551·577·36 : 551·553·21(54)

Runs of Dry and Wet spells during southwest monsoon and onset of monsoon along the west coast of India*

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(*Received 23 June 1958*)

ABSTRACT. The daily rainfall data of five stations on the Konkan coast of India during the southwest monsoon have been analysed to determine the frequencies of rain and no-rain periods of various lengths. The use of persistency as an aid for forecasting rain periods following runs of rainy days or dry days of different lengths is discussed.

Runs of dry days during the southwest monsoon months have also been studied by the theory of extreme values (Jenkinson Probability Method) and the probable maximum run of dry days with zero rainfall in each month has been worked out for various periods giving an idea of the lengths of breaks during the monsoon months due to weakening or temporary withdrawal of the monsoon current.

The runs of dry days from 1 May and 1 June have been separately analysed to estimate the latest possible date of commencement of the monsoon from 1 May and 1 June and the results are compared with the normal dates of onset of the southwest monsoon.

1. Introduction

The southwest monsoon is ushered in along the west coast of India year after year with a rather remarkable suddenness and regularity in the last week of May and it gradually extends northwards to the higher latitudes, bringing finally the entire Indian sub-continent under its sway by the end of June. The yield of agricultural crops in India depends largely upon the strength and timeliness of the coming and going of the SW monsoon; its late arrival or early retreat sometimes causing famine conditions in the country. After several days of no-rain lasting two or even three extremely hot and dry months, the eagerly awaited SW monsoon rain "bursts" on the southwest coast of the country. Besides this "burst" of the monsoon, the prevailing rainy season from June to September (when the monsoon gets well spread over the country) is characterised by its extreme variability and spells of rainy days are interspersed by periods of no-rain days of different lengths. The purpose of this paper is mainly to examine this variability of the SW monsoon.

1.1. The study described in this paper is restricted to the SW monsoon rainfall as it affects the coastal districts of Bombay State, namely, the Konkan coast, comprising of the districts of north Kanara, Marmagoa, Ratnagiri, Kolaba, Thana and Surat. Available daily rainfall data of the five stations, Karwar, Marmagoa, Ratnagiri, Bombay (Colaba) and Surat representative of the different districts for the period May to September from 1921 to 1950 have been utilised in the study.

1.2. In the first part of the study, the runs of rain and no-rain days have been analysed and the frequencies of these runs are utilised to bring out the persistence of prevailing weather. An objective method of forecasting rain or no-rain a few days in advance, on this coast, based on the persistence is also indicated. In the remaining part of the paper the seasonal maximum runs of no-rain (dry) days for the five stations have been analysed by the theory of extreme value distribution as developed by Jenkinson (1955) and the results give an idea of the breaks in the

* Submitted originally for the Symposium on "Monsoons of the World"

TABLE 1

Observed and cumulative frequency of occurrence of different runs of rainy days and frequency expected on chance during SW monsoon

Length of runs in days	Karwar (1921—1938)			Marmagoa (1921—1950)			Ratnagiri (1921—1945)			Bombay (1921—1950)			Surat (1921—1950)		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
1	33	33·9	176	104	135·4	419	70	68·9	283	81	139·7	409	142	386·3	483
2	17	29·4	143	54	106·9	315	23	57·7	213	67	109·0	328	81	221·2	341
3	10	25·5	126	46	83·6	261	23	48·2	190	42	85·1	261	68	126·5	260
4	8	22·1	116	16	65·5	215	20	40·4	167	28	66·3	219	41	72·5	192
5	4	19·2	108	27	51·3	199	18	33·8	147	28	51·7	191	35	41·5	151
6	8	16·7	104	22	40·1	172	9	28·2	129	19	40·3	163	18	23·8	116
7	8	14·4	96	16	31·3	150	9	23·6	120	14	31·4	144	14	13·4	98
8	6	12·5	88	12	24·5	134	6	19·7	111	11	24·6	130	18	7·6	84
9	6	10·8	82	21	19·3	122	8	16·5	105	9	19·0	119	12	4·4	66
10	6	9·4	76	14	15·0	101	7	13·8	97	10	14·7	110	13	2·5	54
11	6	*61·7	70	10	*55·1	87	4	*70·6	90	14	*52·4	100	8	*4·1	41
12	5		64	7		77	2		86	5		86	7		33
13	5		59	10		70	6		84	6		81	1		26
14	1		54	5		60	4		78	12		75	1		25
15	3		53	2		55	7		74	9		63	5		24
16	2		50	1		53	6		67	5		54	3		19
17	1		48	3		52	4		61	2		49	1		16
18	3		47	5		49	2		57	9		47	3		15
19	3		44	4		44	8		55	8		38	0		12
20	5		41	4		40	3		47	3		30	4		12
21	4		36	3		36	5		44	5		27	0		8
22	5		32	5		33	5		39	0		22	2		8
23	3		27	4		28	0		34	1		22	2		6
24	0		24	3		24	4		34	4		21	1		4
25	1		24	3		21	4		30	2		17	0		3
26	2		23	2		18	2		26	1		15	1		3
27	0		21	2		16	3		24	2		14	1		2
28	0		21	3		14	2		21	2		12	0		1
29	0		21	1		11	0		19	0		10	0		1
30	2		21	1		10	0		19	0		10	0		1
31	19		19	9		9	19		19	10		10	1		1
Total	176	255·6		419	628·0		283	421·1		409	634·2		483	903·8	

* greater or equal 11

(*a*) Observed total, Jun—Sep; (*b*) Expected on chance, Jun—Sep; (*c*) Observed cumulative total (reverse)

SW monsoon rainfall. The runs of no-rain (dry) days starting from 1 May and 1 June separately for each of the different five stations have also been examined next by analysing the maximum runs by the same method and the results give the probable average and latest deadline date for the onset of the monsoon at the station and these are compared with the normal dates of onset of the monsoon as observed.

2. The frequency distribution and persistence of rain periods during southwest monsoon

The available daily rainfall data for the period 1921-1950 for the 5 stations on the Konkan coast have been utilised to calculate the frequencies of runs of rainy days for each of the monsoon months June to September and for the season as a whole. A day receiving a measurable amount of 0·01 inch or more of rain was considered a rainy day. When a rain spell started in a month and extended into the next month it was assumed that the spell had 'broken' at the end of the month and that a different spell had started at the beginning of the next month. The seasonal frequencies as determined above for the different stations are given in Table 1. The observed cumulative frequencies (reverse) from the longest to the shortest run for the season have also been computed and are given in the same table for each station.

2.1. The percentage frequencies of runs of rainy days (*i*) lasting less than 10, and (*ii*) more than 20 days for each of the different stations and months have also been worked out to determine the relative variation between months and stations and are given in Table 2. It was observed that runs of longer durations are more frequent in July and August. Also the percentage frequency of the longer runs decreases towards north in the order of stations Karwar, Ratnagiri, Marmagoa, Bombay and Surat. The average length of runs of rain spells also follow the same sequence.

2·2. *Frequency of runs of rainy days expected on chance*—In order to get an idea of the effect of persistence in the runs of the rainy spells, we must consider the number of runs of different lengths expected only due to chance, that is a series in which there is no persistence. The method followed for calculating the above in the present study is the same as that adopted by Jorgensen (1949). The actual number of rainy days for the different stations have been computed for each month and for the season as a whole and are given in Table 3. The probability of rain occurring on chance on any one day, *viz.*, p=(Number of rainy days)/(Total number of days), for each of the stations were computed. The expected frequencies of runs of rainy days of different lengths is given by Cochran's formula (1938)

$$f_{r,m} = 2\, p^r\, q + p^r\, q^2\, (m-r-1) \qquad (1)$$

where $f_{r,m}$ is the frequency of runs of length r days out of m trials for the type of weather having p as the probability of occurrence during the unit period, q=1—p and $1 \leqslant r \leqslant (m-1)$; m= 122 days for June to September.

Values of m, p and q for the different stations and the season as a whole are given in Table 3. The expected frequencies of runs of rainy days of length of at least i days out of m trials is given by the formula—

$$f_{i,m} = p^i + (m-i)\, p^i\, q \qquad (2)$$

The above formula gives the sum of the frequencies from equation (1) for all runs of length i, $i+1$, etc upto m as explained by Bizley (1957). These expected frequencies for spells upto 10 days using equation (1) and for spells 11 days or more using equation (2) have been calculated and are given in Table 1 along with the observed values. The expected frequencies for 1-day rain spell are generally more than the observed 1-day spell except at Karwar and Ratnagiri where they are nearly equal. The expected frequencies for spells from 2 to 10 days are more than the observed frequencies at all the stations showing the existence of persistence in all such cases.

TABLE 2

Percentage frequency of runs of rainy days lasting less than 10 and more than 20 days and the average length of runs

Station	Length of run in days	Jun	Jul	Aug	Sep	Jun to Sep
Karwar	<10	51	21	57	81	60
	>20	22	63	26	1	20
	Average	11·4	22·9	12·3	5·5	10·9
Marmagoa	<10	75	56	79	93	79
	>20	7	29	8	1	9
	Average	7·1	13·0	7·3	3·7	6·9
Ratnagiri	<10	68	40	64	84	68
	>20	11	40	23	3	15
	Average	8·2	16·6	10·7	5·2	9·1
Bombay	<10	83	46	69	90	75
	>20	2	29	5	1	7
	Average	5·7	13·5	7·2	4·7	7·0
Surat	<10	96	85	90	96	91
	>20	0	4	2	0	2
	Average	3·0	6·1	4·7	3·5	4·4

TABLE 3

Station	No. of rainy days					p	$q=1-p$	No. of years	m
	Jun	Jul	Aug	Sep	Jun to Sep				
Karwar	467	550	517	386	1920	0·874	0·126	18	122
Marmagoa	702	859	778	548	2887	0·789	0·211	30	122
Ratnagiri	593	747	707	523	2570	0·843	0·157	25	122
Bombay	594	877	796	610	2877	0·786	0·214	30	122
Surat	318	741	645	408	2112	0·577	0·423	30	122

2·3. *Persistency of rain spells at the station*—The dictum "Weather persists" is unconsciously utilised by meteorologists in their day-to-day weather forecasting. Persistency is a measure of the tendency in excess of chance for a type of weather to continue unchanged, that is, the probability of continuance obtained from the observed records *minus* the probability calculated purely due to chance. The problem of estimating the persistency factor of a particular weather type amounts to computing these probabilities.

2·4. Figs. 1 to 5 indicate the percentage occurrence of various lengths of runs of rain days following wet spells of different lengths for the season June to September and for the 5 stations. The percentages

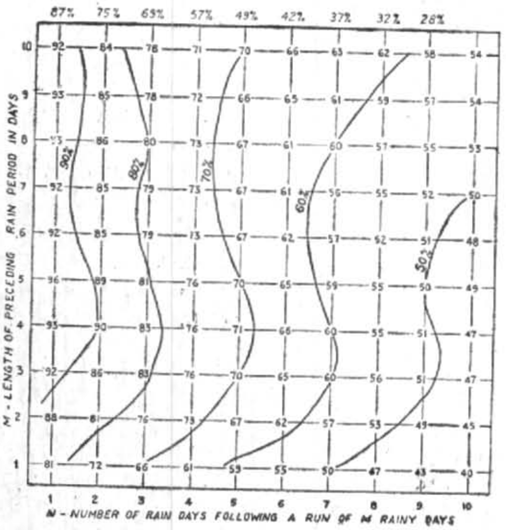

Fig. 1. Karwar (June to September)

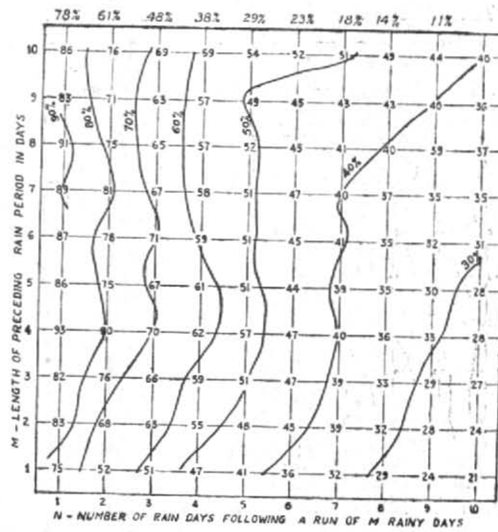

Fig. 2. Marmagoa (June to September)

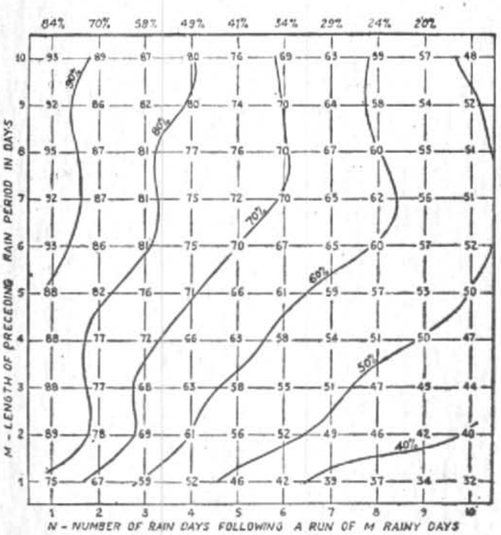

Fig. 3. Ratnagiri (June to September)

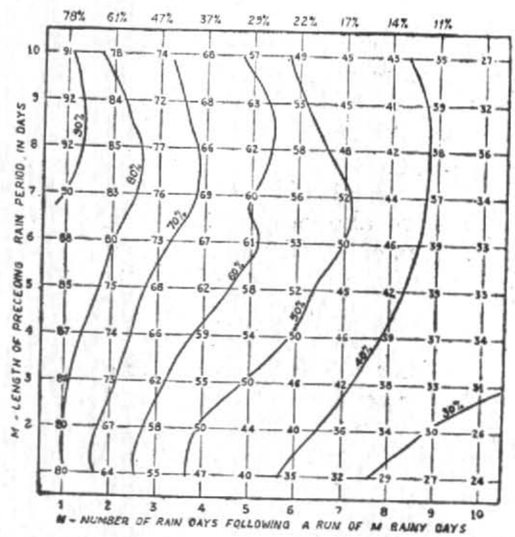

Fig. 4. Bombay (June to September)

Figs. 1-4. Isograms of percentage frequencies of different runs of rainy days

Percentages at the top of the diagrams indicate probability of N consecutive rain days expected on chance

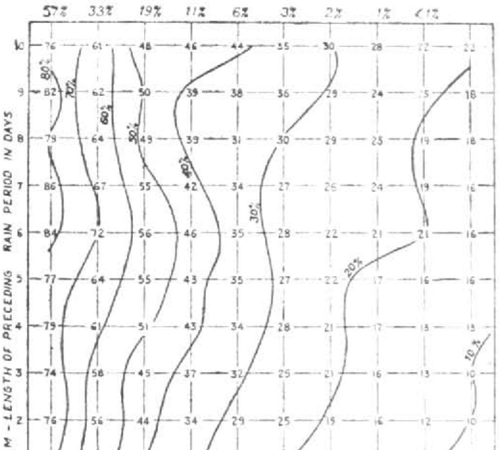

Fig. 5. Isograms of percentage frequencies of different runs of rainy days at Surat (June to September)

Percentages at the top of the diagram indicate probability of *N* consecutive rain days expected on chance

at the top of the figures indicate those expected on mere chance. The percentages on the body of the diagrams are derived from the "Cumulative totals" given in Table 1. Isolines of percentage frequency of occurrence of different runs of rain periods have also been drawn in the diagrams. From the diagrams the forecaster can read off the per cent of the time that "tomorrow" should be wet, following runs of wet periods of different lengths, on a persistence basis alone, after eliminating the per cent due to pure chance. Similarly the per cent times that 2 more, 3 more and other combinations of days will be rainy days, following a rain period of given length according to persistence factor alone, can easily be read off from the diagrams. Generally it appears that for the Konkan coast, during SW monsoon, the persistency increases with the length of preceding wet spell of lengths upto 7 to 9 days, except at Karwar where it shows a decrease after 4 to 5 days. Also higher persistency is found for longer runs of rainy days following.

2.5. For example, taking Bombay it will be noticed that there is a maximum percentage of persistence expectancy of at least one more day of rain after a preceding rain spell of 8 to 9 days. However, the maximum expectancy of 7 days more of rain, is after a preceding rain spell of 6 to 7 days. The value of the per cent to be ascribed solely to the persistence effect, is $92-78 = 14\%$ in the first case and $52-17 = 35\%$ in the latter case showing that the percentage of persistence factor increases.

3. Frequency distribution and persistence of runs of dry days during SW monsoon

A day receiving no measurable rain has been taken as a dry day. A run of dry days starting in one month and ending in another has been credited to the month with the greater portion of the spell, following the convention adopted by Lawrence (1957).

3.1. The observed frequencies and the cumulative frequencies (reverse) of runs of dry days for the monsoon season for the various stations have been given in Table 4. The frequencies of runs of dry days expected on chance, calculated by the method described in Section 2 have also been given in the table. It will be seen that during the SW monsoon period, runs of dry days exceeding 10 days are rare (less than 3%). The occurrence of runs of dry days lasting one and two days are less frequent than such spells expected purely on chance. The expected frequency of run of dry days purely on chance becomes less than 1 for runs of length 4 to 5 days at Karwar, Marmagoa, Ratnagiri and Bombay and for runs of length 9 days at Surat.

3.2. *Persistence of dry spells at stations*—Following the procedure described for the wet spells under Section 2·3, diagrams showing isolines of percentage frequency of occurrence of different runs of dry days following dry spells of different lengths during the monsoon season and for the different stations have been drawn (Figs. 6–10).

TABLE 4

Observed and cumulative frequency of occurrence of different runs of dry days and frequency expected on chance during SW monsoon

Length of runs in days	Karwar (1921—1938)			Marmagoa (1921—1950)			Ratnagiri (1921—1945)			Bombay (1921—1950)			Surat (1921—1950)		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
1	71	211·9	116	178	482·9	328	116	341·3	203	182	486·0	322	204	521·6	433
2	17	31·7	45	79	102·1	150	35	53·9	87	75	103·2	140	78	218·9	229
3	10	5·0	28	24	20·3	71	23	8·5	52	28	21·9	65	35	92·2	151
4	4	0·5	18	12	4·5	47	9	1·3	29	14	4·7	37	21	38·5	116
5	4	0·1	14	16	0·9	35	7	0·02	20	9	0·2	23	27	16·7	95
6	3		10	5	0·2	19	5		13	5	0·06	14	16	7·1	68
7	2		7	1		14	3		8	4		9	15	2·3	52
8	3		5	4		13	1		5	2		5	14	1·2	37
9	1		2	2		9	3		4	1		3	2	0·5	23
10	0		1	3		7	0		1	1		2	9	0·2	21
11	0		1	0		4	0		1	0		1	1		12
12	0		1	2		4	0		1	0		1	2		11
13	0		1	0		2	0		1	1		1	4		9
14	1		1	1		2	1		1				2		5
15				1		1							1		3
16													1		2
17													0		1
18													0		1
19													0		1
20													0		1
21													0		1
22													0		1
23													1		1
Total	116			328			203			322			433		

(*a*) Observed total, June—September; (*b*) Expected on chance, June—September; (*c*) Observed cumulative total (reverse)

3·3. It will be seen that the percentage of persistence factor decreases with the increased length of run of dry days that follow. As an example, taking Bombay, there is a maximum percentage expectance of at least 1 more day of dry period after a preceding spell of 6 days, the value of the per cent ascribed to the persistence being 64—21=43%. But for the 2-day period the maximum per cent corresponds to a preceding run of 5 dry days, the persistence value being 39—5=34%.

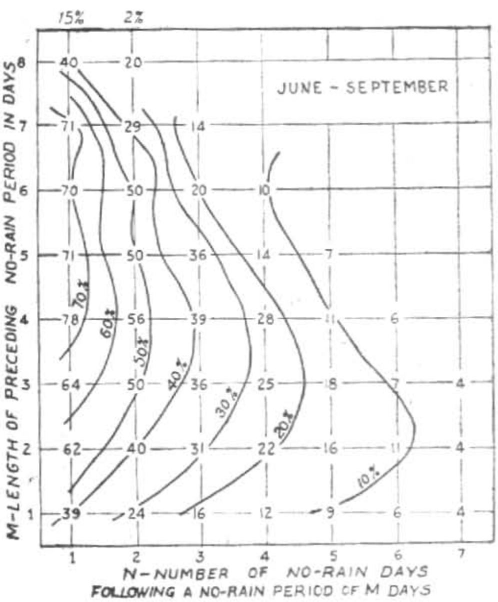

Fig. 6. Karwar

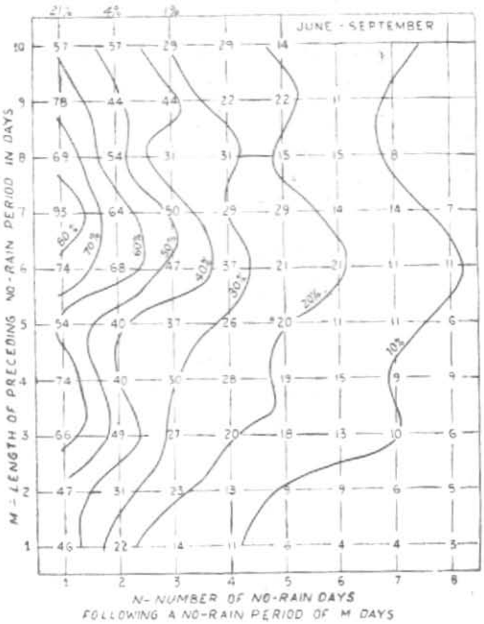

Fig. 7. Marmagoa

Figs. 6 and 7. Isograms of percentage frequencies of different runs of dry days

Percentages at the top of the diagrams indicate probability of N consecutive no-rain days expected on chance

4. Maximum possible "breaks" in the monsoon along the west coast of India from a study of maximum runs of dry days

In the foregoing sections, the nature of the distribution and persistency of the different lengths of runs of dry days and wet days have been discussed in detail. In this section the runs of dry days have been studied in a more detailed manner specially to find out the extreme value of their lengths which, on an average, will be exceeded once in 25,50 or 100 years, in respect of all the stations for each of the monsoon months, *viz.*, June to September. As the runs of dry days correspond generally to the "breaks" (interruptions) due to temporary withdrawals in the monsoon, an estimate of the possible extreme values of these will be of considerable utility in weather forecasting and for other planning purposes. Special interest attaches to prolonged dry periods especially during the rainy season as droughts are one of the problems of agriculture.

4.1. *Method*—Lawrence (1957) in his study of the maximum length of runs of dry spells for SE England used the extreme value distribution law as developed by Jenkinson (1955) for finding out the annual extreme values of meteorological elements which are exceeded once in a specified number of years. The same method has been adopted in the present study. The theory of the method is briefly as follows—

The probability that an annual maximum value exceeds x is $1-\exp\,[-e^{-y}]$ where $y = -\log_e f(x)$ and $f(x)$ is the average number of daily values $> x$.

If we assume that the same value is exceeded once in T years, the probability is

$$\frac{1}{T} = 1-\exp\,[-e^{-y}]$$

Hence we get $y = -\log_e \log_e \dfrac{T}{T-1}$ (3)

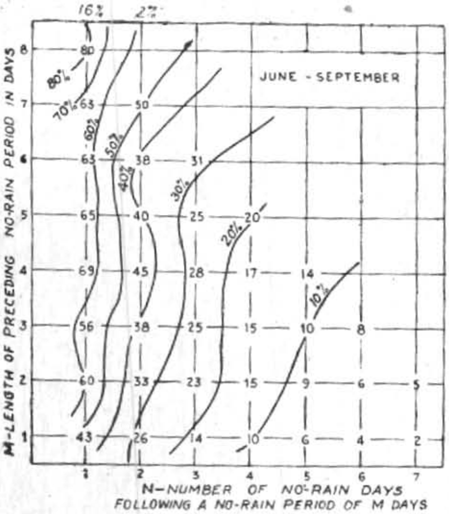

Fig. 3. Isograms of percentage frequencies of different runs of dry days at Ratnagiri

Percentages at the top of the diagram indicate probability of N consecutive no-rain days expected on chance

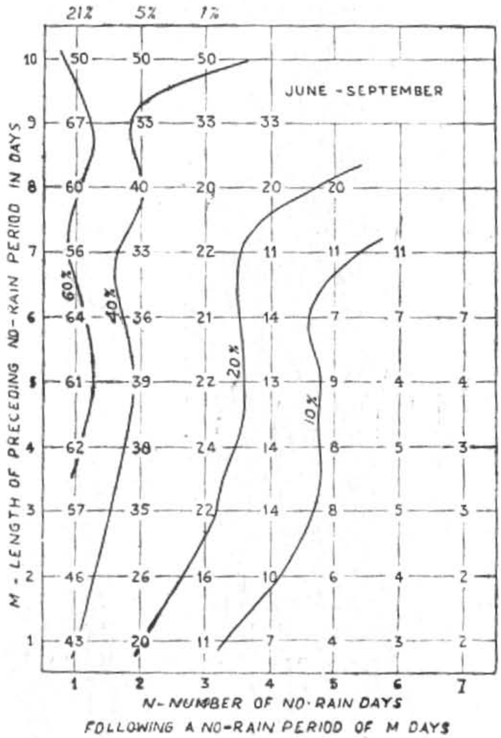

Fig. 9. Isograms of percentage frequencies of different runs of dry days at Bombay

Percentages at the top of the diagram indicate probability of N consecutive no-rain days expected on chance

Jenkinson by studying various types of (y, x) curves occurring in nature has suggested a general equation $x=a\,(1-e^{-ky})$ where y and T are connected by the equation (3). From this equation the annual maximum value x likely to be exceeded once in T years is given by the formula

$$\frac{x-\xi_1}{\sigma_1} = \frac{(k)! - \left\{\log_e \frac{T}{T-1}\right\}^k}{\{(2k)! - (k!)^2\}^{\frac{1}{2}}} \quad (4)$$

where the denominator has the sign of k and $(\sigma_1/\sigma_2) = 2^k$; ξ_1, σ_1 are average and standard deviation of annual maxima respectively and σ_2 is the standard deviation of the greater member in series of 2 annual maxima. Utilising these statistical parameters and Table 4 of Jenkinson's paper, the probable annual maximum value for any return period can be evaluated.

4·2. The values of ξ_1, σ_1 and (σ_1/σ_2) have been worked out for each of the months June to September for the five stations and are shown in Table 5. The values of maximum lengths of runs of dry days which are likely to be exceeded in 5, 10, 25, 50 and 100 years have also been computed and are given in the same table. It will be seen, that the mean and S.D. of maximum lengths of dry days, are smaller for the months of July and August than for the months June and September except in case of Marmagoa in August in which a doubtful observation of a run of 18 dry days in the year 1932 has increased its standard deviation considerably. Some trace of rain during this dry spell has been reported by the observatory. The daily rainfall data of the adjoining provincial

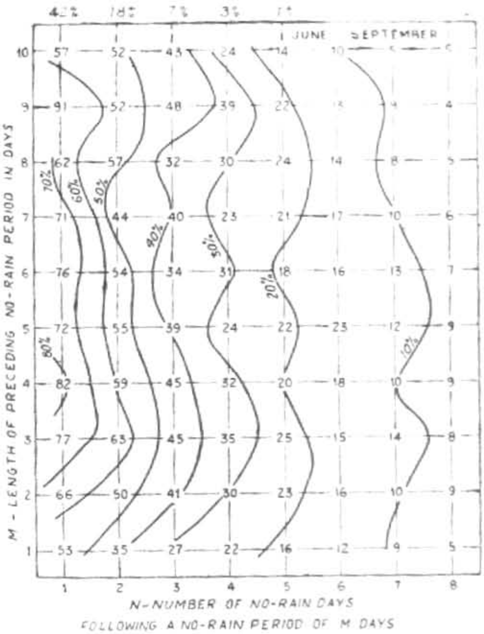

Fig. 10. Isograms of percentage frequencies of different runs of dry days at Surat

Percentages at the top of the diagram indicate probability of N consecutive no-rain days expected on chance

raingauge stations also indicate the impossibility of having a run of 18 dry days in August 1932 at Marmagoa.

4.3. The maximum possible breaks in the monsoon which are likely to be exceeded once in 100 years varies from 7 to 23 days for the month of June, 3 to 9 days for July, 7 to 14 days for August and 11 to 23 days for September, the breaks increasing in length as one proceeds towards the north to Surat.

5. Maximum possible runs of dry days from 1 May and 1 June and commencement of the rainy season

The normal dates of the establishment of the SW monsoon along the west coast of India has been studied statistically by Ramdas *et al.* (1954) based on observations of 60 years. The maximum run of dry days in each year from 1 May or 1 June invariably precedes the 'burst' or commencement of the SW monsoon along the west coast of India. In this section the monthly maximum runs of dry days during May and June for the various years have been analysed by the Jenkinson Probability Method described in Section 4 in order to find out the normal and latest possible dates of the end of the dry period or indirectly the onset of the monsoon.

5·1. The average maximum length of runs of dry days from 1 May or 1 June and its standard deviation as given in Table 5 provides an estimate of the normal dates of the end of the dry season and also an indirect inference about the date of commencement of the monsoon rains as well as its variability. The maximum length of run of dry days expected once in 50 or 100 years give an idea of the longest dry period and by inference the latest possible date of the onset of the monsoon. The dates as found out by this method and on this assumption along with the dates as worked out by Ramdas *et al.* (1954) are given in Table 6 for comparison.

It is interesting that the results show good agreement by the two different methods of study.

5.2. A rainy day, however, has been taken in this study as a day having any rain 0·01 inch or more. The end of a dry spell before the onset of the SW monsoon may be due to pre-monsoon thundershowers and the "burst" of the monsoon is usually associated with heavy rain and as such the dates of the end of a dry spell (or the onset of the monsoon) determined as above is likely to be an underestimate. A study of lengths of spells of days prior to defined threshold values of daily rainfall typical of a "burst of monsoon" is likely to give a better evaluation of the possible maximum dates of the end of such spells and also the probable dates of the bursting of the monsoon.

6. Concluding remarks

The study presented in this paper is only a pilot study and the same when extended to cover the whole of the Indian area, station

TABLE 5

Jenkinson probability calculation of maximum runs of dry days

	Average maximum length of runs in days ξ_1	Standard Deviation σ_1	σ_1/σ_2	Maximum length of runs likely to be exceeded once in T years (x)				
				T=5	T=10	T=25	T=50	T=100
KARWAR								
May	16·8	8·8	0·931	22·3	27·6	35·0	41·0	47·4
Jun	1·7	1·4	0·890	2·5	3·3	4·6	5·6	6·8
Jul	0·4	0·6	0·959	0·9	1·2	1·7	2·1	2·5
Aug	1·4	1·9	0·895	2·5	3·7	5·4	6·8	8·4
Sep	5·3	3·4	1·088	7·9	9·9	11·9	13·3	14·5
June (taking from 1 June)	2·5	2·1	0·996	4·0	5·2	6·7	7·9	9·0
MARMAGOA								
May	22·3	9·2	1·068	29·3	34·7	40·6	44·6	48·4
Jun	3·5	3·8	0·868	5·4	7·6	11·0	14·0	17·4
Jul	1·4	1·5	0·980	2·5	3·4	4·3	5·4	6·3
Aug	2·8	3·6	0·828	4·3	6·2	9·4	12·3	15·9
Sep	5·4	3·0	1·095	7·7	9·4	11·2	12·4	13·4
June (taking from 1 June)	4·4	3·7	0·914	6·6	8·8	12·0	14·6	17·4
RATNAGIRI								
May	26·8	9·4	1·269	35·1	38·9	42·5	44·5	46·1
Jun	2·4	2·9	0·849	3·8	5·5	8·1	10·4	13·2
Jul	0·6	0·8	0·927	1·1	1·6	2·3	2·8	3·4
Aug	1·7	1·7	0·898	2·7	3·7	5·2	6·5	7·9
Sep	4·4	2·3	1·080	6·1	7·4	8·8	9·7	10·6
June (taking from 1 June)	4·4	3·6	0·976	6·9	9·0	11·8	13·9	16·1
BOMBAY								
May	31·9	8·8	1·449	39·7	42·3	44·5	45·5	46·2
Jun	2·9	2·3	0·998	4·5	5·9	7·6	8·9	10·1
Jul	1·2	0·9	1·154	1·9	2·4	2·9	3·2	3·4
Aug	2·3	1·4	0·979	3·3	4·2	5·3	6·1	6·9
Sep	4·5	2·7	0·977	6·4	8·0	10·1	11·7	13·4
June (taking from 1 June)	6·2	3·4	1·194	8·9	10·7	12·2	13·2	14·0
SURAT								
May	39·0	8·0	1·294	46·1	49·2	52·1	53·7	54·9
Jun	6·4	4·3	1·270	10·2	11·9	13·5	14·5	15·2
Jul	2·8	2·2	1·019	4·4	5·7	7·2	8·3	9·4
Aug	4·4	3·0	1·015	6·5	8·3	10·4	11·9	13·5
Sep	8·4	4·1	0·933	11·0	13·5	16·9	19·6	22·6
June (taking from 1 June)	11·3	4·8	1·156	15·1	17·8	20·2	21·8	23·1

TABLE 6

Date of onset of the southwest monsoon

	Karwar	Marmagoa	Ratnagiri	Bombay	Surat
Mean date of establishment	June 4	June 7	..	June 8	..
Standard deviation in days (as given by Ramdas *et. al.* 1954)	6·3	6·0	..	6·1	..
Average date as determined in this study	June 4	June 5	June 5	June 7	June 12
Standard deviation in days	2·1	3·7	3·6	3·4	4·8
Latest date likely to be exceeded once in years (as calculated)					
25 years	June 8	June 13	June 13	June 13	June 21
50 years	June 9	June 15	June 15	June 14	June 23
100 years	June 10	June 18	June 17	June 15	June 24
Date of ending of the longest dry spell during period studied	June 6	June 7	June 11	June 12	June 21

by station or district by district, will on the basis of existing persistence help to solve many problems in climatology and hydrometeorology, and place in the hands of weather forecasters a tool which will help them in local forecasting and for issuing *Farmers Weather Bulletins* with outlook of weather for next 2 or 3 days on the basis of persistence. This study also discusses a method of evaluating the most probable value of the maximum value of the meteorological elements on the basis of extreme values observed for meeting the enquiries from planning and design engineers.

7. Acknowledgement

The authors wish to thank Shri B. N. Sreenivasaiah, Deputy Director General of Observatories, Climatology and Geophysics, Poona and Shri K. N. Rao, Director, Regional Meteorological Centre, Bombay for their encouragement while the study was in progress, and to Shri V. S. Sarma for help in processing of the data.

REFERENCES

Cochran, W. G. 1938 *Quart. J. R. met. Soc.*, **64**, p. 631.

Bizley, M. T. L. 1957 *Probability—An intermediate text book*, Camb. Univ. Press, London, p. 156.

Jenkinson, A. F. 1955 *Quart. J. R. met. Soc.*, **81**, p. 158.

Jorgensen, D. L. 1949 *Mon. Weath. Rev., Wash.*, **77**, p. 303.

Lawrence, E. N. 1957 *Met. Mag., Lond.*, **86**, p. 257.

Ramdas, L. A., Jagannathan, P. and Gopal Rao, S. 1954 *Indian J. Met. Geophys.*, **5**, p. 305.