

THE COMPARISON SPATIAL ANALYSIS OF STORM BEHAVIOR IN PENINSULAR MALAYSIA DURING MONSON SEASONS BY NEYMAN SCOTT RECTANGULAR PULSE MODEL

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ABSTRACT

This study focuses on describing the spatial analysis for the important statistics (mean and probability rain) and the storm behavior by using Neyman-Scott Rectangular Pulse (NSRP) parameters in Peninsular Malaysia. The storm behaviors comprising of the arrivals storm (AS), the number of rain cells (NR), the rain cells intensity (RI), and the rain cells duration (RD) will be analyzed. Due to the limited number of stations, the geostatistical method of ordinary kriging is used to compute the values of properties of storm and to map their spatial distribution. The findings of this study indicate that there were differences in spatial distribution of arrival storm over Peninsula during both seasons, with the highest rate arrival storm over the east compared to other regions during the southwest monsoon (SWM). In contrast, the rate arrival storm significantly decreases over the east regions during the northeast monsoon (NEM). The storm is more common in NEM season than in SWM season. However, no significant difference in rain cells duration during both seasons over Peninsula. This finding explains that the occurrence of a large number of floods and soil erosions would more likely occur in the NEM, especially in the southwest and east region. Therefore, precautionary measures should be taken earlier to prevent any massive destruction of property and loss of life due to the hazards. These research findings are of considerable importance in providing enough information to water resource management, climatologists and agriculturists as well as hydrologists for planning their activities and modeling processes.

Keywords: Neyman-Scott Rectangular Pulse; Raincells; Spatial Analysis

1. INTRODUCTION

Nowadays, the issues regarding the climatic change and global warming receive a considerable attention from various researchers, particularly with regard to the effect of the behavior of the rain. The analysis of rainfall behavior is becoming important in many areas, particularly in water-related sectors such as agriculture, hydrology and water resource management. The expansion of irrigated agriculture, coupled with the development of industrialization and the rapid growth of population, contributes to the demand for the analysis of rainfall behavior, as such analysis can be utilized in rainfall forecasting and the decision making. Studies on rainfall behavior have attracted much attention from scientists throughout the world, such as those carried out by Lana et al. (2004), Martinez et al. (2007), Aravena and Luckman (2008), Sen Roy (2009) and

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Turkes et al. (2009). In studying such behaviors, the intensity of rainfall, extreme rainfall, total rainfall and heavy rains have been studied using several statistical theories such as by using trends (Frich et al., 2002; Brunetti et al., 2000, 2001 ; Piccarreta et al., 2004; Gong et al., 2004; Manton et al., 2001). A similar approach has been used by Zhang et al. (2009) to study the spatial distribution and trend of the rainfall concentration in the Pearl River basin, China. Their findings contributed to the basin-scale water resource management and conservation of the ecological environment. This method has also been applied to other regions such as India (Ananthakrishnan and Soman 1989; Soman and Krishna Kumar 1990) and Catalonia (Burgueno et al.2004, 2005, 2010).

Research on rainfall behavior, particularly examining the sequence of wet and dry days, had been explored successfully by a number of scientists. Williams (1952), who was among the first to be involved in the study of the distribution of wet and dry sequences, suggested a logarithmic series distribution (LSD) for data from England. He found that LSD fitted to the distribution of dry spells very well and many other researchers who have succeeded in this study (Theoharatos and Tselepidaki 1990; Anagnostopoulou et al. 2003; Tolika and Maheras 2005).

In general, Peninsular Malaysia is formed of highland, floodplain and coastal zones. The Titiwangsa Range forms the backbone of the peninsula, which runs from the Malaysia–Thailand border in the north to the south over a distance of 483 km and separates the eastern part from the western part (Suhaila and Jemain 2007). The climate of the peninsula is very much influenced by two main monsoons: the southwest monsoon (SWM) from May to August and the northeast monsoon (NEM) from November to February (Suhaila and Jemain 2009a, b). There have been a few published works on the behavior rainfall of Peninsular Malaysia. Among them are works on detecting the trends in dry and wet spells over the Peninsula during monsoon seasons (Deni et al. 2008, 2009, 2010), changes in extreme rainfall events (Wan Zin et al. 2010), changes in daily rainfall during monsoon seasons (Suhaila et al. 2010) and analysis of rainfall variability (Wong et al. 2009).

Daily rainfall data from 48 rain gauge stations were obtained from the Malaysian Meteorological and Drainage and Irrigation Departments for the period of 1970–2008. Based on the rainfall distribution, Dale (1959) delineated five rainfall regions in Peninsular Malaysia: northwest, west, Port Dickson-Muar coast, southwest, and east (Lim and Azizan 2004). In this study, the stations located on the Port Dickson-Muar coast were combined with those in the southwest region, due to the very limited number of stations available. A list of the 48 stations is provided in Table 1

Table 1 The list of 48 rain gauges stations with their geographical coordinates

Region	Stations	Code	State	Longitude	Latitude
Southwest	Kota Tinggi	S1	JOHOR	103.72	1.76
	Batu Pahat	S2	JOHOR	102.93	1.84
	Endau	S3	JOHOR	103.62	2.65
	Labis	S4	JOHOR	103.02	2.38
East	Batu Hampar	S5	TRENGGANU	102.82	5.45
	Bertam	S6	KELANTAN	102.05	5.15
	Besut	S7	TRENGGANU	102.62	5.64
	Sg Chanis	S8	PAHANG	102.94	2.81
	Dabong	S9	KELANTAN	102.02	5.38
	Dungun	S10	TRENGGANU	103.42	4.76
	Gua Musang	S11	KELANTAN	101.97	4.88
	Kemaman	S12	TRENGGANU	103.42	4.23
	Sg Kepasing	S13	PAHANG	102.83	3.02

Region	Stations	Code	State	Longitude	Latitude
	Kg Aring	S14	KELANTAN	102.35	4.94
	Kg Dura	S15	TRENGGANU	102.94	5.07
	Machang	S16	KELANTAN	102.22	5.79
	Paya Kangsar	S17	PAHANG	102.43	3.90
	Kg Sg Tong	S18	TRENGGANU	102.89	5.36
	Ulu Tekai	S19	PAHANG	102.73	4.23
	Pekan	S20	PAHANG	103.36	3.56
West	Ampang	S21	SELANGOR	102.00	3.20
	Bkt Bendera	S22	PULAU PINANG	100.27	5.42
	Chin Chin	S24	MELAKA	102.49	2.29
	Genting Klang	S25	W. PERSEKUTUAN	101.75	3.24
	jasin	S26	MELAKA	102.43	2.31
	Kalong Tengah	S28	SELANGOR	101.67	3.44
	Kampar	S29	PERAK	101.00	5.71
	Kg Sawah Lebar	S30	N.SEMBILAN	102.26	2.76
	ladang bikam	S31	PERAK	101.30	4.05
	Kg Kuala Sleh	S32	W. PERSEKUTUAN	101.77	3.26
	Petaling	S33	N.SEMBILAN	102.07	2.94
	Rompin	S34	N.SEMBILAN	102.51	2.72
	Seremban	S35	N.SEMBILAN	101.96	2.74
	Sg Batu	S36	W. PERSEKUTUAN	101.70	3.33
	Sg Bernam	S37	SELANGOR	101.35	3.70
	Sg Mangg	S38	SELANGOR	101.54	2.83
	Sg Pinang	S39	PULAU PINANG	100.21	5.39
	merlimau	S40	MELAKA	102.43	2.15
	Siti Awan	S41	PERAK	100.70	4.22
	Sg Sp Ampat	S42	PULAU PINANG	100.48	5.29
	Telok Intan	S43	PERAK	101.04	4.02
	Tanjung Malim	S44	PERAK	101.52	3.68
Northwest	Alor Setar	S45	KEDAH	100.39	6.11
	Arau	S46	PERLIS	100.27	6.43
	Baling	S47	KEDAH	100.74	5.58
	Kuala Nerang	S48	KEDAH	100.61	6.25
	Padang Katong	S49	PERLIS	100.19	6.45
	Pdg Mat Sirat	S50	KEDAH	99.67	6.36

2. THEORETICAL CONSIDERATION

NSRP modeling initially uses these following conditions;

1. Every storm arrival, which is symbolized as $l_i, i = 1, 2, 3, \dots$, is exponentially distributed in poisson process with parameter λ ,
2. Every rain cells, $c_{ij}, i = \text{storm index of } i, j = \text{rain cell index of storm-}i$, has poisson or geometry distribution with mean of $E(C)$,
3. Every waiting time for cells after the storm origin, $b_{ik}, i = \text{index storm of } i, k = \text{time of rain cell at storm-}i$, will be exponentially distributed with mean β .
4. In every rain cell, there are two other parameters forming cluster as rain cell intensity $x_{jh}, j = \text{jth cell}, h = \text{intensity at } j \text{ th cell}$, which is exponentially distributed with mean $E(X)$, and the duration of rain $t_{js}, j = \text{jth cell}, s = \text{duration at } j \text{th cell}$, is exponentially distributed with mean η .

Those four conditions can be depicted on the Figure.1 below

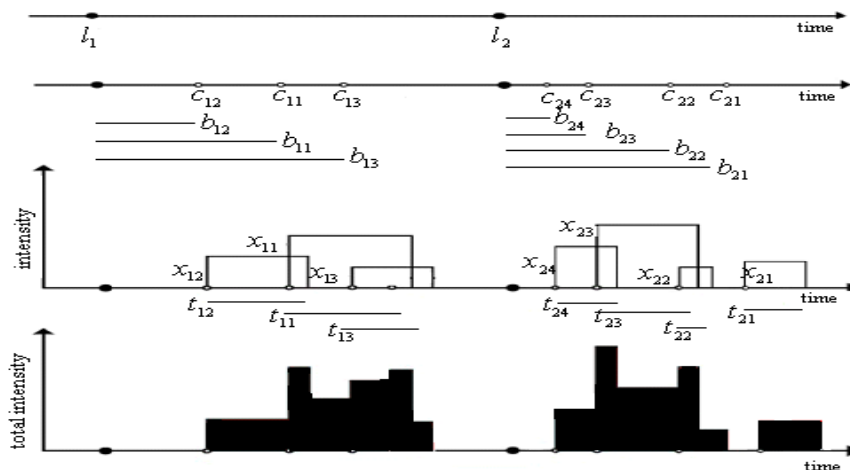


Figure 2 NSRP modeling, l_i storm arrival time, c_{ij} of rain cell, b_{ik} waiting time of rain cell, t_{js} duration of rain cell and x_{jh} intensity of rain cell.

There are five parameters of the NSRP model to be estimated, so the usual procedure would be to equate five statistical properties taken from the observed time series with their derived expressions for the model, and to solve the resulting set of simultaneous equations for the parameter estimates. The model would then fit five sample moments exactly, with the fit to other statistics not guaranteed. A more flexible fitting procedure is adopted here which assumes that it is more desirable to fit a larger set of sample moments approximately rather than a smaller set exactly. In general, the parameters of the NSRP model can be estimated by selecting a set that matches, as closely as possible, the expected statistics of the generated time series with the corresponding statistics estimated from observed rainfall time series. To implement this, the model parameters are estimated by minimizing

$$z(X) = \sum_{k,\tau} \left[1 - \frac{\Theta_k(X,\tau)}{\Theta_k^*(\tau)} \right]^2 \quad (1)$$

where k is a set of statistics, τ each with a specified aggregation level, $\Theta_k(X,\tau)$ is the expected value of k for the NSRP model using a given set of parameters and $\Theta_k^*(\tau)$ denotes the sample estimate of k evaluated from observed data. A numerical optimizing routine, such as the Simplex algorithm, is used to find the parameter set that minimizes the $z(x)$ function subject to fixed upper and lower bounds applied to the parameters.

3. RESULTS AND DISCUSSION

The following sections discuss the application of the NSRP model to produce parameter based on hourly rainfall data of 48 rain gauges stations used in this study. Hence, using a method of the Kriging especially on statistical spatial distribution will be carried out in Peninsular Malaysia, based on SWM and NEM. Two important statistics namely mean and probability for 1 and 24 hours-rain will be used to produce the spatial distribution. The similar spatial distribution of the statistics observed and estimated is very important to guarantee that the NSRP model has been success in Peninsular Malaysia. In figure 3,

it can be seen that the spatial distribution of the statistical mean of 1 and 24 hours-rainfall estimated was similar to the statistical observations, especially for the months of June through September. From these results, it can be found that the NSRP modeling has successfully carried out during the SWM. To strengthen this result, the spatial distribution statistics probability of 1 and 24 hours-rain of observed and estimated were produced, from figure 4, it has been found that the spatial distribution of the observed and estimated statistics for the months during the SWM were not significantly different. From this result, it is known that the NSRP modeling has successfully done in Peninsular Malaysia especially in May, June, August and September during the SWM.

Figure 3 depicts the spatial distribution mean of an hour-rain for the SWM season recorded during the period of 1970-2008. From this spatial distribution, it is found that almost all areas of the southwest region have a higher mean of 1 hour-rain than any other areas in Peninsula, it was recorded as more than 1.5 mm. A few small and isolated areas in west region, which were found to have the largest mean of 1 hour-rain during the SWM season, and during this season, the lowest statistics of < 0.5 mm was observed in the west and east regions, particularly on June and August. While most of the larger mean of 24 hours-rain during the the SWM season was recorded along southwest region with the value over 50 mm. However, a few and isolated areas in the west region, which were found to have the largest mean of 24 hour-rain during the SWM season with the value over 70 mm, particularly on July.

In term of the probability of an hour-rain it can be concluded that almost all areas in Peninsula experienced the same probability of an hour-rain between 0.03 and 0.09 during the SWM season, as shown in Fig. 4. Only a few places in the west region, recorded more than 0.20 during the SWM season. During this season, particularly on September, the probability of an hour-rain increases almost in all areas in the northwest region with the value between 0.09 and 0.19. In this season, a few areas on the northwest region, particularly on May, the probability of an hour-rain with the value between 0.09 and 0.15 was observed. Small parts of the east region also received the value between 0.08 and 0.13 during the SWM season particularly on June. The similar value was also found on the southwest region, particularly on July and August. While the largest probability of the 24 hours- is identified in several areas including the east and northwest, ranging from 0.5 to 0.69 during the SWM season. The lowest probability of 24 hours-rain was observed in a few areas in the west region, with the value between 0.26 and 0.36 during the SWM season, while in this season, particularly on September, the lowest probability of 24 hours-rain was observed in a few areas at the east and southwest regions, with the value between 0.41 and 0.48. During the SWM season, the probability of 24 hours-rain significantly increases on September, with the value between 0.41 and 0.69.

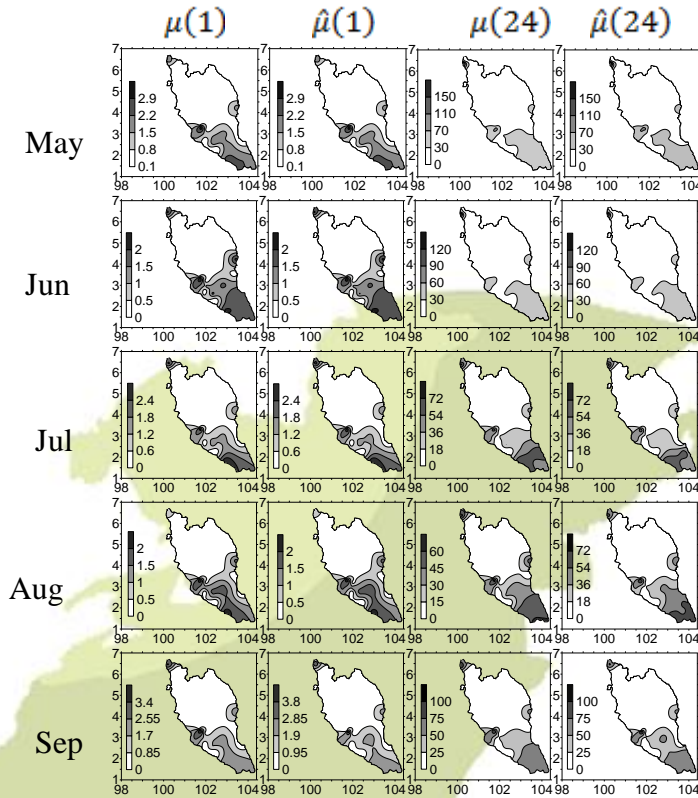


Figure 3 The mean of rain an 1 , 24 hours observed $\mu(1)$, $\mu(24)$, and estimated $\hat{\mu}(1)$, $\hat{\mu}(24)$ during SEW

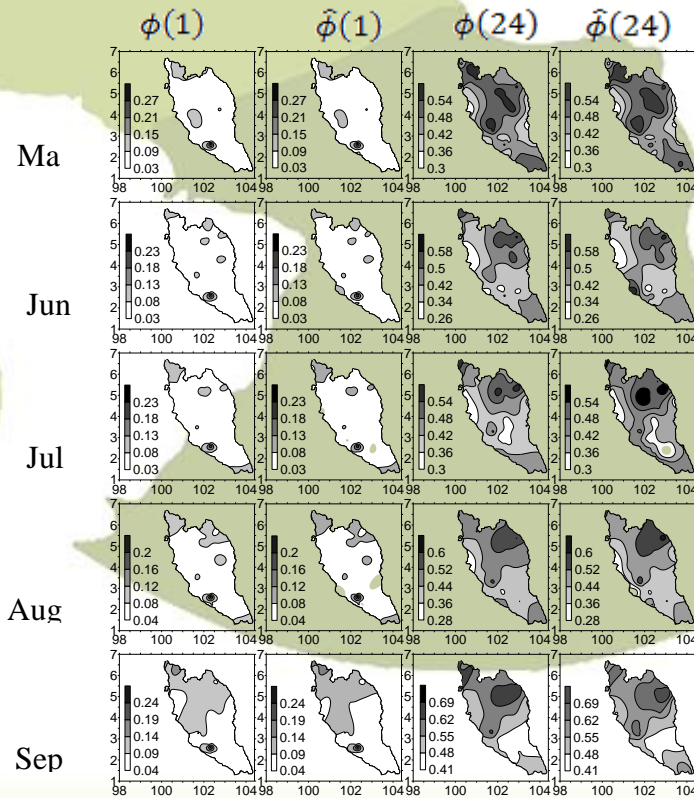


Figure 4 Probability of rain 1, 24 hours observed $\phi(1)$, $\phi(24)$ and estimated $\hat{\phi}(1)$, $\hat{\phi}(24)$ during SWM

4. CONCLUSION

The results of this study indicate that the highest RI and NR were found in the southwestern for SWM and NEM seasons, and the highest AR and RD during the SWM and NEM seasons were found in the eastern and western regions, respectively. However, the rate of AR during the NEM season is higher than the SWM season, It can be concluded that the storm is more common in the NEM season. Based on these results, it can be said that the southwest and east regions are more likely to be considered as the wettest area during the NEM season. This also explains the more likely of occurrences of floods and soil erosions during the NEM, particularly for the southwest and east regions. The presence of the mountains separating the eastern and western parts of Peninsula could be the best reason to explain the differences in the behavior of the storm of each region. The result of mapping the important statistical parameters, namely mean and probability of 1 hour-rain and 24 hours-rain during the SWM and NEM seasons indicated that the southwest and the east regions are more likely to be considered as the wettest area.

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