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Daily rainfall persistence over Sri Lanka

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सार—बेसॉन के अनुलम्बना गुणांक का प्रयोग करके 15 क्रमिक वर्षों (1971–1985) के दैनिक वर्षा के आंकड़ों से दैनिक वर्षा की अनुलम्बना के क्षेत्रीय बंटन का अध्ययन किया गया। सभी बारह महीनों का अलग-अलग और पूरे वर्ष के लिए अलग से दैनिक वर्षा के अनुलम्बना गुणांकों का अध्ययन किया गया है। श्रीलंका में जहां जनवरी और फरवरी न्यूनतम वर्षा अनुलम्बना गुणांक प्रदर्शित करते हैं, वहीं अक्टूबर से दिसम्बर के महीने उच्चतम गुणांक सूचित करते हैं। मानसूनी वायुमंडलीय अवस्थाओं के अतिरिक्त वर्षा के अनुलम्बना बंटन पर स्थलाकृति का प्रबल क्षेत्रीय एवं सामयिक प्रभाव पड़ता है। दैनिक वर्षा के अनुलम्बना गुणांक, श्रीलंका के शुष्क क्षेत्र की अपेक्षा आर्द्र क्षेत्र में उच्चतर मान रिकार्ड करते हैं। समाश्रयण विश्लेषण से पता चलता है कि आर्द्र बौछारों की माध्य लम्बाई और दैनिक वर्षा के अनुलम्बना गुणांक के मध्य बेहतर रैखिक संबंध प्रकट होते हैं। परिणामी अंतिम समीकरण इस प्रकार हैं: $Y_R = 0.1093 + 0.1600\ X_M$, जिसमें 0.721 सहसंबंध गुणांक है जो कि 0.01 प्रतिशत स्तर पर सार्थक है।

ABSTRACT. The spatial distribution of daily rainfall persistence is examined adopting Besson's persistence coefficient and using daily rainfall data for 15 consecutive years (1971-1985). The daily rainfall persistence coefficients have been studied separately for all the twelve months individually and for the whole year. Where January and February indicate the lowest rainfall persistence coefficients the period from October to December indicates the highest coefficients over Sri Lanka. Besides the monsoonal atmospheric conditions, the topography has a strong influence on the rainfall persistence distribution over space and time. The daily rainfall persistence coefficients record higher values in the wet zone then in the dry zone of Sri Lanka. Regression analysis shows a better linear relationship between mean length of wet spells and the daily rainfall persistence coefficients and the resultant final equation is $Y_R = 0.1093 + 0.1600 + X_M$ having the correlation coefficient of 0.721 which is significant at the 0.01% level.

Key words — Rainfall persistence, Spatial distribution, Correlation coefficients.

1. Introduction

Daily rainfall plays a great role in weather phenomena, especially in tropical countries, and helps to determine the agricultural land use potential and in hydrological investigations. Although many parameters of daily rainfall are important for these investigations, forecasting of the spatial and temporal patterns of monsoon rainfall occurrence is a vitally important climatological aspect for Sri Lanka since its economy mainly depends on agriculture. It is widely known that the analysis of daily rainfall persistence does provide reliable information on weather forecast concerned with the short-term prediction of rainfall occurrence associated with daily atmospheric circulation systems (Sumner 1978, Jackson 1981, Singh *et al.* 1981, Singh and Kripalani 1986). Detailed examination of synoptic systems explains the nature of the atmospheric circulation patterns which are favourable or otherwise for rainfall occurrence (Singh *et al.* 1978, 1981).

In view of the monsoon flow patterns over Sri Lanka, four rainfall seasons were defined by Domroes (1974) : the first inter-monsoon from March to mid-May, the southwest monsoon from mid-May to September, the second inter-monsoon from October to November and the northeast monsoon from December to February. Although many attemps have been made to examine the monsoonal rainfall characteristics in Sri Lanka and to study the rainfall variability and anomalies, the persistence of daily rainfall has not yet been discussed in detail. Therefore, an attempt has been made in this study to examine the spatial distribution of daily rainfall persistence over Sri Lanka for all the twelve months as well as for the year separately.

2. Data and methods

Daily rainfall data have been analysed for a 15-year period (1971-1985) for 31 rainfall stations (Fig. 1 & Table 1). In this analysis, the nature of the daily rainfall data was studied, alongwith the spatial variation of daily rainfall totals. An attempt has been made, therefore, for grouping of the stations with a view to identify the homogeneous areas in respect of daily rainfall. This is done in such a way that all the stations in a group should be significantly correlated with the stations in the same group than stations in any other group as widely discussed by Jackson (1972, 1974). This method would be adequate to identify stations with similar pattern of daily rainfall for the present study. Therefore, an

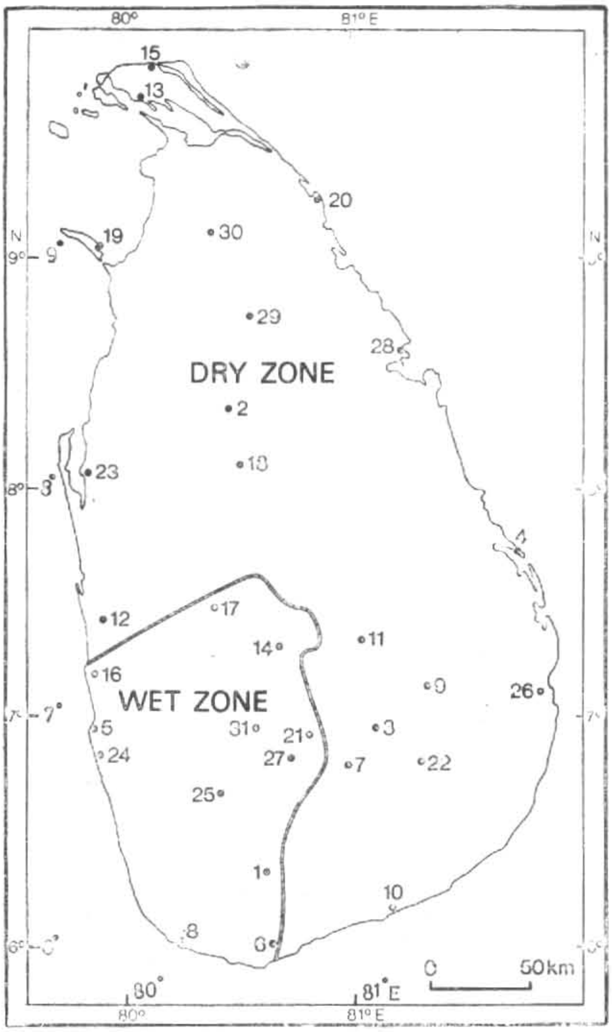
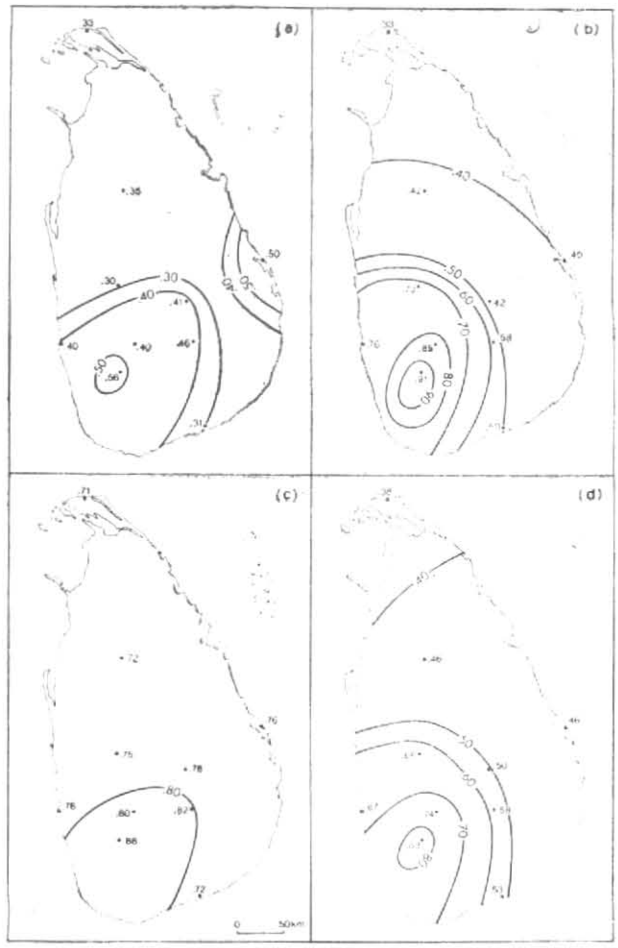


Fig. 1. Location of the rainfall stations in Sri Lanka and the boundary between the wet zone and dry zone [*after* Domroes 1971(b)]



Figs. 2(a-b). The spatial distribution of daily rainfall persistence patterns : (a) Jan & Feb, (b) Mar-Sep, (c) Oct-Dec, and (d) whole year. Average daily rainfall persistence coefficient for the ten representative stations for the respective period are displayed in each chart

inter-station daily rainfall correlation matrix was computed leading to the result that 85% of the coefficients are significant at the 0.01% level and the rest at the 0.05% level. Following the above method, all 31 review stations were divided into 10 groups and the most representative station was chosen from each group (Anuradhapura, Badulla, Batticaloa, Colombo, Hambantota, Horaborawewa, Kankesanturai, Kurunegala, Ratnapura, Watawala) on the basis of a significant correlation within the group, in order to investigate the daily rainfall persistence coefficients for Sri Lanka.

In the present study, a rainy day was considered as a day with precipitation more than 0.25 mm within 24 hours as defined by the Department of Meteorology of Sri Lanka. According to Berger and Goossens (1983), a wet spell (S) is expressed as a sequence of n rainy days, immediately preceded and followed by a rainy day ($S=1, 2, 3, \ldots, n$). P, expressing the probability of a rainy day, P_1 the conditional probability of the event after an occurrence on an immediately preceding occasion, and S values for each representative group were computed for each month separately. Similar calculations have been done for the whole year. The values obtained were used to compute the persistence coefficients as follows :

$$R = \frac{P_1 - P}{1 - P_1}$$

The derivation of this method was explained by Besson (1924) who had studied the persistence coefficient in order to identify the daily rainfall sequences for Paris. Similar methods were described by Feyarherm and Bark (1964), Erikson (1965), Singh (1981) and Berger & Goossens (1983).

Besson's persistence coefficient provides a much better explanation for the spatial distribution of daily rainfall occurrences which reflect the nature of circulation systems. This coefficient becomes zero if no persistence occurs for the event concerned. On the other hand, when the occurrence of a concerned event is followed by its occurrence immediately preceding, the coefficient shows a positive value. The persistence coefficients vary from 0 to 1.

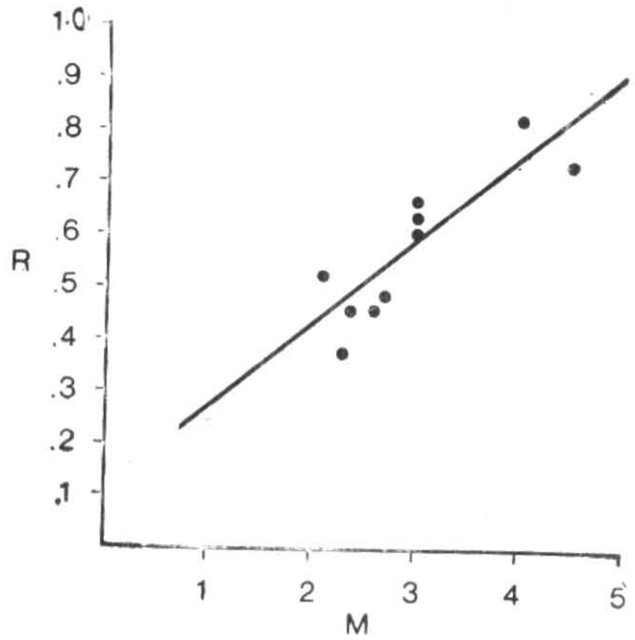


Fig. 3. Daily rainfall persistence cofficients (R) and mean length of wet spells (M). Dotted marks identify the representative ten stations. Both values were computed using the continuous data series (5475 cases, 1971-1985)

3. Rainfall occurrences in Sri Lanka

Monthly and annual means for daily rainfall sequences in Sri Lanka are given in Table 2 The 15-year observation period (1971-1985) which accounts for a total number of 2100 rainy days shows a large proportion of 85% from April through December for Sri Lanka as a whole. It is noteworthy that the total number of rainy days and their probability (P) greatly vary with different circulation patterns showing two maxima : (*i*) in April/May, (*ii*) from September to December; and a minimum in January/February. Moreover, the mean length of a wet spell, expressed in days, varies greatly in coincidence with the number of rainy days in each month. The length of wet spells of 4.1 and 3.8 days occurs in October /November while January, February and March show shorter wet spells of 2.4, 2.4 and 2.1 days respectively. However, the mean length of a wet spell is 3.2 days for the whole year.

4. The spatial distribution of daily rainfall persistence over Sri Lanka

The examination of the characteristic of the daily rainfall persistence coefficients for each of the twelve months shows, however, a similar spatial distribution for some consecutive months, *viz.*, (a) January and February, (b) March to September, and (c) October to December [Figs. 2(a-d), where Fig. 2(d) represents the whole year]. The occurrence of these rainfall persistence patterns is primarily due to the rainfall activities associated with the monsoonal circulation systems over Sri Lanka and their seasonal variation.

January and February [*Fig.* 2(*a*)] — The occurrence of daily rainfall persistence over Sri Lanka is less pronounced showing a spatial distribution of persistence coefficients from 0.3 to 0.5. The highest values are apparent on the east coast (Batticaloa) and on the southwest slopes of the Central Highland (Ratnapura), while lower persistence coefficients exist for most parts of Sri Lanka. Although rainfall activities are weak for Sri Lanka due to gradual withdrawal of the northeast monsoon in January and February, surprisingly the mean length of a wet spell of 5.6 days is found for Batticaloa. This particular feature is limited to the east coast during this period, which implies that this area is exposed to the effect of the wet airmass from the Bay of Bengal. However, as a result of the weak northeast monsoon wind system, shorter wet spells occur at other stations from which it can be suggested that the synoptic situation over Sri Lanka is unfavourable for the occurrence of wet spells during this period.

March-September [*Fig.* 2(*b*)] — During this period covering the first inter-monsoon and southwest monsoon, the daily rainfall persistence distribution shows remarkable differences in space and the highest coefficients appear in the southwest quadrant of Sri Lanka. In March, the ITCZ advances northward and in April it is found across Sri Lanka. Thus, long wet spells occur frequently, associated with ample rainfall in most parts of the country. The synoptic situation in May shows a large-scale variation in the atmospheric circulation pattern over south Asia as a whole and it has been found that the southwest monsoon is related to strong upper easterlies (Flohn 1960, Parthasarathy *et al.* 1987, Suppiah 1988). It could be shown that the core area of the southeast monsoon winds is located at the 150 hPa level between 5 and 15°N. Due to this large-scale atmospheric circulation change, the southwest monsoon sets in over the southwest coast of Sri Lanka in mid-May, followed by increased occurrences of wet spells in this area during the period.

Further, it is pertinent to note that a gradient of rainfall persistence coefficients exists in Sri Lanka from southwest to northeast. This gradient is largely due to the interaction between the local topography and near-surface circulation during the southwest monsoon season. Since the central highland greatly disturbs the circulation patterns, foehn phenomena can be seen. This effect is responsible for copious rainfall on the windward (western) side of the central highland while the southwest monsoon winds become warm and dry on the lee-ward (eastern) side [Domroes 1969, 1971(a)]. With regard to the daily rainfall persistence coefficients, higher values are found for the stations in the wet zone* in comparison to the stations in the dry zone†.

October-December [*Fig.* 2(*c*)] — Highest daily rainfall persistence coefficients indicate the occurrence of longer wet spells all over Sri Lanka. The governing weather phenomenon for the enhanced rainfall persistence coefficients is the southward migrating ITCZ in October and November. However, in

*, † — Domroes (1971) has identified the wet zone and dry zone by an "effective dry period" which has been defined by Wikkramatileke (1955) by a period of three or more consecutive months each of which receiving less than 102 mm (4 inches) of rainfall. Subsequently, on a long-term average, the wet zone is not experiencing such an effective dry period while it affects the dry zone.

TABLE 1

Rainfall reference stations in Sri Lanka

S. No.	Station	Latitude (N)			Longitude (E)			Elevation (m)	Daily mean (mm)	S.D. (mm)
		(°)	(′)	(″)	(°)	(′)	(″)			
1	Anningkanda	6	20	55	80	36	40	558	9.4	18.9
2	Anuradhapura	8	21	00	80	23	00	93	2.6	9.5
3	Badulla	6	59	25	80	02	35	670	3.4	9.7
4	Batticaloa	7	43	00	81	42	00	3	2.8	10.9
5	Colombo	6	54	25	79	52	05	7	6.1	15.6
6	Dandeniya	6	01	50	80	39	00	49	3.3	9.8
7	Diyatalawa	6	49	00	80	58	00	1248	3.1	8.6
8	Galle	6	02	00	80	13	00	13	4.5	12.8
9	Gal Oya	7	07	00	81	15	00	325	3.8	12.4
10	Hambantota	6	07	00	81	07	50	16	2.0	8.5
11	Horaborawewa	7	21	55	81	00	28	110	4.6	12.7
12	Horakelle	7	27	00	79	50	55	15	4.1	12.4
13	Jaffna	9	39	00	80	01	20	4	2.4	10.6
14	Kandy	7	20	00	80	38	00	477	3.6	10.4
15	Kankesanturai	9	48	00	80	04	00	15	3.4	13.3
16	Katunayake	7	10	00	79	52	45	9	4.3	13.8
17	Kurunegala	7	28	00	80	22	00	116	4.3	12.8
18	Maha Iluppallama	8	07	00	80	28	00	138	2.7	10.6
19	Mannar	8	58	45	79	54	50	4	2.0	9.7
20	Mullaitivu	9	16	05	80	48	45	3	3.5	14.7
21	Nuwara Eliya	6	58	00	80	46	00	1895	3.8	10.1
22	Okkampitiya	6	49	00	81	18	20	339	4.2	12.2
23	Puttalam	8	02	00	79	50	00	2	2.6	10.5
24	Ratmalana	6	49	00	79	53	00	5	4.9	14.3
25	Ratnapura	6	41	00	80	24	00	34	7.6	17.3
26	Sakaman Tank	7	07	38	81	48	00	12	2.6	11.2
27	Sandringham	6	50	55	80	45	00	1615	6.4	12.5
28	Trincomalee	8	35	00	81	15	00	3	2.6	10.5
29	Vavuniya	8	45	00	80	30	00	98	2.7	10.6
30	Vaunikulam	9	06	05	80	20	05	70	3.1	11.6
31	Watawala	6	57	55	80	31	40	1003	14.1	26.8

S.D. — Standard deviation.

Daily mean and standard values are computed from the daily rainfall data for 15 years (1971-1985).

TABLE 2

Main characteristics of daily rainfall sequences in Sri Lanka

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
N	106	88	123	193	181	166	166	148	183	242	263	240	2100
P	.23	.21	.26	.43	.39	.37	.36	.32	.41	.52	.58	.52	.38
M	2.4	2.4	2.1	2.8	2.7	3.6	3.1	2.7	3.1	4.1	3.8	3.6	3.2

N — Number of rainy days, *P* — Probability of rainy days, *M* — Mean length of wet spells (in days). All data are averages of ten representative stations for Sri Lanka and all values were computed using daily rainfall data for a 15-year period (1971-1985).

December the onset of the northeast monsoon is more favourable for rainfall occurrence. It can be noted that tropical depressions and cyclones frequently appear in the Bay of Bengal, which give evidence of high rainfall in Sri Lanka during this period (Thambyahpillay 1954, Domroes 1974, Suppiah 1984, 1988). The daily rainfall distribution over Sri Lanka is fairly uniform during this period and shows remarkably similar persistence coefficents of 0.70 even for the stations in the dry zone and higher values of 0.80 for the stations in the wet zone.

The distribution of daily rainfall persistence coefficients for the whole year [Fig. 2(d)] shows a fairly similar pattern to the coefficients distribution of March-September [Fig. 2(b)], but relatively low persistence coefficients are found in the wet zone. It must be noted that the persistence coefficients also show a gradient from southwest to northeast for the whole year, however, the declining trend is less noticed than for March-September [Fig. 2(b)].

5. Correlation between : (a) mean length of wet spells and Besson's persistence coefficients, (b) daily rainfall intensity and mean length of wet spells

The product moment correlation was analysed between the above weather parameters obtained from the10 representative stations. It is interesting to note that the correlation coefficients are significant at the 0.01% level between both pairs of parameters, but a marked difference was found between the coefficients. However, a higher correlation coefficient was apparent between the mean length of wet spells and Besson's persistence coefficients ($r=.849$) as well as between the daily rainfall intensity and mean length of wet spells ($r=.626$). According to the strong relationship between these parameters, a higher rainfall intensity occurs for the stations under reference which is associated with the greater number of rainy days and hence a longer wet spell establishes. Occurrence of this characteristic is largely due to the different circulation of systems over Sri Lanka and these weather parameters show a strong relationship with the sequences and distribution of the daily rainfall persistence pattern.

Morevoer, a form of relationship between mean length of wet spells and Besson's persistence coefficients was examined adopting a regression analysis (Fig. 3). The r^2 value and also the standard error of regression estimate ($S_{Y \cdot X}$) were performed to assess the goodness of fit in the final equation. A strong relationship was identified between these two parameters which shows a linear form of $Y_R=0.1093+0.1600\ X_M$ expressing a higher r^2 value (0.721) significant at the 0.01% level, and a lower $S_{Y \cdot X}$ value (0.079) which was found to be most appropriate (Fig. 3).

6. Conclusion

The present analysis which examined the spatial distribution of daily rainfall persistence in Sri Lanka using Besson's persistence coefficients for 15-year data, reflects the nature and behaviour of the atmospheric circulation systems. It is worthwhile to note that the occurrence of daily rainfall persistence and its characteristic greatly varies over space and time, in association with different synoptic processes which produce the four seasons over Sri Lanka. From October to December high persistence values are apparent for all stations which coincide with dominant tropical depressions and cyclone activities which can be explained as most favourable synoptic systems for the rainfall producing conditions in Sri Lanka. In examining the different daily rainfall persistence distribution, it is found that the wet zone strongly establishes higher coefficients in most months.

Significant correlation coefficients were found between the mean length of wet spells and daily rainfall persistence coefficients as well as between the daily rainfall intensity and mean length of wet spells. It is also found that the daily rainfall persistence coefficients appear to have a better linear relation with mean length of wet spells.

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References

Berger, A. and Goossens, Ch., 1983, "Persistence of wet and dry spells at Uccle (Belgium)", *J. Climatol.*, **3**, pp. 21-37.

Besson, L., 1924, "On the probability of rain", *Mon. Weath. Rev.*, **52**, p. 308.

Domroes, M., 1969, Die Niederschlagsverhältnisse im Uva-Backen auf Ceylon, eine geländeklimatologische Untersuchung, *Erdkunde*, **23**, pp. 117-127.

Domroes, M., 1971 (a), The rainfall pattern of the Uva Basin, *Ceylon Geogr.*, **20**, pp. 74-81.

Domroes, M., 1971 (b), Wet Zone and Dry Zone Möglichkeiten einer klimaökologischen Raumgliederung der Insel Ceylon, Erdkundliches Wissen, **27**, pp. 205-232.

Domroes, M., 1974, The agroclimate of Ceylon, A contribution towards the ecology of tropical crops, Wiesbaden : Franz Steiner, Verlag.

Erikson, B., 1965, "A climatological study of persistency and probability of precipitation in Sweden", *Tellus*, **18**, pp. 484-498.

Feyarherm, A.M. and Bark, L.D., 1964, "Some statistical methods for persistent precipitation patterns", *J. Appl. Met.*, **4**, pp. 320-328.

Flohn, H., 1960, Recent investigation on the mechanism of the "Summer Monsoon" of southern and eastern Asia; in : Monsoons of the world, ed. by S. Basu, *et al.*, New Delhi, pp. 75-88.

Jackson, I.J., 1972, "The spatial correlation of fluctuation in rainfall over Tanzania : A preliminary analysis", *Arch. Met. Geoph. Biokl.*, **B, 20**, pp. 167-178.

Jackson, I.J., 1974," Inter-stations rainfall correlation under tropical conditions, *Catena*, **1**, pp. 235-256.

Jackson, I.J., 1981, "Dependence of wet and dry days in the tropics," *Arch. Met. Geoph. Biokl.*, **B, 29,** pp. 167-179.

Parthasarathy, B., Poly, G.W. and Weickmann, K.M., 1987, "Relationship between Pacific Ocean zonal wind indices and Indian monsoon rainfall", *Trop. Ocean-Atmos. Newsl.* (*TOAN*), **41,** pp. 3-7.

Singh, S.V., Mooley, D.A. and Kripalani, R.H., 1978, "Synoptic climatology of the daily 700 mb summer monsoon flow patterns over India", *Mon. Weath. Rev.*, **106,** pp. 510-521.

Singh, S.V., Kripalani, R.H., Shaha, P., Ismail, P.M. and Dahale, S.D., 1981, "Persistence in daily and 5-day summer monsoon rainfall over India", *Arch. Met. Geoph. Biokl.*, **A, 30,** pp. 261-277.

Singh, S.V. and Kripalani, R.H., 1986, "Analysis of persistence in daily monsoon rainfall over India", *J. Climatol.*, **6,** pp. 625-639.

Sumner, G.N., 1978, "The prediction of short-duration storm rainfall intensity maxima", *J. Hydrol.*, **37,** pp. 91-100.

Suppiah, R. and Yoshino, M.M., 1984, "Rainfall variations of Sri Lanka, Part I : Spatial and temporal pattern", *Arch. Met. Geoph. Biokl.*, **B, 34,** pp. 329-340.

Suppiah, R., 1988, Atmospheric circulation variations and the rainfall of Sri Lanka, Science Report, Inst. of Geosci., Univ. of Tsukuba, Japan, Sec. A, 9, pp. 75-142.

Thambyahpillay, G., 1954, "The rainfall rhythm in Ceylon," *Univ. Ceylon Rev.*, 12, pp. 224-273.

Wikkramatileke, W.A.R., 1955, "Climate of the southeast quadrant of Ceylon', *J. Trop. Geogr.*, **17,** pp. 55-72.