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Trends of Wet Spells over Peninsular Malaysia during Monsoon Seasons
(Trend Rentetan Hari Basah bagi Semenanjung Malaysia pada Musim Monsun)

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ABSTRACT

This study attempts to trace changes in the wet spells over Peninsular Malaysia based on the daily rainfall data from 32 selected rainfall stations which include four sub-regions; northwest, west, south and east, for the period of 1975 to 2004. Six wet spells indices comprising of the main characteristics (maximum, mean, standard deviation), the persistency of two consecutive wet days and the frequency of the short and long duration of wet spells will be used to identify whether or not these indices increase or decrease over Peninsular Malaysia during the monsoon seasons. The study indicates that the eastern areas of the peninsula could be considered as the wettest areas since almost all the indices of wet spells over these areas are higher than over the other regions during the northeast monsoon (NE). The Mann-Kendall (MK) trend test revealed that almost all of the stations located in the eastern areas of the peninsula exhibited a positive trend in the mean, variability and persistency of wet spells indices during the NE monsoon, while a negative trend was observed during the southwest monsoon (SW) in these areas. Moreover, these indices showed a positive trend and at the same time a decreasing trend was observed in the frequency of the long wet spells in most stations located over the west coast of Peninsular Malaysia during the SW monsoon for the period of 1975 to 2004.

Keywords: Mann-Kendall trend test; wet spells; persistency; indices

ABSTRAK

Kajian ini bertujuan menjejaki perubahan rentetan basah di dalam hujan harian bagi Semenanjung Malaysia berdasarkan data pemerhatian dari 32 buah stesen hujan yang merangkumi empat kawasan; barat laut, barat, selatan dan timur untuk tahun 1975 hingga 2004. Terdapat enam indeks rentetan basah yang terdiri dari rentetan yang paling maksima, purata, sisihan piawai, keberterusan hujan bagi dua hari berturut-turut serta frekuensi rentetan basah untuk tempoh jangka pendek dan jangka panjang akan digunakan di dalam menentukan sama ada indeks ini menunjukkan tren positif ataupun negatif bagi Semananjung Malaysia pada musim monsun Timur Laut dan Barat Daya. Hasil kajian mendapati kawasan di sebelah timur semenanjung adalah yang paling basah di mana hampir semua indeks rentetan basah bagi kawasan ini menunjukkan nilai yang lebih tinggi dari kawasan lain pada musim monsun Timur Laut. Ujian tren Mann-Kendall (MK) pula mendapati bahawa hampir kesemua stesen hujan di sebelah timur semenanjung menunjukkan tren positif bagi indeks purata, sisihan piawai dan keberterusan rentetan basah pada monsun Timur Laut, sementara itu, indeks tersebut menunjukkan tren negatif pada monsun Barat Daya di kawasan ini. Seterusnya, indeks-indeks tersebut menunjukkan tren menaik dan pada masa yang sama, tren menurun bagi frekuensi tempoh jangka panjang rentetan basah diperhatikan di kebanyakan kawasan di pantai barat Semenanjung Malaysia pada monsun Barat Daya untuk tahun 1975 hingga 2004.

Kata kunci: Ujian tren Mann-Kendall; rentetan basah; keberterusan; indeks

INTRODUCTION

With the development in industrialization as well as the rapid growth in the population, analyzing rainfall characteristics particularly on tracing the trends of wet spells is one of the important components in managing water resources not only in Malaysia but also everywhere in the world. Various types of rainfall indices have been used by previous researchers in determining the trends of climatic events. For example, Schmidli & Frei (2005) examined the trends of heavy precipitation and wet and dry spells in Switzerland using fourteen rainfall indices which included the mean dry (wet) day persistence, the maximum number of consecutive dry (wet) days and the mean dry (wet) spells length. Bai et al. (2007) studied the annual number of wet spells, annual precipitation amount and the mean daily precipitation in a wet spells in China for the period of 1951 to 2003. In addition, several studies have emphasized on the long dry (wet) spells since these variables greatly influenced agriculture and drought (Lana et al. 2003; Anagnostopoulou et al. 2003; Burgueno et al. 2005; Gong et al. 2004, 2005; Tolika & Maheras 2005; Cislaghi et al. 2005; Serra et al. 2006; Su et al. 2006; Seleshi & Camberlin 2006).

According to the Intergovernmental Panel on Climate Change (IPCC) (2007), it is very likely that hot extreme heat waves and heavy precipitation events become more frequent. Similarly, IPCC (2001) also reported that the overall global land precipitation has increased about 2% since the beginning of the 20th century. Karl & Knight (1998) reported that the number of rainy days has increased by 6% during the 20th century in the United States (USA). Meanwhile, there have been other studies that supported the findings of IPCC (2001) (Easterling et al. 2000; New et al. 2001; Groisman et al. 2005). The variations in meteorological droughts and wet spells during the period of 1900 to 1995 using the Palmer Drought Severity Index (PDSI) were conducted by Dai et al. (1998). They reported that excessive wetness and drought have increased in many parts of land areas such as the USA, mid-latitude Canada, Europe and South East (S.E.) Australia. However, Manton et al. (2001) reported that the number of rainy days had decreased significantly throughout Southeast Asia. In addition, Brunetti et al. (2004) reported that the number of wet days has shown a decreasing trend all over Italy for the last 120 years. Gong et al. (2004) reported that a negative trend was found in the frequency of long wet spells (≥ 3 days) with a linear trend of -5.6% per decade, whereas the occurrence of long dry spells showed an increasing trend at a rate of 7.2% per decade.

Identifying changes in the trend of wet spells characteristics as well as the persistency will provide useful information in predicting future climatic events since these variables are closely related to extreme weather events such as floods and landslides. Most recently, the widespread flooding which occurred in the southern areas of Peninsular Malaysia from mid December 2006 to late January 2007 caused by the extreme rainfall and prolonged intense wet spells contributed to around USD 500 million losses to the country. Tangang et al. (2008) indicated that three extreme precipitation episodes led to floods that occurred during 17-20 December 2006, 24-28 December 2006 and 11-14 January 2007. They had reported that the occurrence of these three episodes were associated with the strong northeast cold surge, the absence of Borneo vortex and the influence of eastward propagating Madden-Julian-Oscillation (MJO) disturbances. Moreover, landslides which occurred due to the prolonged heavy rain spells also contributed to a disaster to the country. Thus, particular attention should be paid to further investigate the changes in the various types of rainfall indices in the climatic events specifically in the characteristics of wet spells because of their tremendous impact on the economy, society and environment.

Previous studies found that there was a shift in the El Nino/Southern Oscillation (ENSO) on both the atmosphere and oceans that occurred in the mid 1970s (Ye & Hsieh 2006; Zhang et al. 1997; An & Wang 2000). Thus, this present study is aimed to trace changes in the rainfall characteristics particularly on the sequences of wet days which include the frequency of various lengths of wet spells, the persistency, the maximum duration, the mean length and the variability over Peninsular Malaysia for the period of 1975 to 2004. The analysis of trend will be focused on the individual stations and on the regional basis for the sequences of wet days during the northeast and southwest monsoon seasons.

MATERIALS AND METHODS

Daily rainfall data for the selected 32 stations which comprise of four subregions, namely; northwest, west, south and east, over Peninsular Malaysia were obtained from the Malaysian Meteorology Department and Drainage and Irrigation Department for the period of 1975 to 2004. The data used in this present study can be considered good quality data with less than 15% missing values throughout the 30-year period. The missing values in the data series for the period of 1975 to 2004 were estimated using various types of modified weighting methods such as the inverse distance, the normal ratio and the correlation between the target and the neighboring stations (Suhaila et al. 2008; Teegavarapu & Chandramouli 2005; Sullivan & Unwin 2003; Eischeid et al. 2000). The homogeneity of the data series was checked using four types of homogeneity tests as recommended by Wijngaard et al. (2003), the standard normal homogeneity test, the Buishand range test, the Pettit test and the Von Neumann ratio test. Table 1 displays the geographical coordinates of the 32 selected rainfall stations for the period of 1975 to 2004 in Peninsular Malaysia. In addition, Figure 1 displays the physical map indicating the locations of the selected rainfall stations that will be used in the analysis.

A wet day is defined as a day with the rainfall amount of at least 0.1 mm, and the wet spells is represented as a number of consecutive wet days which is followed and preceded by a dry day. Based on the various types of the rainfall indices used by previous researchers, this present study will consider six indices for the length of wet spells characteristics including the maximum consecutive number of wet days, mean, standard deviation, the persistency of wet event, and the frequency of short and long durations of wet spells length. The maximum (MxW) represents the longest annual duration of wet days for individual stations or regions. The mean (MnW) and the standard deviation (SdW) calculate the annual mean and variability of the length of wet spells, respectively. Moreover, the persistency of two consecutive wet days (2CW), is based on the conditional probability of a wet day given that the previous day was also wet. Additionally, the frequency of the short spells (SSW) which represents the frequency of having the wet event from 1 up to 3 days consecutively, and the long spells (LSW) which represents the frequency of having the length of wet days for more than 3 days consecutively, will be considered in this present study.

Each of the indices of wet spells will be computed annually for each station before further analysis is conducted in identifying the trend for individual stations and also for the regional basis during both monsoon seasons. In order to identify the trend for regional basis, all

TABLE 1. List of the stations used in this present study

No.	Station name	Station code	Latitude	Longitude	% missing
1	Bayan Lepas	N1	5.30	100.27	0.0
2	Air Itam	N2	5.38	100.25	4.4
3	Bkt. Bendera	N3	5.42	100.27	3.9
4	Bumbong Lima	N4	5.55	100.43	3.4
5	Alor Setar	N5	6.20	100.40	0.0
6	Ampang Pedu	N6	6..23	100.77	3.8
7	Kangar	N7	6.43	100.18	3.5
8	Kg. Bahru	N8	6.50	100.17	0.3
9	Seremban	W1	2.73	101.95	5.4
10	Ampang	W2	3.15	101.91	3.5
11	G.Kelang	W3	3.23	101.75	4.3
12	Bagan Terap	W4	3.72	101.07	9.3
13	Sitiawan	W5	4.22	100.70	0.0
14	Ipoh	W6	4.57	101.10	0.0
15	Bt. Kurau	W7	4.97	100.80	8.0
16	Selama	W8	5.13	100.68	0.8
17	Johor Bharu	S1	1.47	10375	3.1
18	Senai	S2	1.63	103.67	0.0
19	Kota Tinggi	S3	1.75	103.72	4.0
20	Batu Pahat	S4	1.87	102.97	7.5
21	P.K. Sembrong	S5	1.87	103.05	3.1
22	Kluang	S6	2.02	103.32	0.0
23	Tangkak	S7	2.25	102.57	2.9
24	Melaka	S8	2.27	102.25	0.0
25	Bkt. Iban	E1	3.17	102.97	14.8
26	Pekan	E2	3.55	103.35	4.3
27	Kuantan	E3	3.78	103.22	0.0
28	JPS Kemaman	E4	4.22	103.42	7.7
29	Dungun	E5	4.75	103.42	3.5
30	Kg. Menerong	E6	4.93	103.05	4.3
31	K.Terengganu	E7	5.32	103.13	6.3
32	Kota Bharu	E8	6.17	102.28	0.0

the six indices are computed annually for each station, and then all the values are averaged according to the region in a way to get the annual regional means. The trend of the six indices of wet spells for individual stations and also for the regional basis can be traced using a non-parametric Mann-Kendall (MK) test (Kendall & Gibbons 1990). The slope of the linear trends for each of the indices is estimated using the ordinary least square method.

In the Mann-Kendall test, the indicator variable of interest, I, for each element $x_i (i = 1,...,n)$ of the series where $(i < j)$, is denoted as follows

$$I(x_i < x_j) = \begin{cases} 1 & x_i < x_j \\ 0 & \text{otherwise} \end{cases}$$

The test statistics τ is given by $\tau = \sum_{i=1}^{n} \sum_{j=i+1}^{n} I(x_i < x_j)$.

In the case where no trend exists (null hypothesis), is asymptotically normal, independently from distribution of function, and $u(\tau) = \frac{\tau - \bar{\tau}}{\sqrt{\text{var}(\tau)}}$ has the standard normal distribution, with $\bar{\tau}$ and var (τ) given by $\bar{\tau} = n(n-1)/4$ and var $(\tau) = n(n-1)(2n + 5)/72$.

In this present study, the null hypothesis will be rejected at 5% level, i.e. $|u(\tau)| > 1.96$.

Results and Discussion

MEAN SPATIAL PATTERN OF WET SPELLS

Table 2 displays the mean and the standard deviation of the annual main characteristics of the length of wet spells, the persistency of two consecutive wet days and the frequency of various lengths of wet spells for each station. It is consistent with the previous work where the eastern areas can be classified as the wettest area during the NE monsoon (Juneng et al. 2007; Dale 1960). All the wet spells indices, except the frequency of short spells, at this station are observed to be higher than those at the other stations. The

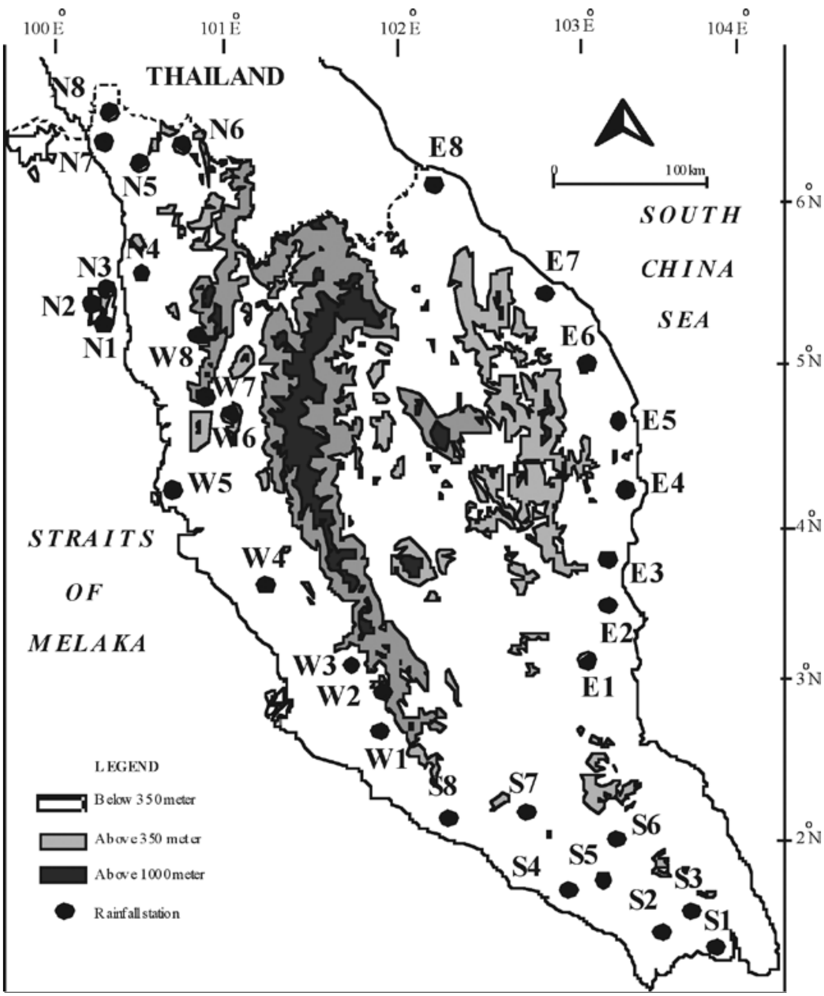

FIGURE 1. The physical map indicating the 32 selected rainfall stations in Peninsular Malaysia

annual maximum duration of wet spells is found to vary from 12 to 17 days over these areas, whereas a slightly shorter duration is observed in the other areas during the NE monsoon season, i.e. from 6 to 14 days. The results in Table 2 also indicate that the mean of the annual maximum duration of wet days during the SW monsoon is found to vary from 4 to 9 days in most stations over the Peninsula. Moreover, the mean of wet spells is found to vary from 1 to 3 days in most stations over the Peninsular during both monsoon seasons, except in the eastern areas during the NE monsoon which is found to vary from 4 to 6 days.

In this present study, the persistency of wet spells indicating the probability of wet occurrence on a given day is based on that the previous day was also wet. The findings indicate that the persistency of two consecutive wet days is found higher over the eastern areas during the NE monsoon season. Furthermore, it could be seen that the mean of the frequency of short wet spells (1-3 days) over the eastern areas varied from 7 to 11 times over the 30-year period which was slightly lower than at other regions during the NE monsoon. During the SW monsoon, it could be seen that the mean of the frequency of short spells was found to vary from 16 to 24 times in most stations over the Peninsula. Over the study period, it is observed that almost all the stations situated in the eastern areas experienced having the most frequent long wet spells (≥ 4 days) of more than 6 times during the NE monsoon season, which was the highest mean frequency than at the other stations. However, during the SW monsoon season, N5 was the only station that experienced having a more frequent longer duration of wet spells for at least 4 days over the Peninsula. The chances of getting longer wet spells for at least 4 days were found slightly higher over at the eastern and northwestern areas, respectively, than at the other regions during the NE and SW monsoon seasons.

TREND OF WET SPELLS DURING NE AND SW MONSOON SEASONS

The trends of the individual stations in Figure 2 indicate that the annual maximum of wet spells duration is found to decrease over the peninsula during the NE monsoon. As the maximum duration of wet spells shows a decreasing trend, the frequency of a long wet spells also shows a decreasing trend; however, at the same time the frequency of short spells exhibits a positive trend in most stations located in the west coast of Peninsular Malaysia. It is

TABLE 2. Descriptive summaries of the six indices of wet spells over the four regions in Peninsular Malaysia during monsoon seasons

		Northeast Monson												Southwest Monsoon											
		MxW		MnW		SdW		2CW		SSW		LSW		MxW		MnW		SdW		2CW		SSW		LSW	
Region	Code	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
North	N1	7.21	3.02	2.33	0.54	0.74	0.19	0.56	0.09	15.34	4.08	3.07	1.62	8.21	2.82	2.60	0.39	0.75	0.18	0.62	0.06	17.21	3.66	4.86	1.81
West	N2	7.03	2.34	2.32	0.52	0.75	0.21	0.56	0.11	13.48	3.88	2.83	1.79	8.10	2.57	2.48	0.36	0.77	0.17	0.59	0.06	17.72	3.54	4.69	1.63
	N3	8.93	4.72	2.50	0.55	0.85	0.30	0.59	0.09	12.97	4.14	2.90	1.61	8.79	2.24	2.64	0.39	0.80	0.15	0.62	0.06	16.76	4.30	5.00	1.65
	N4	5.93	2.85	1.90	0.39	0.69	0.20	0.46	0.13	15.00	4.11	1.55	1.15	6.99	3.63	2.04	0.65	0.72	0.19	0.48	0.11	17.72	4.48	2.52	1.55
	N5	6.93	3.33	2.28	0.63	0.74	0.22	0.55	0.13	11.97	3.61	2.28	1.53	8.31	2.38	2.71	0.43	0.73	0.11	0.63	0.06	16.62	3.64	6.07	1.56
	N6	7.28	2.71	2.45	0.52	0.75	0.20	0.59	0.08	10.34	3.49	2.34	1.40	8.31	2.92	2.51	0.43	0.77	0.17	0.60	0.08	17.38	4.71	4.62	1.74
	N7	5.93	2.88	2.20	0.48	0.67	0.23	0.53	0.11	10.93	3.02	2.21	1.70	797	2.47	2.57	0.50	0.74	0.15	0.61	0.07	16.83	3.57	5.00	1.81
	N8	5.90	3.61	2.16	0.60	0.68	0.26	0.51	0.12	11.24	3.68	1.69	1.44	6.86	2.22	2.23	040	0.73	0.16	0.55	0.08	18.72	4.72	3.66	1.63
West	W1	8.90	4.71	2.63	0.77	0.79	0.25	0.60	0.11	14.79	4.90	3.72	2.10	6.62	3.59	1.93	0.38	0.72	0.21	0.47	0.09	20.24	4.10	241	1.32
	W2	10.00	4.05	2.72	0.50	0.83	0.20	0.63	0.08	15.34	3.72	4.48	1.70	7.24	2.29	2.30	0.49	0.73	0.15	0.56	0.08	18.31	4.25	3.86	1.94
	W3	8.69	2.92	2.55	0.49	0.81	0.20	0.61	0.08	15.76	3.84	4.10	2.04	7.41	2.56	2.27	0.39	0.73	0.16	0.57	0.07	19.62	4.82	4.07	1.79
	W4	12.00	7.92	2.93	0.88	0.93	0.38	0.64	0.09	15.14	4.82	4.59	1.99	9.38	7.34	2.59	1.70	0.80	0.29	0.54	0.17	15.83	4.88	2.41	1.72
	W5	9.14	2.92	2.65	0.54	0.84	0.19	0.62	0.08	16.66	3.00	5.14	1.71	5.79	1.42	1.99	0.31	0.66	0.12	0.49	0.08	19.00	4.11	2.62	1.35
	W6	9.48	2.73	2.82	0.63	0.81	0.14	0.64	0.08	16.52	3.83	5.55	1.90	8.00	2.71	2.43	0.38	0.75	0.16	0.59	0.07	18.21	3.73	4.24	1.68
	W7	13.38	8.30	3.36	1.45	0.92	0.22	0.68	0.09	14.59	4.63	4.69	1.58	9.93	4.33	2.85	1.15	0.84	0.16	0.63	0.11	15.93	5.08	4.69	1.54
	W8	7.28	3.07	2.28	0.56	0.74	0.19	0.55	0.11	17.69	4.45	3.72	1.71	6.52	3.79	1.98	0.55	0.70	0.22	0.48	0.11	19.79	3.97	2.34	1.61
South	S1	8.10	1.97	2.71	0.50	0.76	0.14	0.62	0.06	14.28	4.29	4.97	1.86	6.79	3.94	2.12	0.52	0.70	0.20	0.52	0.09	20.59	4.12	3.03	1.38
	S2	10.62	3.92	3.19	0.53	0.86	0.19	0.69	0.05	13.41	2.97	5.59	1.74	7.97	3.01	2.45	0.51	0.73	0.16	0.59	0.07	20.07	4.57	5.24	2.12
	S3	10.00	3.24	3.07	0.50	0.83	0.20	0.67	0.06	12.28	3.18	4.41	1.35	8.48	6.94	2.27	0.59	0.80	0.32	0.56	0.10	19.90	4.38	3.83	1.75
	S4	9.21	5.26	2.45	0.79	0.84	0.31	0.58	0.13	16.17	4.49	3.24	1.92	7.38	6.20	2.09	1.33	0.73	0.27	0.45	0.17	19.97	7.02	2.03	1.72
	S5	9.45	6.42	2.42	0.80	0.86	0.31	0.56	0.15	17.03	5.14	3.45	1.74	6.97	6.49	1.89	0.68	0.70	0.30	0.44	0.14	22.03	4.48	1.93	1.96
	S6	10.55	3.52	3.00	0.46	0.85	0.17	0.66	0.05	13.17	2.84	5.17	1.63	7.79	2.78	2.29	0.39	0.75	0.14	0.55	0.07	21.41	3.78	4.72	1.91
	S7	9.21	3.14	2.57	0.44	0.85	0.22	0.61	0.06	15.59	3.82	4.00	1.58	6.76	1.92	2.19	0.26	0.70	0.15	0.55	0.06	21.28	2.83	3.83	1.07
	S8	6.00	6.84	1.73	0.91	0.64	0.46	0.34	0.21	15.28	5.69	1.07	1.28	4.03	2.41	1.42	0.34	0.54	0.25	0.27	0.14	20.48	4.76	0.66	0.81
East	E1	13.45	5.44	3.89	1.32	0.90	0.18	0.72	0.07	10.52	3.21	5.48	1.66	6.00	5.44	1.88	0.65	0.65	0.31	0.45	0.12	21.38	4.45	1.83	1.73
	E2	11.79	5.56	3.56	1.00	0.84	0.21	0.70	0.07	11.00	3.66	5.38	1.88	4.55	2.23	1.60	0.26	0.59	0.18	0.38	0.10	21.28	4.32	1.38	1.29
	E3	15.07	4.46	4.00	0.93	0.99	0.20	0.74	0.06	10.76	3.31	5.76	1.57	5.97	1.61	1.99	0.28	0.68	0.12	0.50	0.07	23.10	3.41	3.45	1.48
	E4	15.86	7.93	4.45	1.28	0.93	0.25	0.77	0.06	8.62	2.81	5.76	1.35	7.17	4.11	2.08	0.89	0.73	0.24	0.48	0.12	20.03	4.88	2.59	1.94
	E5	13.45	5.08	3.88	1.51	0.90	0.22	0.73	0.08	10.24	4.00	5.86	1.92	5.59	2.04	1.85	0.36	0.66	0.15	0.46	0.10	19.28	3.50	1.90	1.29
	E6	16.86	5.91	5.47	1.35	0.87	0.21	0.82	0.04	6.69	2.09	6.66	1.74	8.76	2.95	2.53	0.50	0.79	0.17	0.60	0.07	18.76	4.45	5.17	2.22
	E7	12.52	3.91	3.76	0.97	0.90	0.22	0.73	0.06	10.24	4.37	5.24	1.68	7.00	4.93	1.97	0.51	0.73	0.29	0.47	0.12	18.79	3.54	2.00	1.54
	E8	13.28	4.03	3.38	0.65	0.97	0.21	0.70	0.06	11.66	2.94	4.93	1.51	6.34	2.13	2.03	0.35	0.70	0.15	0.50	0.09	20.72	4.08	3.24	1.55

observed that almost all of the stations located in the eastern areas of the Peninsula exhibit a positive trend in the mean, variability and persistency of wet spells indices during the NE monsoon season. This may be due to the more frequent rainy days that these areas receive from the NE monsoon which always occur from the months of November to February.

Meanwhile, during the SW monsoon season, the wet spells indices such as the maximum duration, the mean, the variability and the persistency show a positive trend, and at the same time a decreasing trend is observed in the frequency of the long wet spells over the west coast of Peninsular Malaysia. It can also be seen in Figure 3 that all the indices of wet spells exhibit a negative trend over the eastern areas

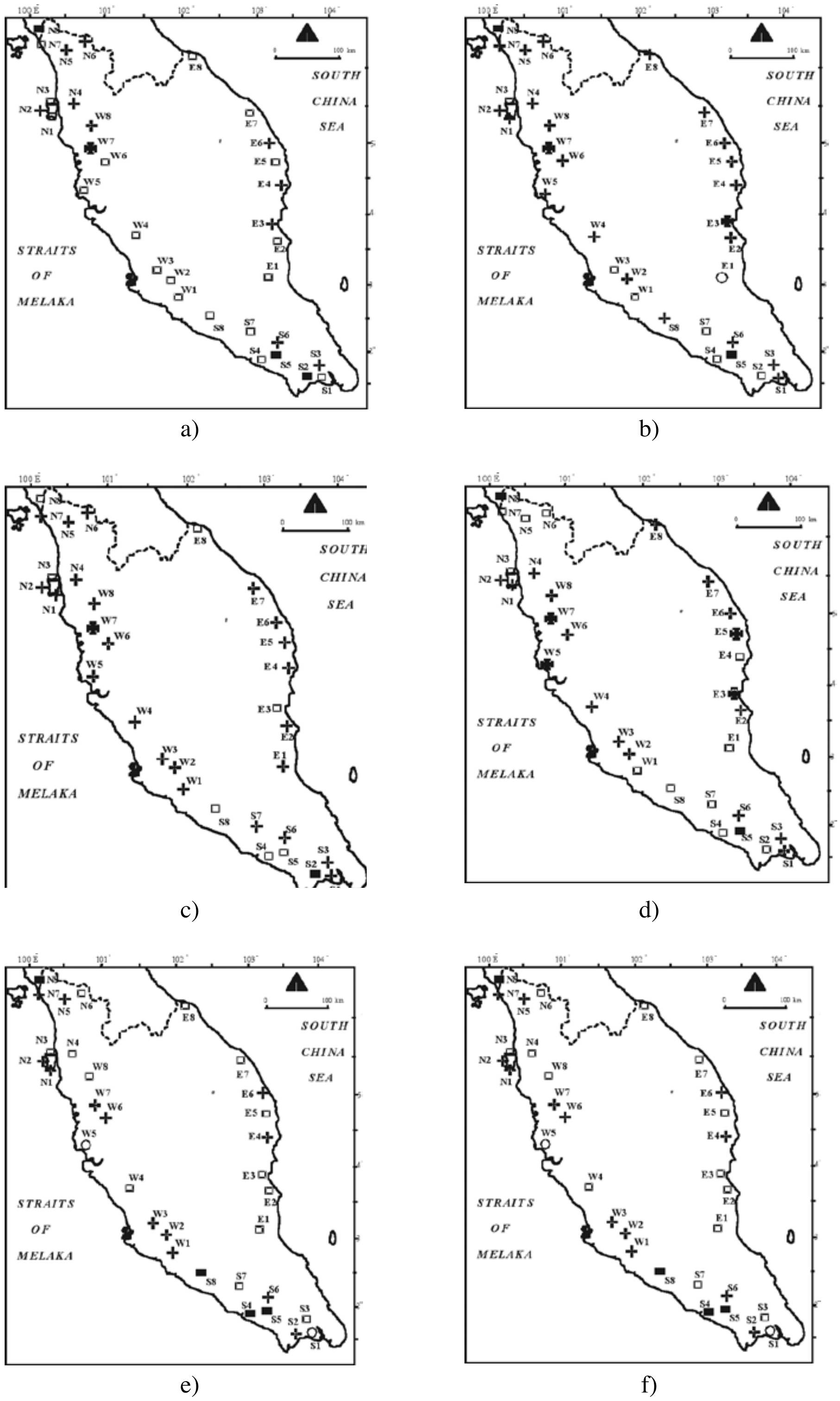

FIGURE 2. The trend of the wet spells during NE monsoon, a) MxW b) MnW c) SdW d) 2CW e) SSW and f) LSW.
✚ significant positive trend, + positive trend, ■ significant negative trend, □ negative trend and ○ no trend

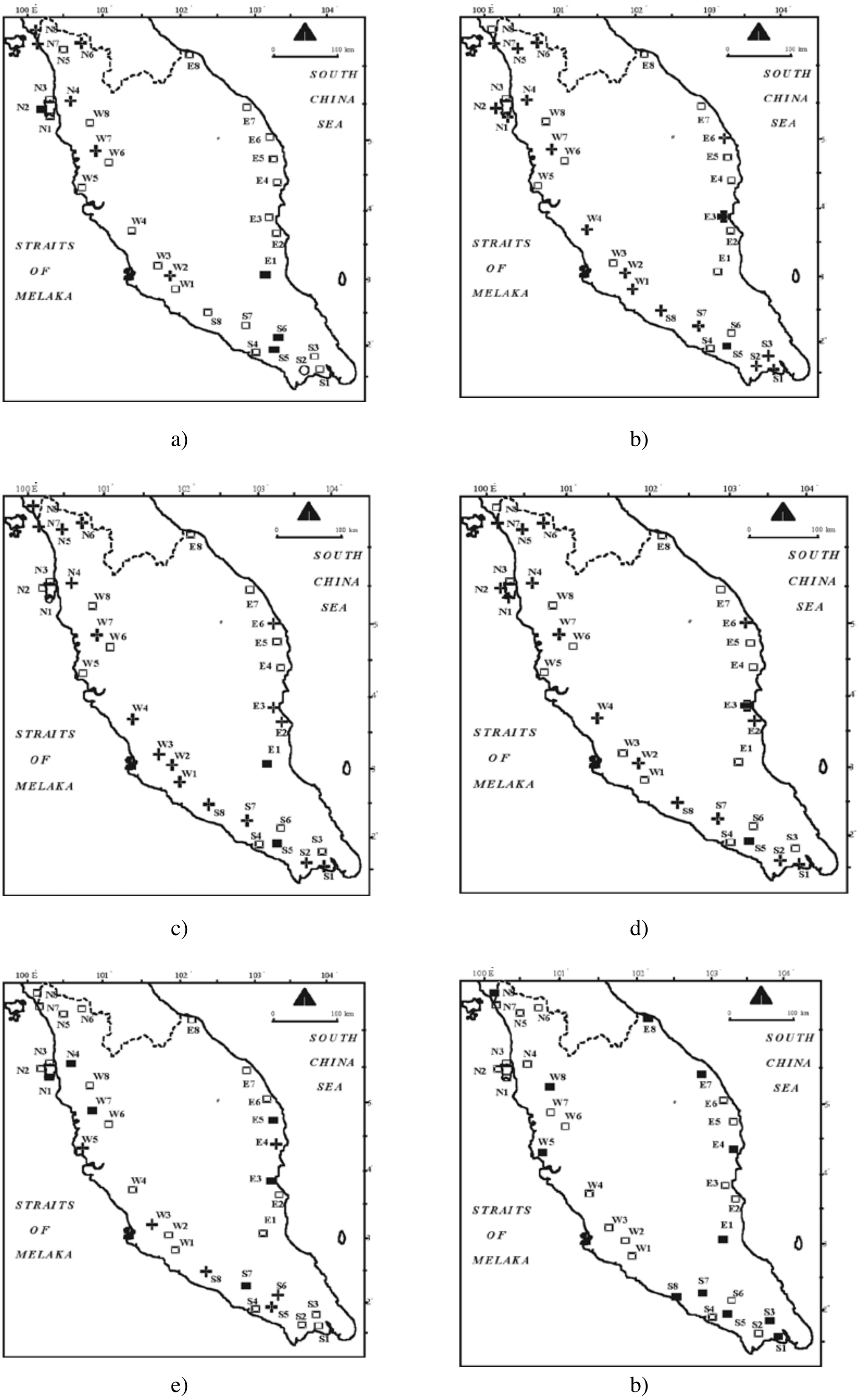

FIGURE 3. The trend of the wet spells during SW monsoon, a) MxW b) MnW c) SdW d) 2CW e) SSW and f) LSW. ✚ significant positive trend, + positive trend, ■ significant negative trend, □ negative trend and ○ no trend

of the Peninsular during the SW monsoon. Similar as in Figure 2, the frequency of long wet spells shows significant negative trends in almost all stations during both monsoon seasons for the period of 1975 to 2004.

REGIONAL TREND OF WET SPELLS DURING NE AND SW MONSOON SEASONS

The descriptive summaries for the six indices of wet spells over the four regions during the NE and SW monsoon seasons are displayed in Table 3. As mentioned earlier, almost all of the indices of wet spells are observed to be higher over the eastern areas than at the other regions during the NE monsoon season. The annual regional mean of the maximum number of consecutive wet days in these areas is found to be almost twice than that at the other regions in Peninsular Malaysia. According to the sensitivity experiments conducted by Juneng et al. (2007) who studied the extreme rainfall events during 9-11 December 2004 over the east coast of Peninsular Malaysia, local topography can influence the rainfall distribution around the area of maximum rainfall. Their findings showed that terrain elevation played an important role in blocking the westward progression of the system and inhibited excessive rainfall in the inland areas of Peninsular Malaysia. Meanwhile, the results of the annual regional mean as shown in Table 4 reveal that an increasing trend is observed in the maximum duration of wet spells over the northwestern and western areas during both monsoon seasons. On the other hand, the persistency of two consecutive wet spells of the regional mean exhibits negative trends in all regions during both monsoon seasons. It is remarkable that a decreasing trend is observed for all the indices of wet spells over the eastern areas during the SW monsoon season. Similar results are observed for the maximum duration, mean, variability and the persistency which result in a positive trend for the frequency of short spells over the southern areas during both monsoon seasons. At the same time, however, the frequency of long spells exhibits a positive and significant negative trend during the NE and SW monsoons, respectively.

TABLE 3. Descriptive summaries for the annual regional means of the six indices of the distribution of wet spells over the four regions in Peninsular Malaysia during monsoon seasons

		MxW		MnW		SdW		2CW		SSW		LSW	
Region		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
North West	NE	6.89	2.07	2.28	0.35	0.74	0.15	0.53	0.07	12.65	2.39	2.36	1.14
	NW	7.90	1.26	2.47	0.22	0.76	0.09	0.59	0.05	17.37	2.43	4.56	0.95
West	NE	9.87	2.14	2.74	0.39	0.83	0.11	0.62	0.06	15.81	2.12	4.50	1.02
	SW	7.61	1.60	2.28	0.32	0.75	0.09	0.54	0.06	18.37	2.13	3.33	0.85
South	NE	9.13	2.04	2.65	0.31	0.82	0.12	0.59	0.06	14.64	2.03	3.98	0.91
	SW	7.03	2.49	2.09	0.37	0.69	0.12	0.50	0.06	20.72	2.22	3.16	0.85
East	NE	14.04	2.76	4.05	0.58	0.91	0.10	0.74	0.05	9.97	1.54	5.63	0.76
	SW	6.43	1.50	2.00	0.24	0.69	0.10	0.48	0.06	20.42	1.79	2.69	0.93

TABLE 4. Linear trend per decade (LT) for annual regional means of the six indices of the distribution of wet spells over the four regions in Peninsular Malaysia during monsoon seasons. The Mann-Kendall (MK) trend test results are indicated as NT for no trend, I for non-significant increased trend, SI for significant increased trend, D for non-significant decreased trend and SD for significant decreased trend at 5% level

		MxW		MnW		SdW		2CW		SSW		LSW	
Region		LT	MK	LT	MK	LT	MK	LT	MK	LT	MK	LT	MK
North West	NE	0.07	I	0.04	D	0.01	D	0.00	SD	0.80	I	0.39	I
	SW	0.18	I	0.04	D	0.01	D	0.02	SD	-1.04	SD	-0.09	D
West	NE	0.82	I	0.22	I	0.00	D	0.08	D	-0.26	D	0.57	SI
	SW	0.39	I	0.04	D	0.01	D	-0.01	SD	0.07	I	0.09	I
South	NE	-0.49	D	-0.06	D	-0.03	SD	-0.06	SD	1.21	SI	0.02	I
	SW	0.12	D	-0.06	D	0.00	SD	-0.05	SD	0.15	I	-0.36	SD
East	NE	0.27	I	0.16	I	-0.01	SD	0.05	SD	-0.23	D	0.22	I
	SW	-0.38	D	-0.03	SD	-0.03	SD	0.01	SD	-0.11	D	-0.23	D

Conclusion

Tracing changes in the trend of wet spells characteristics as well as the persistency will provide useful information in predicting future climatic events since these variables are closely related to extreme weather events such as floods and landslides. Based on various sensitivity experiments conducted by Juneng et al. (2007), local topography can influence the rainfall distribution over the peninsula. The findings of this present study indicated that most of the stations located at the eastern areas of the peninsula had a slightly higher mean of the annual maximum of wet spells than at the other regions during the NE monsoon season. These results were similar to that of Dale's (1960) who stated that the highest intensities or the more frequent wet spells occurred along the east coast due to the heavy rains that these stations received during the NE monsoon. However, this present study also revealed that the mean of the annual maximum wet spells was slightly lower over the northwestern areas during the NE monsoon. This may be due to the fact that this area is considered drier than the other regions over the Peninsula during the NE monsoon season as reported in many studies (Dale 1960; Camerlengo 1999; Deni et al. 2008) who also found that the dry spells were largely dependent on latitude and were longer and more frequent in the northern areas than in the southern areas of the peninsula. Moreover, Cheang et al. (1986) also noted that the northwest region began to experience long dry spells earlier than the other parts of Peninsular Malaysia during the NE monsoon due to the influence of the easterlies which brought about drying the atmosphere.

Furthermore, the eastern areas could be considered as the wettest areas and it has been proven in this present study that almost all the indices of the wet spells over these areas were higher than over the other regions during the NE monsoon. It is also observed that almost all of the stations located in the eastern areas of the peninsula exhibited a positive trend in the mean, variability and persistency of wet spells indices during the NE monsoon season for the period of 1975 to 2004. This may be due to the more frequent rainy days that these areas received from the NE monsoon which always occurred from the months of November to February. Meanwhile, it could be seen that the frequency of long wet spells showed decreasing trends in most stations over the peninsula during both the monsoon seasons, but a slightly increasing trend in the frequency of short dry spells over the northwestern and southern areas of the peninsula during the NE monsoon season. However, during the SW monsoon, a negative trend was observed in the mean, variability and persistency which also resulted in a decreasing trend of the frequency of short and long wet periods over the east coast areas. The observed trends in the wet spells characteristics for both monsoon seasons as reported in this present study may be due to the cold surges, Borneo Vortex, Madden-Jullian Oscillation (MJO), the Indian Ocean Dipole (IOD), and the El Nino-Southern Oscillation (ENSO). These phenomena could influence the extreme rainfall event over Peninsular Malaysia (Juneng et al. 2007; Tangang et al. 2008). Moreover, the trends of the wet spells characteristics prior to this present study period 1975 to 2004 could be different, due to apparent climate shift in mid 1970s (Ye & Hsieh 2006).

Future studies should address the trace changes in the trend of other indices in the rainfall characteristics such as the precipitation amount and also the extreme rainfall events which include more regions over the Peninsula. Further research is also suggested in detecting the trends on various rainfall indices during the monsoon seasons and the intermonsoon period.

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