Chapter 4

Analysis of Storm Rainfall in Peninsular Malaysia Using Neyman-Scott Rectangular Pulse Modeling

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70043

Abstract

This paper aims to estimate Neyman-Scott rectangular pulse (NSRP) modeling application in representing the storm rainfall that occurred in Peninsular Malaysia. This research utilized hourly rainfall data from 48 rain gauges in Peninsular Malaysia during the period from 1970 to 2008. The raingauge stations are given in four territories, namely northwest, west, southwest, and east. The goodness-of-fit test from NSRP model should be done before the other applications of the model. The conclusion of this research revealed that NSRP model is able to show the rainfall data in Peninsular Malaysia.

Keywords: storm rainfall, NSRP, Peninsular Malaysia, modelling of storm

1. Introduction

Nowadays, there are many problems regarding climate change and global warming investigated by researchers, especially for the storm rainfall to society. Furthermore, the observation of storm rainfall becomes necessary action in a few sectors, such as agriculture, hydrology, and water resource management. Because of the growth of irrigated agriculture, industrialization, and population, the analyst can be used in forecasting rainfall and making decision. These studies, an intensity extreme rainfall, total rainfall, and heavy rains, have invited much attention of scientists in the world to research, such as research carried out by Lana et al. [1] and Burgueno et al. [2].

There have been a few published works on the behavior of storm rainfall in Peninsular Malaysia. Among them are works on detecting trends in dry and wet spells over the Peninsula during monsoon seasons [3, 4], changes in extreme rainfall events [5], changes in daily rainfall during monsoon seasons [6], and analysis of rainfall variability [7]. In these studies, various objectives and approaches have been highlighted in describing the characteristics of rainfall in this area.

2. Methodology

In this matter, the data used are the hourly rainfall data from 48 rain-gauge stations from 1970 to 2008. The data can be acquired from the meteorology, drainage, and irrigation department of Malaysia. All stations are divided into four classes, by [8, 9]. Dale [9] has defined five rainfall regions in Peninsular Malaysia, such as west, Port Dickson-Muar coast, southwest, and east. Nevertheless, a few of stations located on the Port Dickson-Muar coast were combined with people in the region of the southwest. The lists of stations are given in **Table 1**, and there are 48 stations that can be delineated in **Figure 1**.

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	Terengganu	102.82	5.45
	Bertam	S6	Kelantan	102.05	5.15
	Besut	S7	Terengganu	102.62	5.64
	Sg Chanis	S8	Pahang	102.94	2.81
	Dabong	S9	Kelantan	102.02	5.38
	Dungun	S10	Terengganu	103.42	4.76
	Gua Musang	S11	Kelantan	101.97	4.88
	Kemaman	S12	Terengganu	103.42	4.23
	Sg Kepasing	S13	Pahang	102.83	3.02
	Kg Aring	S14	Kelantan	102.35	4.94
	Kg Dura	S15	Terengganu	102.94	5.07
	Machang	S16	Kelantan	102.22	5.79
	Paya Kangsar	S17	Pahang	102.43	3.90
	Kg Sg Tong	S18	Terengganu	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

Region	Stations	Code	State	Longitude	Latitude
	Jasin	S26	Melaka	102.43	2.31
	Kalong Tengah	S28	Selangor	101.67	3.44
	Kampar	S29	Perak	101.00	5.71
	Kg Saw 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
	Teluk 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

Table 1. The list of 48 raingauge stations with their respective regions and geographical coordinates.

The Neyman-Scott rectangular pulse (NSRP) modeling is used to model the rainfall number of each station in Peninsular Malaysia. The single-site NSRP model is marked by the flexible structure where parameters of model relate to the basically physical features monitored in rainfall. Theoretically, the NSRP model assumes that the sources of storm follow a Poisson process with parameter λ. Additionally, a random figure of $E(C)$ cell origins is displaced from storm provenance by exponentially distributed distance with parameter β. A rectangular pulse, with duration and intensity, showed by other two independent random variables, presumed to be exponentially distributed with parameter η and $E(X)$ successively, is connected to every original cell. The total intensity on every point of time is given by the number of the active cell intensities in that certain point. Therefore, the NSRP model has a total of five parameters which can be estimated by minimizing an aim function, evaluated as

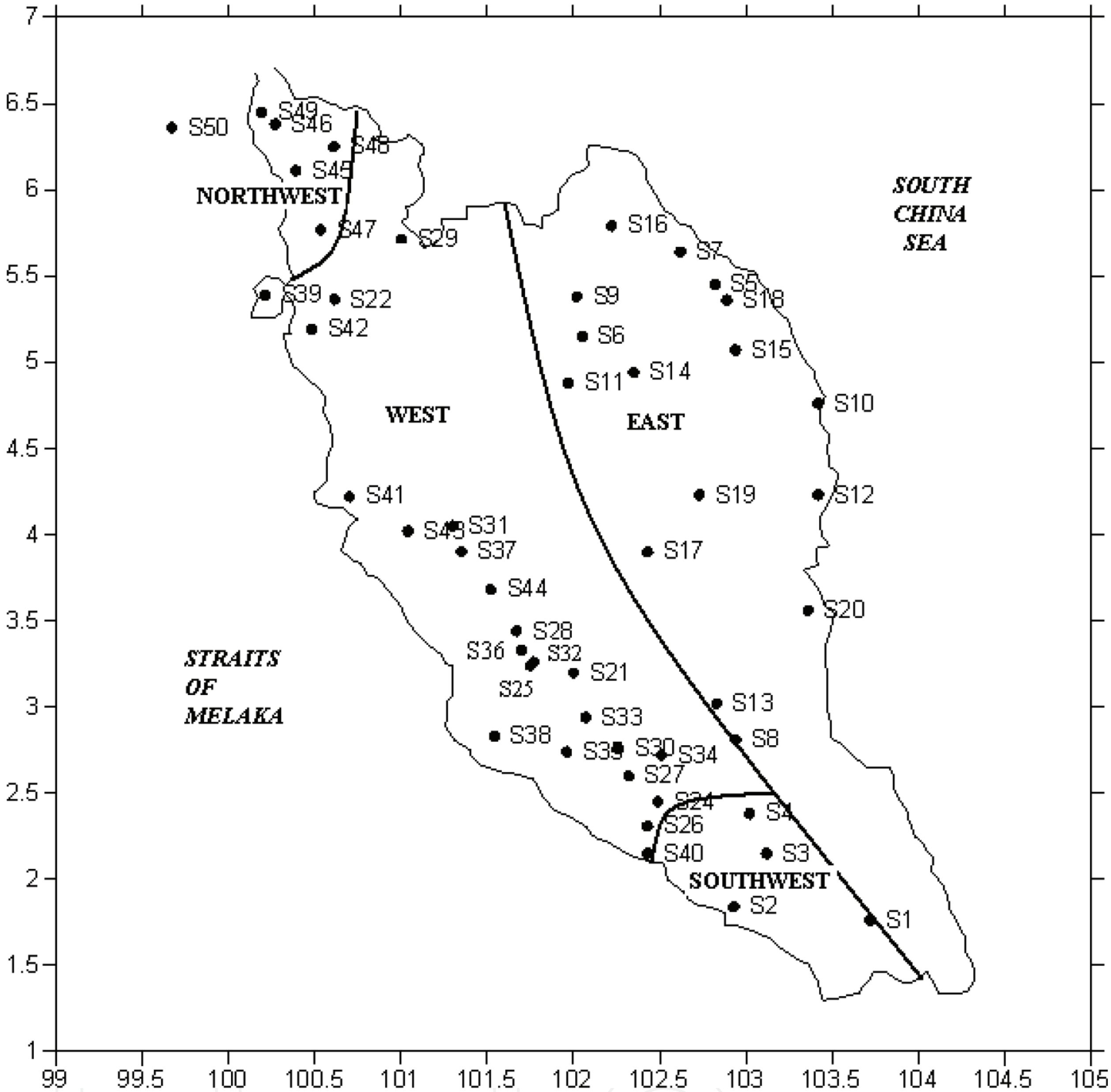

Figure 1. Map of Peninsular Malaysia showing geographical regions and the selected 48 stations.

the number of normalized residuals between the characteristic statistics and theoretical expressions that are observed [10, 11]. This model is able to produce statistics estimation values close to the observed values [11].

The main feature of the NSRP model can be summarized as follows:

1. Every storm arrival, represented by l_i, $i = 1, 2, 3, \ldots$, is exponentially distributed in Poisson process with parameter λ.

2. Every rain cell, c_{ij}, $i =$ storm index of i, $j =$ rain cell index of storm i, has Poisson or geometry distribution with a mean of $E(C)$.

3. every waiting time for cells after the storm origin, b_{ik}, i = index storm of i, k = time of rain cell at storm i, will be exponentially distributed with mean β,

4. Two parameters, intensity x_{jh}, j = jth cell and h = intensity at jth cell which is exponentially distributed with mean $E(X)$, and duration of rain t_{js}, j = jth cell and s = duration at jth cell which is Exponentially distributed with mean η, form cluster in every rain cell.

These four conditions can be depicted as in **Figure 2**.

Each station's hourly data are fitted with NSRP and the yielding NSRP parameters $(\lambda, E(x), E, \beta, \wedge \eta)$ are noted monthly. To control and make sure that the NSRP model obtained shows the actual rainfall data, the mean of the 1-h rainfall and probabilities of 1- and 24-h rainfall estimated from the model have been compared with this statistic values calculated from the data which are observed.

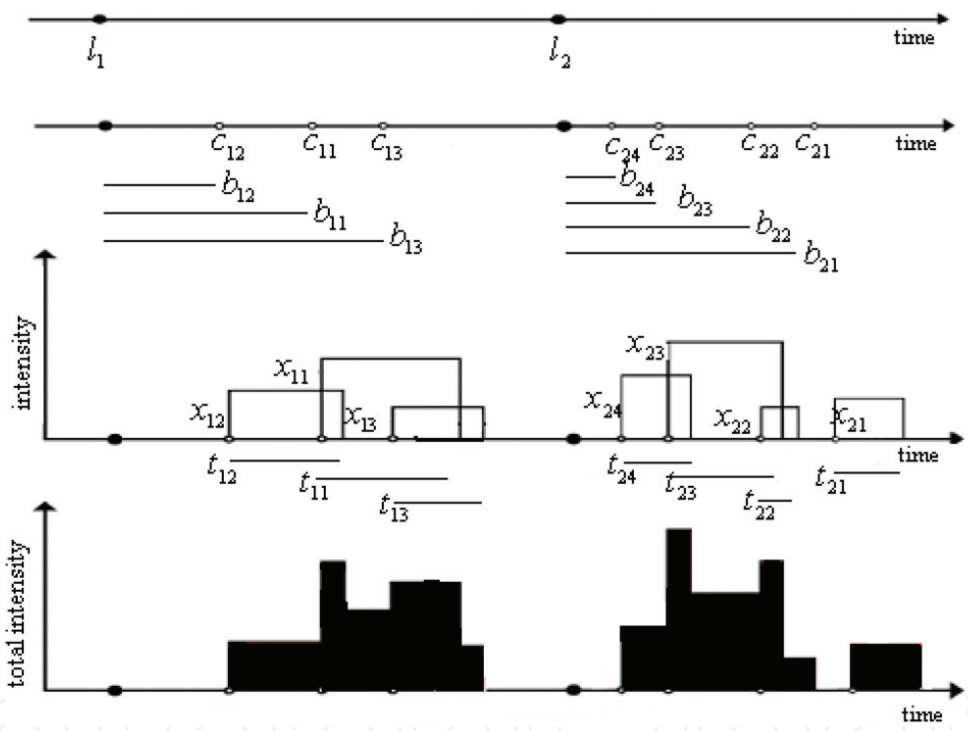

Figure 2. NSRP modeling, l_i storm arrival time, c_{ij} of rain cell, b_{ik} waiting time of rain cell, t_{js} duration of rain cell, and x_{jh} intensity of rain cell.

3. NSRP modeling

Rodriguez-Iturbe et al. [11] applied the formula to produce the first and the second statistical moments, whereas the moment is obtained using rainfall data scaling.

There are three statistical moments such as mean, variance and autocorrelation, and the probability of succession rain as Eq. (1)–(4) which are used to obtain the NSRP's parameters.

$$E\left(Y_i^{(\tau)}\right) = \frac{\lambda}{\eta} E(C)E(X)\tau \tag{1}$$

$$Var\left(Y_i^{(\tau)}\right) = \Omega_1(\lambda, E(C), E(X))\,\Psi_1(\eta,\tau) + \Omega_2(\lambda, E(C), E(X))\;\Psi_2(\beta,\eta,\tau) \tag{2}$$

$$\begin{aligned} Cov\left(Y_i^{(\tau)}, Y_{i+k}^{(\tau)}\right) &= \Omega_1(\,\lambda, E(C), E(X)\,)\,\Psi_3(\beta,\eta,\tau) \\ &+ \Omega_2(\lambda, E(C), E(X)\,)\,\Psi_4(\beta,\eta,\tau) \end{aligned} \tag{3}$$

$$1 - \Pr\left\{Y_i^{(\tau)} = 0\right\} \tag{4}$$

This research just have four equations where the others questions explain four equations before

$$\begin{aligned} \Pr\left\{Y_i^{(\tau)} = 0\right\} = \exp\Bigg(& -\lambda\tau + \lambda\beta^{-1}(E(C)-1)^{-1}\{1 - \exp\left[1 - E(C) + (E(C)-1)\exp\left(-\beta\tau\right)\right]\} \\ & - \lambda\int_0^\infty [1 - p(t,\tau)]\,dt\Bigg) \end{aligned}$$

$$\begin{aligned} p(t,\tau) = & \left(\exp\left[-\beta\,(t+\tau)\right] + 1 - \left[\eta\exp\left(-\beta t\right) - \beta\exp\left(-\eta t\right)\right] / \left[\eta - \beta\right]\right) \\ & \times \exp\Bigg(-(E(C)-1)\,\beta\left[\exp\left(-\beta t\right) - \exp\left(-\eta t\right)\right]/\left[\eta-\beta\right] - (E(C)-1)\exp\left(-\beta t\right) \\ & + (E(C)-1)\exp\left[-\beta\,(t+\tau)\,\right]\Bigg) \end{aligned}$$

$$\Omega_1(\,\lambda, E(C), E(X)\,) = 2\lambda\,E(C)E\left(X^2\right)$$

$$\Omega_2(\,\lambda, E(C), E(X)\,) = \lambda E\left(C^2 - C\right)E^2(X)$$

$$\Psi_1(\eta,\tau) = \frac{1}{\eta^3}\left(\,\eta\tau - 1 + \exp\left(-\eta\tau\right)\right)$$

$$\Psi_2(\beta,\eta,\tau) = \Psi_1(\eta,\tau)\frac{\beta^2}{\beta^2-\eta^2} - \frac{\beta\tau - 1 + \exp\left(-\beta\tau\right)}{\beta\left(\beta^2-\eta^2\right)}$$

$$\Psi_3(\beta,\eta,\tau) = \frac{1}{2\eta^3}\left(1 - \exp\left(-\eta\tau\right)\right)^2\exp\left(\,-\eta(k-1)\tau\,\right)$$

$$\Psi_4(\beta,\eta,\tau) = \Psi_3(\beta,\eta,\tau)\frac{\beta^2}{\beta^2-\eta^2} - \frac{\left(1 - \exp\left(-\beta\tau\right)^2\exp\left(-\beta(k-1)\right)\right)}{2\beta\left(\beta^2-\eta^2\right)}$$

k = autocorrelation of lag 1, 2, 3

τ = rain aggregation

http://dx.doi.org/10.5772/intechopen.70043

4. NSRP's parameter estimation and good-fit test

Rodriguez-Iturbe et al. [11] and Cowpertwait [10] have used a moment method to estimate NSRP's parameter. Other methods estimating the same parameters are also conducted by other researchers, who applied the method of log-likelihood maximum probability. Some researchers, who have provided usual procedure, which is needed to convert hourly rainfall data into aggregate rainfall data, in estimating NSRP's parameter, are [10, 12, 13]. The application of scaling to obtain the rainfall data of some scales. For example, the 1-h rainfall scale, 6-h rainfall scale, and 24-h rainfall scale used Eqs. (1)–(4) and then produced some nonlinear equations. So, the expected parameters of NSRP's can be obtained numerically by optimizing Eq. (5).

$$Z(X) = \sum_{k,\tau} \left[1 - \frac{\Theta_k(X,\tau)}{\Theta_k^*(\tau)}\right]^2 \tag{5}$$

$\Theta_k^*(\tau)$ is the second moment statistics and rainfall probability from scaled data or generally called as observation statistics, and $\Theta_k(x,\tau)$ is the second moment statistics and rainfall probability stated on Eqs. (1)–(4) or generally called as theoretical statistics.

The equation solution numerically requires an accurate initial value. Researches on non-linear numeric model often require it in order to enable them to estimate some required parameters. Some initial values, to estimate the parameters of NSRP, have been presented by Calenda and Napolatino accurately. In fact, it requires testing many of initial values to make z value on equation (5) to be optimum. This makes it difficult to perform the numerical solution. Favre et al. [14] has tried the best method on estimating NS parameter easier; The research is conducted by dividing parameters into two sets, which comprise $\{\beta, (\eta)\}$ and $\{E(C)\}, \lambda, (E(X))$ providing an initial value for parameter $\{\beta, (\eta)\}$. it can make the estimated numerical solution simpler and easier to handle. The other method of numerical solution of estimating the parameter of NSRP conferred fluctuation scale values linking one parameter with the other four parameters; in addition, based on the four chosen parameters, the value will be optimum. This simplifying numerical solution is also contributed by Calenda and Napolatino [15]. In this paper, the proportion of rainfall cell of each storm will be contributed under Poisson condition; thus $E(C^2 - C) = E^2(C) - 1$, this result has been well investigated [12].

Good-fit test, which is used to define the best-fit distribution in rainfall cell intensity of four given distribution in this research, will be applied by sorting residual value gained from a value of the second moment statistics and observed rainfall probability and from a value of the second moment and theoretical rainfall probability. Velghe et al. [12] used residual value as equation

$$S = \frac{1}{n}\left[\sum_{n} \left|1 - \frac{X_n}{X_{his,n}}\right|\right]$$

Assume X_n as the second moment and rainfall probability based on theory (NSRP model), $X_{his,n}$ as the second moment statistics and rainfall probability based on observation, and n as the number of statistics used in this model. whereas n is 8 representing the average of an hour rainfall; the variance used for the rainfall includes periods of 1, 6, and 24 h, autocorrelation lag 1 for 1-h rainfall, autocorrelation lag 1 for a 24-h rainfall scale, a probability of 1-h rainfall, and a probability of 24-h rainfall scale.

5. Applications

5.1. Study region

Peninsular Malaysia is located between 1 and 7 north of the equator which is the tropical area. Generally, these areas experience a wet and humid tropical climate throughout the year; this country has characteristic such as high annual rainfall, humidity, and temperature. Peninsular Malaysia has a stable temperature year-round from 25.5 to 32°C. Normally, the annual rainfall is between 2000 and 4000 mm, whereas the annual number of wet days ranges from 150 to 200.

The climate of Peninsular Malaysia describes two monsoons separated by two inter-monsoons. In May through September, the southwest monsoon (SWM) occurs and the northeast monsoon (NEM) occurs from November to March. The two inter-monsoons occur in April (FIM) and October (SIM). In Peninsular Malaysia, the main range mountains, widely known at the circumstances as Banjaran Titiwangsa, run southward from the Malaysia-Thai border in the north, spanning a distance of 483 km and separating the eastern part of the peninsula which receives heavy rainfall. By contrast, regions sheltered by the main range, as shown in **Figure 1**, are more or less free from its influence.

5.2. Goodness of fit of NSRP

Table 2 provides information about the parameters of the NSRP model for rainfall occurring in November dan December for 48 terminals in Peninsular Malaysia. The NSRP model with parameters, which is identified for every terminal, and various statistic values are the initial foundation for contraction of the rainfall data. In particular, the mean and probability values

Region	Station	November					December				
		λ	$E(X)$	$E(C)$	β	η	λ	$E(X)$	$E(C)$	β	η
Southwest	S1	0.025	93.70	2.56	0.116	2.23	0.012	56.82	7.88	0.078	1.48
	S2	0.028	221.46	1.46	0.020	2.08	0.021	70.67	4.58	0.109	2.56
	S3	0.033	15.58	1.39	0.221	2.22	0.012	5.96	5.70	0.081	2.16
	S4	0.003	74.40	16.28	0.001	1.48	0.015	85.30	5.41	0.112	1.96
East	S5	0.012	12.69	4.34	0.068	3.03	0.021	11.94	3.22	0.197	3.08
	S6	0.022	5.28	5.77	0.098	2.23	0.012	4.31	15.23	0.081	2.13
	S7	0.012	8.65	13.68	0.034	1.50	0.009	4.93	22.14	0.026	1.03
	S8	0.027	89.30	2.80	0.193	2.31	0.012	94.99	10.56	0.097	2.22
	S9	0.017	6.24	7.69	0.062	1.64	0.011	5.39	16.08	0.061	1.60

Region	Station	November					December				
		λ	$E(X)$	$E(C)$	β	η	λ	$E(X)$	$E(C)$	β	η
	S10	0.014	5.17	11.08	0.054	1.08	0.010	3.86	14.21	0.045	0.71
	S11	0.026	7.87	3.81	0.088	2.12	0.010	4.75	10.91	0.055	1.56
	S12	0.013	56.95	14.20	0.071	1.42	0.010	35.41	36.41	0.060	1.32
	S13	0.029	95.27	2.67	0.132	2.31	0.012	69.41	7.45	0.054	1.67
	S14	0.022	7.24	5.49	0.050	1.92	0.012	6.23	17.26	0.066	1.83
	S15	0.021	8.16	8.95	0.047	1.91	0.013	4.99	20.43	0.040	1.24
	S16	0.015	4.71	14.23	0.095	1.72	0.008	3.65	94.52	0.097	3.23
	S17	0.020	7.41	3.75	0.066	1.98	0.014	5.27	6.69	0.053	1.68
	S18	0.020	8.06	9.27	0.054	1.77	0.013	7.87	13.76	0.034	1.01
	S19	0.023	13.26	5.63	0.126	3.31	0.012	6.26	44.97	0.111	4.95
	S20	0.025	8.36	3.54	0.083	1.54	0.011	6.09	10.71	0.055	0.96
West	S21	0.007	5.67	10.95	0.037	2.30	0.008	7.62	5.65	0.096	2.82
	S22	0.027	8.64	2.83	0.074	1.74	0.012	8.83	2.90	0.067	1.97
	S24	0.028	2.71	11.38	0.478	3.02	0.012	5.96	5.70	0.081	2.16
	S25	0.037	82.69	2.57	0.121	2.08	0.009	85.79	6.55	0.042	2.03
	S26	0.031	6.28	7.30	0.786	4.92	0.009	5.15	10.32	0.076	2.62
	S28	0.051	6.69	2.44	0.177	1.95	0.016	5.90	5.05	0.059	1.86
	S29	0.038	10.65	2.51	0.089	2.13	0.026	11.14	2.48	0.076	1.94
	S30	0.015	79.97	4.67	0.044	2.15	0.014	44.10	5.34	0.066	1.80
	S31	0.032	8.78	3.26	0.085	2.18	0.038	11.58	2.80	0.798	3.23
	S32	0.048	110.72	1.95	0.263	2.52	0.015	107.19	3.47	0.051	2.63
	S33	0.026	61.91	3.22	0.139	2.16	0.016	60.17	4.11	0.080	2.02
	S34	0.023	60.32	4.92	0.080	2.17	0.014	44.12	6.91	0.061	1.69
	S35	0.034	7.09	3.15	0.169	2.14	0.014	6.56	4.53	0.069	2.07
	S36	0.038	129.97	2.35	0.051	2.48	0.033	97.96	2.42	0.170	2.46
	S37	0.036	8.51	3.46	0.186	2.74	0.020	11.08	3.78	0.091	2.83
	S38	0.037	63.64	4.47	0.658	3.49	0.024	97.53	3.78	0.198	3.71
	S39	0.030	7.27	3.57	0.281	2.07	0.010	6.87	3.98	0.103	1.82
	S40	0.024	8.45	4.98	0.141	4.31	0.011	4.97	6.61	0.102	2.36
	S41	0.031	6.56	2.55	0.236	2.05	0.017	8.57	3.86	0.092	2.31
	S42	0.028	6.78	3.20	0.100	1.65	0.016	6.77	3.19	0.122	1.79
	S43	0.033	7.64	3.38	0.186	2.19	0.024	8.67	3.10	0.181	2.01
	S44	0.037	7.94	3.31	0.110	2.22	0.022	8.86	3.12	0.086	2.43
Northwest	S45	0.007	2.09	16.27	0.113	2.05	0.007	5.46	7.40	0.086	2.58
	S46	0.010	5.70	16.49	0.054	2.61	0.005	8.23	24.89	0.067	3.98

Region	Station	November					December				
		λ	$E(X)$	$E(C)$	β	η	λ	$E(X)$	$E(C)$	β	η
	S47	0.012	5.04	5.97	0.127	2.39	0.006	9.60	5.57	0.097	3.34
	S48	0.022	4.11	5.16	0.147	1.89	0.008	3.62	6.92	0.080	1.51
	S49	0.078	67.53	1.01	0.179	2.57	0.003	16.50	22.20	0.048	1.09
	S50	0.011	6.89	8.10	0.061	2.43	0.008	7.68	4.09	0.098	2.86

Table 2. List of NSRP parameter for the 48 raingauge stations.

of the 1- and 24-h rainfall amount are then calculated. To describe the condition of a data set, these statistics are chosen.

To control how well the representation of the rainfall data is made by the NSRP model obtained, the mean of the 1-h rainfall and the probabilities of the 1- and 24-h rainfall estimated from the model are compared with these statistics values calculated from the observed data. Part of the results, focusing on the month of November and December only, is displayed in **Table 3**. It can be seen that there are no major differences between the estimated and the observed values of the statistics of interest.

Region	Station	November						December					
		AO	AE	PO	PE	PO2	PE2	AO	AE	PO	PE	PO2	PE2
Southwest	S1	2.74	2.72	0.08	0.08	0.57	0.57	3.31	3.54	0.11	0.12	0.51	0.47
	S2	3.45	4.38	0.11	0.06	0.64	0.61	2.73	2.67	0.11	0.11	0.56	0.58
	S3	0.29	0.32	0.10	0.06	0.58	0.58	0.19	0.19	0.08	0.08	0.44	0.45
	S4	2.61	2.58	0.09	0.08	0.55	0.69	2.80	3.52	0.11	0.10	0.49	0.47
East	S5	0.23	0.22	0.06	0.06	0.42	0.44	0.27	0.26	0.08	0.07	0.47	0.49
	S6	0.29	0.30	0.14	0.14	0.66	0.63	0.32	0.36	0.16	0.17	0.60	0.52
	S7	0.89	0.93	0.20	0.20	0.70	0.69	0.96	0.98	0.27	0.27	0.72	0.72
	S8	2.91	2.96	0.09	0.09	0.58	0.57	4.23	5.62	0.13	0.13	0.58	0.48
	S9	0.47	0.50	0.16	0.16	0.69	0.64	0.54	0.61	0.18	0.19	0.66	0.57
	S10	0.70	0.76	0.21	0.21	0.73	0.65	0.71	0.76	0.21	0.22	0.64	0.58
	S11	0.36	0.37	0.12	0.12	0.68	0.66	0.32	0.34	0.14	0.14	0.56	0.52
	S12	6.68	7.66	0.20	0.20	0.70	0.59	8.31	9.42	0.26	0.27	0.68	0.58
	S13	3.18	3.25	0.10	0.10	0.65	0.62	3.43	3.60	0.11	0.11	0.56	0.53
	S14	0.45	0.45	0.15	0.15	0.73	0.73	0.58	0.69	0.19	0.20	0.69	0.57
	S15	0.78	0.80	0.22	0.22	0.79	0.78	1.00	1.04	0.29	0.29	0.73	0.73
	S16	0.53	0.58	0.19	0.20	0.65	0.57	0.74	0.88	0.22	0.23	0.57	0.46
	S17	0.28	0.28	0.10	0.10	0.60	0.60	0.30	0.29	0.12	0.12	0.57	0.58
	S18	0.80	0.83	0.21	0.21	0.75	0.74	0.97	1.45	0.25	0.26	0.75	0.74

http://dx.doi.org/10.5772/intechopen.70043

Region	Station	November						December					
		AO	AE	PO	PE	PO2	PE2	AO	AE	PO	PE	PO2	PE2
	S19	0.40	0.52	0.14	0.13	0.71	0.61	0.48	0.69	0.20	0.23	0.64	0.53
	S20	0.47	0.48	0.12	0.12	0.64	0.64	0.70	0.76	0.17	0.17	0.61	0.55
West	S21	0.18	0.18	0.09	0.09	0.46	0.45	0.12	0.13	0.05	0.05	0.33	0.32
	S22	0.38	0.38	0.11	0.11	0.65	0.66	0.16	0.16	0.05	0.05	0.39	0.39
	S24	0.29	0.29	0.10	0.15	0.58	0.57	0.19	0.19	0.08	0.08	0.44	0.45
	S25	3.80	3.74	0.12	0.12	0.68	0.71	2.37	2.45	0.08	0.08	0.48	0.46
	S26	0.28	0.29	0.12	0.11	0.56	0.57	0.17	0.18	0.09	0.09	0.41	0.40
	S28	0.43	0.43	0.16	0.15	0.75	0.79	0.27	0.26	0.11	0.11	0.55	0.58
	S29	0.49	0.48	0.13	0.12	0.70	0.74	0.37	0.37	0.09	0.09	0.60	0.61
	S30	2.70	2.63	0.09	0.09	0.56	0.58	1.81	1.79	0.10	0.10	0.51	0.51
	S31	0.44	0.43	0.13	0.13	0.68	0.73	0.36	0.38	0.12	0.09	0.63	0.63
	S32	4.14	4.13	0.11	0.11	0.73	0.73	2.16	2.13	0.07	0.07	0.51	0.52
	S33	2.42	2.40	0.10	0.10	0.59	0.59	1.97	1.94	0.08	0.08	0.49	0.50
	S34	3.21	3.17	0.14	0.14	0.65	0.66	2.43	2.45	0.12	0.12	0.56	0.55
	S35	0.36	0.35	0.13	0.13	0.64	0.67	0.21	0.21	0.08	0.08	0.48	0.50
	S36	4.67	4.64	0.11	0.11	0.77	0.78	3.15	3.15	0.10	0.10	0.63	0.63
	S37	0.40	0.39	0.14	0.13	0.67	0.69	0.30	0.29	0.09	0.09	0.54	0.56
	S38	2.99	2.98	0.11	0.11	0.63	0.63	2.47	2.42	0.09	0.09	0.53	0.55
	S39	0.37	0.37	0.11	0.11	0.60	0.59	0.15	0.16	0.05	0.05	0.35	0.34
	S40	0.24	0.23	0.12	0.11	0.56	0.59	0.16	0.16	0.08	0.08	0.40	0.41
	S41	0.26	0.26	0.10	0.10	0.59	0.60	0.24	0.24	0.08	0.08	0.50	0.49
	S42	0.37	0.37	0.12	0.12	0.65	0.66	0.20	0.20	0.07	0.07	0.43	0.44
	S43	0.40	0.39	0.13	0.13	0.63	0.65	0.32	0.32	0.09	0.09	0.53	0.53
	S44	0.45	0.44	0.15	0.15	0.71	0.74	0.26	0.25	0.09	0.09	0.57	0.58
Northwest	S45	0.11	0.11	0.09	0.09	0.28	0.29	0.12	0.11	0.06	0.06	0.29	0.30
	S46	0.37	0.38	0.17	0.17	0.57	0.57	0.23	0.28	0.10	0.10	0.40	0.34
	S47	0.15	0.15	0.08	0.08	0.38	0.38	0.10	0.10	0.04	0.04	0.25	0.25
	S48	0.25	0.25	0.13	0.13	0.58	0.57	0.13	0.13	0.07	0.07	0.36	0.35
	S49	2.45	2.08	0.10	0.10	0.51	0.85	0.96	0.90	0.07	0.07	0.21	0.22
	S50	0.25	0.25	0.10	0.10	0.50	0.50	0.09	0.09	0.04	0.04	0.29	0.29

AO = mean of 1-h rainfall (observed data), AE = mean of 1-h rainfall (NSRP model), PO = probability of 1-h rainfall (observed data), PE = probability of 1-h rainfall (NSRP model), and PO2 = probability of 24-h rainfall (observed data, PE2 = probability of 24-h rainfall (NSRP model).

Table 3. The representation of the statistics which are estimated from the NSRP model compared with the statistic obtained from the analyzed data for the 48 raingauge terminal.

6. Conclusions

The results of this study proved that the Neyman-Scott rectangular pulse model is able to imitate the pattern of actual rainfall in Peninsular Malaysia by comparing the parameters as well as the spatial distribution of the means and probabilities of 1- and 24-h rain. Thus, the results from the NSRP model fitting for each station are valid to be used for further analysis, that is, to evaluate the behavior of storm rainfall.

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