in Peninsular Malaysia for the period 1975 to 2004. The statistics of rainfall indices which measure the mean in each season gave a clear indication in distinguishing the regions. In terms of the total amount of rainfall, frequency of wet days, rainfall intensity, and extreme indices, the highest mean was found in the northwestern areas during the SWM season. In contrast, the NEM has the greatest impact in characterizing the rainfall patterns for

stations in the eastern areas, and less so in the western part of the Peninsula, especially the northwestern areas. The existence of the Titiwangsa Range, which blocks the northeasterly winds, could be one of the possible influences on the rainfall patterns for most of the stations along the western part of the Peninsula.

The analysis of a 30 year record from 30 rain gauges showed that, in general, significant trends in five rainfall indices were observed at several stations. The total amount of rainfall was found to have decreased insignificantly at most of the stations during the SWM period. However, a significantly decreasing trend in the frequency of wet days was observed at most of the stations in the northwestern, eastern and southwestern areas. In contrast, an increasing trend in the total amount of rainfall was detected during the NEM season, with a total of six stations indicating significant trends. Besides, the frequency of wet days was also observed to have increased significantly at a few stations especially in the eastern and western regions.
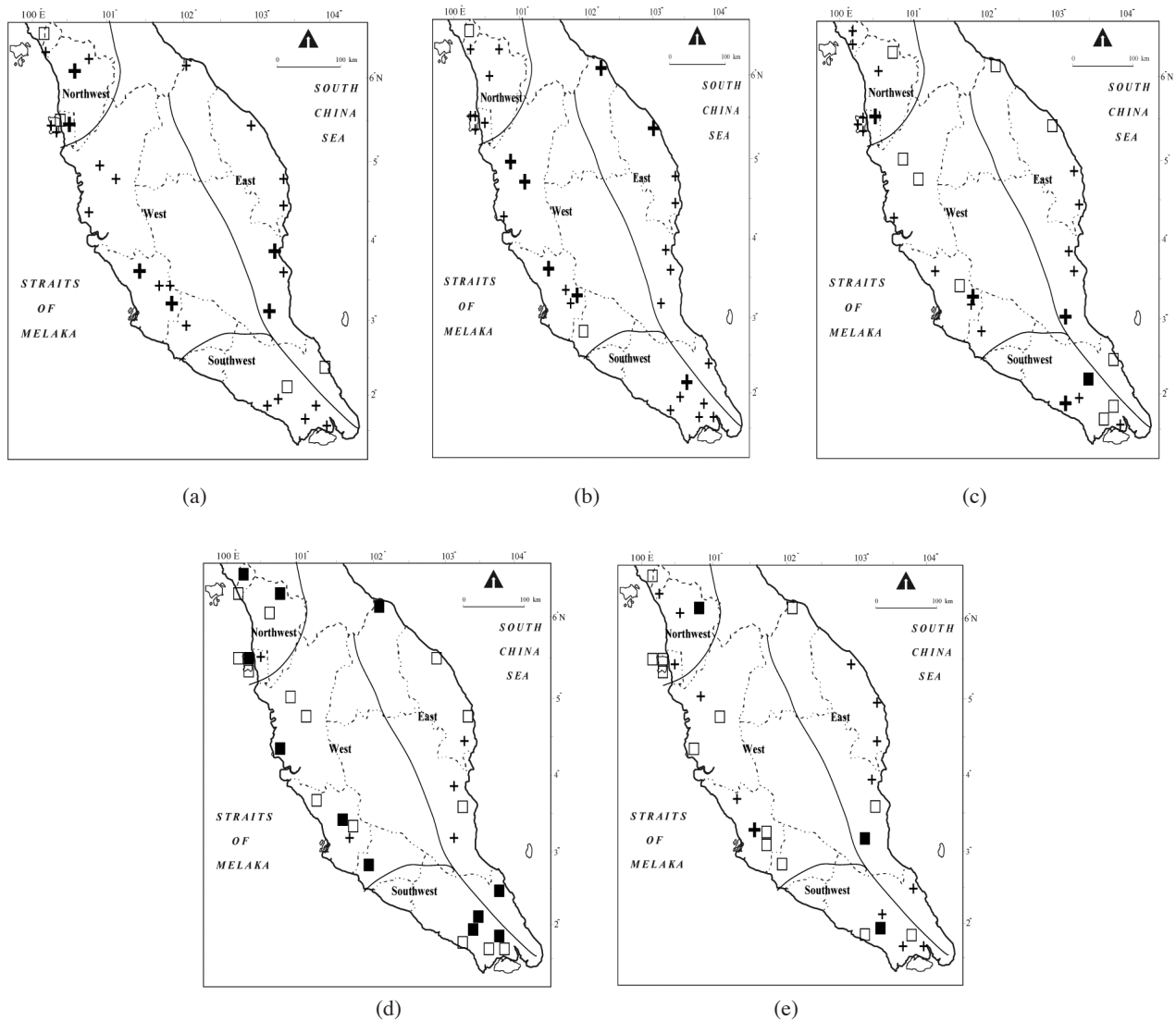

FIGURE 5. Trends in northeast monsoon rainfall indices: (a) TAR, (b) FREQ, (c) RI, (d) XFREQ, (e) XI
(□) negative trend, (■) significant negative trend, (+) positive trend, and (**+**) significant positive trend

However in terms of rainfall intensity, both seasons showed significant increasing trends at a few stations scattered across the region despite the different results obtained. For extreme rainfall indices, large numbers of significant decreasing trends in extreme frequency were observed over the Peninsula for both seasons, but a smaller number of significant trends in extreme intensity was observed.

The trends found in this study were somehow consistent with the findings of the recent study by Manton et al. (2001) regarding the extreme frequency of wet days. The study by Manton et al. (2001), which covered the period 1961-98, found that there was a significant decrease in the frequency of wet days at extreme percentiles and no other significant trends in the indices of extreme rainfall considered. In their study the 99th percentile was used to represent extreme rainfall but in this study the 95th percentile was chosen to indicate extreme rainfall. However, the different percentiles gave the same results and we could conclude that the significant decreasing trend in extreme frequency has been observed since the 1960s and that the trends seem to have continued with the new dataset. The annual pattern of extreme frequency seems to be influenced by both seasons which show decreasing trends.

The decrease in extreme rainfall indices at most stations will reduce the risk of floods. However, a decrease in the total amount of rainfall and the frequency of wet days during the SWM season could also create problems for the agriculture, forestry and energy sectors, public health and water resources. Therefore, the government should take precautionary measures to make the public aware of the changes in climatic events. The findings from this present study can provide some information to the government on water management and for predicting future climatic events. Nevertheless, further studies should be conducted to consider more characteristics of rainfall occurrences, amounts, and extremes as well as other climate variables. The results also suggest the need for further analyses such as bootstrap and permutation tests, which should be conducted in order to verify whether the significant trends found among nearby stations occurred by chance. Additionally, these could be used to identify whether that particular region has field significant trends.

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