Mausam, (1983), 34, 2, 179-184

551.578.42 : 551.553.21(547)

The sub-divisional rainfall distribution across the Western Ghats during the southwest monsoon season

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(Received 19 November 1979)

सार — इस शोधपत्र में मानसून ऋतु (जून से मध्य सितम्बर तक) में सात वर्षों (1970-1976) में समूचे पश्चिमी घाटों पर वर्षा की स्थिति का परीक्षण किया गया है । परिमाणतः घाटों के दोनों ओर के मौसमवैज्ञानिक उपमण्डलों की साप्ताहिक माध्यवर्षा के साथ उत्तरी और केन्द्रीय खण्डों की वर्षा का धनात्मक सहसंबंध है लेकिन दक्षिणी खण्ड की वर्षा का ऋणात्मक । ये तीनों महसंबंधों एक प्रतिशत स्तर तक सार्थक हैं । घाटों क उत्तरी और दक्षिणी भागों म हुए सहसंबंध के इस रोचक परिवर्तन का स्पष्टीकरण सिनॉप्टिक विश्लेषण की सहायता से प्रस्तुत किया गया है ।

ABSTRACT. The behaviour of rainfall across the entire length of the Western Ghats has been examined for the monsoon season (June to mid-September) for a period of 7 years (1970-1976). It is found that the relation between weekly mean rainfall of the meteorological sub-divisions on either side of the Ghats is one of positive correlation in the northern and central sectors and of negative correlation in the southern sector. All these three correlations are significant at 1% level. An explanation for the interesting change in the correlation from north to south of the Ghats is presented on the basis of synoptic analysis.

1. Introduction

The difference in the amounts of rainfall across an extensive mountatin range is a subject of considerable meteorological interest. The Western Ghats, which run almost parallel to the west coast of India, provide a suitable region for such studies during the southwest monsoon season when the low-level winds blow almost across the massive mountain barrier. The influence of mountain waves in the distribution of rainfall across the Western Ghats has been brought out by Sarker (1965). In this paper the simultaneous weekly mean rainfall in meteorological sub-divisions on either side of the Ghats has been studied for the northern sector, central sector and southern sector.

2. Orographic features

The Western Ghats run almost parallel to the west coast of Peninsular India leaving a narrow strip of plain land between the Ghats and the Arabian Sea. The orographic features of the mountainous region are presented in Fig. 1. The lay-out of the meteorological sub-divisions, adjoining the east and west sides of the Ghats, which have been considered for the present study are also shown in this figure together with the locations of some important observatory stations whose data have been used in this study. For the convenience of the present study, the Ghat section has been divided into the following three sectors comprising pairs of meteorological sub-divisions across and adjoining the Ghats, namely,

(*i*) *Northern sector* — Konkan to the west and Madhya Maharashtra to the east;

(*ii*) *Central sector* — Coastal Karnataka to the west and Interior Karnataka (north and south) to the east and

(*iii*) *Southern sector* — Kerala to the west and Tamil Nadu to the east.

In the northern and central sectors, the average elevation of the Ghats is about 600 to 900 metres. At a few places like Mahabaleshwar etc, the elevation rises to 1500 metres. In the southern sector, the Ghats have an average elevation of about 1000 metres but at Dodebetta and Anaimudi peaks the elevation rises to about 2200 to 2500 metres. Considerable difference exists between the east side slopes of the Ghats in the northern, central and the southern sectors. In the northern and central sectors, the slope is gradual and gentle towards the Deccan and Mysore plateau while in the southern sector the slope is large and abrupt towards the plains of Tamil Nadu. Two

TABLE 1

Correlation coefficients of rainfall between pairs of sub-divisions

Sector (Sub-divisional pairs)	No. of weeks covered	Mean rain-fall (mm)	Coefficient of cor-relation
Northern (Konkan & Madhya Maharashtra)	113	146.9 22.1	+.67
Central [Coasta Karna-taka and Interior Karnataka (North & South)]	113	186.8 23.5	+.30
Southern (Kerala and Tamil Nadu)	113	90.4 13.4	—.25

Note — The correlation coefficient are found to be significant at 1% level.

sections across the Ghats, one at 17°30′ N and the other at 11°30′N are presented in Fig. 2(a) and Fig. 2(b) respectively to bring out these features.

3. Data material and analysis

Weekly mean rainfall data of the three pairs of meteorological sub-divisions across and adjoining the Ghats (mentioned in section 2) as published in the *Weekly Weather Reports* of India Meteorological Department have been used for this study. In all 113 values of weekly rainfall for each of the three pairs of sub-divisions from June to mid-September covering the period 1970 to 1976 were extracted and correlation coefficients (C.C.) between each pair of sub-division were worked out. The values of C.C. are given in Table 1.

4. Discussions

An examination of the coefficients of correlation of simultaneous weekly rainfall between the pairs of sub-divisions across the Western Ghats (presented in Table 1), brings out some interesting features.

The coefficients are positive in the northern and central sectors with a southward decreasing tendency. Moving still further southwards into the southern sector a reversal occurs and the coefficient becomes negative. This means that in the northern sector when the weekly rainfall is above normal in one of the pair of sub-divisions, the rainfall is above normal in the other also. For example, when weekly rainfall happens to be above normal in Konkan, it is also above normal in Madhya Maharashtra as well and *vice-versa*. But, in the southern sector the trend of rainfall is reversed. That is, when Kerala experiences above normal rainfall in a particular

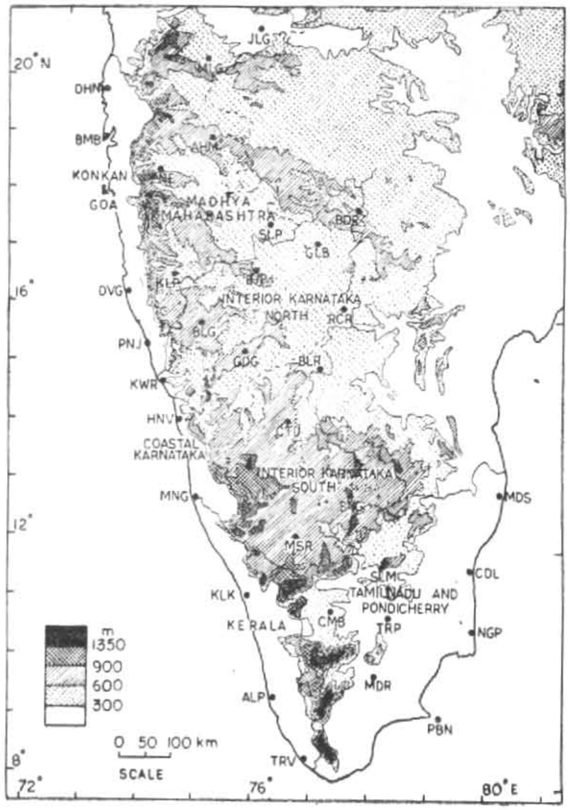


Fig. 1. Orographic features of Peninsular India showing the meteorological sub-divisions adjoining Western Ghats

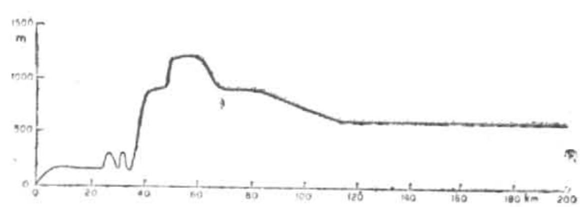


Fig. 2 (a). Variation of contour heights from the coast at 17° 30′ N latitude

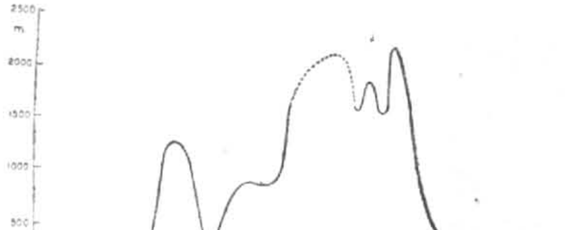
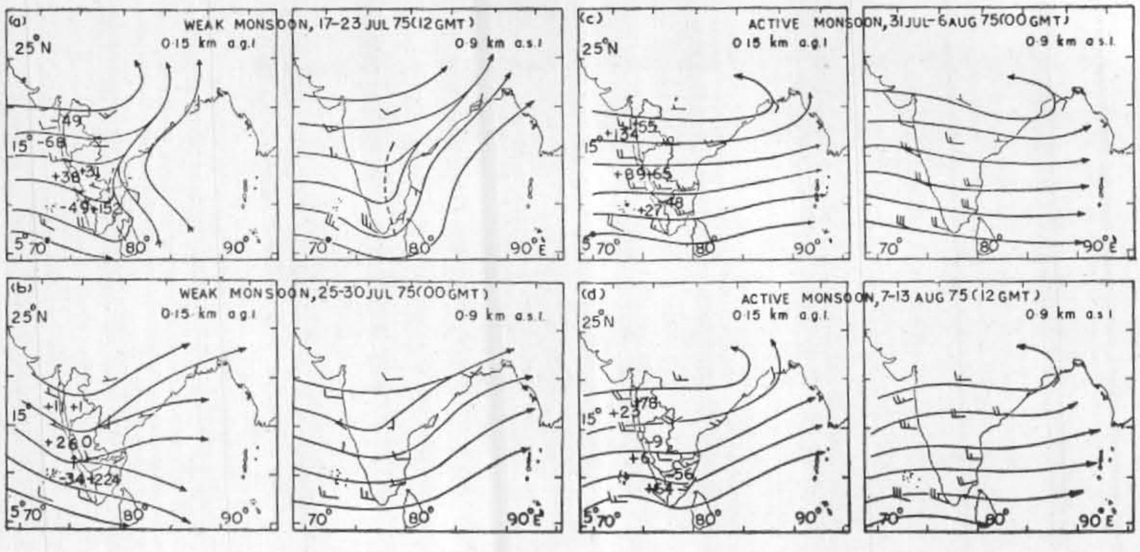


Fig. 2 (b). Variation of contour heights from the coast at 11° 30′ N latitude



Figs. 3 (a-d). Mean flow patterns

(Note : The figures shown against the sub-divisions indicate the percentage departure of rainfall

week, rainfall in Tamil Nadu is below normal in that week and *vice-versa.* It is necessary to emphasise here that the above trends in rainfall across the Ghats in different sectors have been identified statistically on the basis of a sample containing as many as 113 weeks (1970-1976) and the C.Cs. obtained therefrom are found to be significant at 1% level. The above trends are, therefore, not expected to be spurious in nature, and should have some realistic basis. An attempt has been made in the following paragraphs to understand the basis of the interesting change in the trend of rainfall across the Ghats that takes place from the northern to the southern sectors from synoptic point of view.

4.1. *Synoptic features*

Charts depicting the mean upper air circulation pattern at low levels from 0.15 km a.g.l. to 2.1 km a.s.l. for some selected weeks when monsoon was active and weak during the period under study were specially prepared from the daily wind data for 00 and 12 GMT hours. These mean weekly low-level charts were then carefully analysed. An interesting feature was observed. In the mean flow patterns at 12 GMT for the weeks representing weak monsoon phase, invariably a well marked trough in the westerlies extending from ground level upto 1.5 km a.s.l. was seen in the southern sector and adjoining areas of the northern sector roughly between 77°E and 79°E and 6° to 12°N. On most occasions, this trough lay in a south to north direction across Tamil Nadu but on some occasions it extended into South Interior Karnataka and thereafter aligned itself southwestwards across Andhra Pradesh. In some weak monsoon phases, this trough was quite conspicuous even in the morning (00 GMT) but in others it was not so although its existence could be traced. On the other hand, this trough could not be traced on most occasions in the mean weekly flow patterns representing active to vigorous monsoon epochs. A typical mean flow pattern at 12 GMT representing a weak monsoon phase is shown in Fig. 3(a). The trough (indicated by thick dotted-line) can clearly be seen both at 0.15 km a.g.l. and 0.9 km a.s.l. But in another mean flow pattern in the morning at 00 GMT Fig. 3(b), also representing a weak monsoon phase, the trough does not clearly extend into Tamil Nadu but it is more marked over Interior Karnataka in the northern sector. However, by evening (12 GMT), the trough becomes well-marked over Tamil Nadu also (figure not shown).

A typical mean flow pattern in the morning at 00 GMT for an active monsoon phase is shown in Fig. 3(c). Here no trough in the westerlies can be seen both at 0.15 km a.g.l. and 0.9 km a.s.l. Another mean flow pattern in the evening (at 12 GMT), also representing an active monsoon phase, is shown in Fig. 3(d). Here, although near the ground level (0.15 km a.g.l.) there is some suggestion of a feeble trough in the westerlies over Tamil Nadu, aloft at 0.9 km a.s.l. this trough is not detectable.

4.2. *Influence of the low-level trough*

During the weak monsoon phase, the presence of the well-marked trough in the evening at the low levels throughout the period over Tamil Nadu and adjoining areas leads to sustained convective activity and increased rainfall in that area particularly during evening and night. Thus, during a weak monsoon phase, the rainfall over Kerala decreases in the normal way but that over Tamil Nadu increases on account of the presence of the low-level trough. On the other hand, during an active monsoon phase while the rainfall

TABLE 2

Percentage number of days wind from different directions at 1700 hours (based on data for 1931-60)

Station	Month	E+SE+S	SW	W	Station	Month	E+SE+S	SW	W
Playamkottai	June	1	12	72	Madras	June	75	8	11
	July	4	6	78		July	61	13	19
	August	8	3	75		August	68	9	13
	September	17	9	60		September	71	8	10
Pamban	June	58	41	1	Gulbarga	June	6	26	44
	July	67	29	3		July	3	25	53
	August	82	17	0		August	2	17	52
	September	81	17	1		September	12	11	32
Madurai	June	7	22	48	Bijapur	June	4	28	41
	July	10	22	43		July	1	26	46
	August	16	19	33		August	2	17	50
	September	28	12	20		September	5	12	39
Nagapatinam	June	45	45	9	Belgaum	June	6	40	42
	July	45	36	16		July	7	35	51
	August	56	30	10		August	7	34	52
	September	64	24	9		September	6	26	53
Trichirapally	June	5	9	67	Gadag	June	1	2	34
	July	4	7	70		July	0	0	31
	August	13	7	53		August	1	0	26
	September	19	9	31		September	6	1	21
Coimbatore	June	30	49	19	Pune	June	3	18	66
	July	25	51	22		July	0	14	77
	August	27	51	21		August	0	10	78
	September	33	46	13		September	2	8	62
Salem	June	12	33	37	Sholapur	June	3	53	18
	July	9	26	42		July	2	62	17
	August	11	27	27		August	2	52	19
	September	14	18	31		September	5	25	18
Cuddalore	June	58	24	11	Miraj	June	3	22	61
	July	51	26	16		July	0	17	68
	August	61	16	13		August	1	13	64
	September	69	11	7		September	4	9	56
Vellore	June	7	28	30	Aurangabad	June	8	14	56
	July	7	28	35		July	1	16	70
	August	13	23	27		August	1	11	68
	September	18	19	19		September	4	8	36

TABLE 3

Number of days of thunderstorm

Station	No. of days of precipitation 0.3 mm or more				No. of days of thunder			
	June	July	August	September	June	July	August	September
Vellore	7	9	11	10	4	3	4	4
Cuddalore	6	9	11	9	3	3	5	5
Salem	9	13	13	12	6	6	8	8
Coimbatore	8	11	7	5	1.0	0.6	1.9	3
Madurai	3	6	9	8	3	2	5	4
Pamban	0.7	1.7	1.3	1.9	0	0	0	0.3
Madras	9	14	15	11	5	5	7	8
Tiruchirapaly	3	4	7	8	3	3	7	6
Ahmednagar	11	12	10	12	1.3	0.1	0.2	1.1
Pune	13	24	23	14	3	0.3	0.9	4
Sholapur	11	16	15	15	4	1.4	1.6	4
Miraj	10	19	18	12	3	0.3	1.1	2
Aurangabad	13	19	18	14	7	1.9	2	4
Bidar	12	19	16	14	1.9	0.8	0.7	1.5
Gulbarga	9	16	13	13	3	0.3	0.9	3
Bijapur	9	12	11	11	1.7	0.4	0.9	0.2
Belgaum	19	27	25	17	1.7	0.1	1.2	2
Gadag	9	15	14	11	2	0.6	5	3
Chitradurga	10	16	15	11	1.1	0.1	0.9	3
Mysore	10	16	13	10	2	0.8	2	3
Bangalore	13	18	18	15	4	2	4	4

over Kerala increases in the normal way on account of large scale orographic ascent of the moisture laiden air, Tamil Nadu gets very little rain in absence of the low-level trough which appears only during weak monsoon phase. This explains the negative correlation in the rainfall between Kerala and Tamil Nadu particularly in the weak phases of the southwest monsoon.

As mentioned earlier, during the weak phases of the monsoon, the low-level trough sometimes extend into Interior Karnataka as well particularly in the evening but rarely does it penetrate into Madhya Maharashtra. In other words, so far as rainfall distribution across the Ghats is concerned, the influence of the trough is sometimes felt as far as Interior Karnataka but rarely further northwards over Madhya Maharashtra. This feature may perhaps, to some extent, account for the decreasing trend in the correlation coefficient from north to south in the northern and central sectors, finally becoming negative in the southern sector.

The establishment of the well-marked trough in the low levels over Tamil Nadu would mean more frequent presence of southerly to easterly surface winds over the southern sector than over the northern sector. Whether this happens actually during the southwest monsoon season was examined. In Table 2, the percentage number of days of wind from different directions at a few stations in the two sectors based on long term climatological data (1931-1960) is presented. The percentage frequencies of days with surface winds from east, southeast and south are between 5 & 10 for stations situated in northern sector while those for the same wind directions are between 10 & 20 for stations in the southern sector. The coastal stations in the southern sector like Madras, Cuddalore, Nagapattinam experience winds from east, southeast and south directions very frequently on an average of 50 to 75% occasions. Thus winds from east, southeast and south are more common at stations in the southern sector than in the northern sector.

4.3. *Influence of thunderstorm activity*

Penetration of southeasterlies deep inland during weak monsoon periods can help to release the latent instability in the atmosphere generated in the region around the low-level trough and trigger off fairly widespread thunderstorm activity during evening and night over Tamil Nadu.

During strong monsoon periods, the southeasterlies would be absent and there will be a lull in the thunderstorm activity over Tamil Nadu. in the northern sector, however, this does not happen whether the monsoon is weak or strong. Table 3 brings out this aspect. Thunderstorm activity is more in the southern sector than in the northern sector during the southwest monsoon season.

5. Conclusions

(1) This study reveals that the weekly rainfall between a pair of sub-divisions across and adjoining the Western Ghats during the southwest monsoon season is not everywhere positively correlated along the entire length of the mountain barrier. This relationship varies from one region to the other. In the northern sector between the pair of sub-divisions Konkan and Madhya Maharashtra the correlation coefficient is found to be +.67. Moving southwards in the central sector the C. C. between pair of sub-divisions, coastal Karnataka and Interior Karnataka remains positive but decreases to value of +.30. But moving still southwards, into the southern sector, the relationship reverses and a negative correlation of .25 is obtained between Kerala and Tamil Nadu The C. Cs. are all found significant at 1 per cent level.

(2) The southward decrease of C. C. in the northern sector and its reversal into a negative value in the southern sector may be due to the presence of a low-level trough in the westerlies across Tamil Nadu during weak monsoon epochs.

(3) The relationship in the weekly rainfall between the pairs of sub-divisions across the Western Ghats may serve as an useful tool to predict rainfall distribution across different regions of the Ghats both in weak and strong monsoon phases.

Acknowledgement

The authors are grateful to Dr. R. P. Sarker, Deputy Director General of Meteorology (Climatology & Geophysics) for his encouragement.

References

India Met. Dep., 1967, *Climatological Tables of Observatories in India (1931-1960).*

Sarker, R.P., 1965, *Indian J. Met. Geophys.*, **16**, pp. 673-684.