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Seasonal features of the spatial distribution of rainfall in pre-partitioned India

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ABSTRACT. The spatial distribution of rainfall in accordance with the practice prevalent in the India Meteorological Department, *viz.*, "few falls", "local" and "widespread" during the four seasons and the whole year in the different meteorological sub-divisions of the pre-partitioned India have been studied with a view to find any common features that may exist between the three types of rainfall distribution. Distribution of total number of rainy days in the various meteorological sub-divisions during the four seasons and the year have also been discussed.

1. Introduction

In a country like India where agriculture depends for its success much upon the rainfall and its distribution, the spatial distribution of rainfall forms an interesting and important part of the study of the problem of rainfall. In an earlier study of the problem of the spatial distribution of rainfall, the author (Sinha 1952) made an analysis of the monthly frequencies of the "widespread", "local" and "few falls" of rain, occurring in the individual meteorological sub-divisions of pre-partitioned India. Some inter-connecting features of the three types of rainfall distribution, and the seasonal distribution over the different parts of the country in respect of the days of widespread, local and few falls of rain and the total number of days of rainfall of the meteorological sub-divisions are discussed in this paper.

2. Data

The basic data employed here are the daily rainfall data of the meteorological observatories, published in the *Indian Daily Weather Reports* during the ten years from 1930—1939. Some refinements of the results might accrue if both these observatories and the state raingauge stations could be taken into consideration. Hariharan (1956) made an analysis of the spatial distribution of rainfall in respect of one or two meteorological sub-divisions, based on (*i*) the India Meteorological Department observatories and (*ii*) both the India Meteorological Department observatories and the State raingauge stations, to exhibit the differences that might be noticeable in the two cases. It may be inferred from the analysis that with the increase in the network of the stations, there is an increase in the number of occasions of scattered rainfall and a decrease in the other types of the rainfall distribution. Although it may be desirable to consider more years of data and the data of all the rainfall recording stations for detailed study, ten years data of the India Meteorological Department observatories may be taken to serve the purpose of bringing out the general features of the spatial distribution of the rainfall.

3. Frequencies of 'widespread', 'local' and 'few falls' of rain in different seasons

The average number of days of the three types of rainfall distribution for the different seasons (1) winter period covering the months of December to March, (2) the pre-monsoon period of April and May, (3) the monsoon period comprising the months of June to September, (4) the post-monsoon period of October and November and also for the year is given in Table 1.

TABLE 1

Average number of days of 'widespread', 'local' and 'few falls' of rain during the different seasons and the year

S. No.	Meteorological sub-divisions	Rainfall distribution	No. of days				
			Winter	Pre-monsoon	Monsoon	Post-monsoon	Whole year
1	Assam	Few falls	**23·1**	17·3	20·6	12·0	73·0
		Local	6·7	16·1	40·3	6·2	69·3
		Widespread	3·3	15·5	**52·9**	5·1	**76·8**
		Total	33·1	48·9	113·8	23·3	219·1
2	Bengal	Few falls	**16·9**	**23·9**	26·7	**15·8**	**83·3**
		Local	3·8	12·9	49·2	6·6	72·5
		Widespread	0·3	3·9	44·4	3·1	51·7
		Total	21·0	40·7	120·3	25·5	207·5
3	Orissa	Few falls	6·8	9·3	27·1	7·7	50·9
		Local	3·9	5·4	36·7	6·5	52·5
		Widespread	1·6	2·2	**37·9**	4·5	46·2
		Total	12·3	16·9	101·7	18·7	149·6
4	Chota Nagpur	Few falls	6·0	6·1	21·7	3·3	37·1
		Local	3·5	2·6	24·8	2·9	33·8
		Widespread	4·3	2·5	**46·4**	4·6	**57·8**
		Total	13·8	11·2	92·9	10·8	128·7
5	Bihar	Few falls	4·3	8·6	24·7	3·8	41·4
		Local	3·6	4·9	42·2	3·9	54·6
		Widespread	2·0	0·5	30·3	1·7	34·5
		Total	9·9	14·0	97·2	9·4	130·5
6	United Provinces, East	Few falls	4·0	4·5	19·5	2·6	30·6
		Local	4·7	1·9	36·2	2·7	45·5
		Widespread	2·7	0·5	31·9	1·3	36·4
		Total	11·4	6·9	87·6	6·6	112·5
7	United Provinces, West	Few falls	6·5	5·5	21·9	2·7	36·6
		Local	7·5	3·2	40·9	1·4	53·0
		Widespread	3·5	0·6	27·4	0·7	32·2
		Total	17·5	9·3	90·2	4·8	121·8
	Punjab, East and North	Few falls	8·8	6·4	21·5	3·6	40·3
		Local	9·9	5·0	34·9	1·3	51·1
		Widespread	4·9	0·7	11·7	0·1	17·4
		Total	23·6	12·1	68·1	5·0	108·8
9	Punjab, Southwest	Few falls	8·2	3·7	15·8	0·8	28·5
		Local	3·7	1·7	10·9	0·2	16·5
		Widespread	2·0	0·2	2·3	0·0	4·5
		Total	13·9	5·6	29·0	1·0	49·5
10	Kashmir	Few falls	14·3	8·2	29·6	5·9	58·0
		Local	24·3	13·6	13·6	4·8	56·3
		Widespread	9·7	4·2	2·2	0·8	16·9
		Total	48·3	26·0	45·4	11·5	131·2
11	Northwest Frontier Province	Few falls	11·7	10·7	23·2	4·0	49·6
		Local	10·9	7·1	13·5	2·5	34·0
		Widespread	8·6	3·4	2·0	0·2	14·2
		Total	31·2	21·2	38·7	6·7	97·8
12	Baluchistan	Few falls	16·4	7·4	17·7	1·3	42·8
		Local	10·3	2·5	2·5	0·0	15·3
		Widespread	3·9	0·2	0·0	0·0	4·1
		Total	30·6	10·1	20·2	1·3	62·2

NOTE—The type of rainfall distribution having the highest frequency in the different seasons and the year is given in bold types

TABLE 1 (*contd*)

S. No.	Meteorological sub-divisions	Rainfall distribution	No. of days				
			Winter	Pre-monsoon	Monsoon	Post-monsoon	Whole year
13	Sind	Few falls	2·4	1·6	4·2	0·8	9·0
		Local	2·5	0·7	5·7	0·0	8·9
		Widespread	0·6	0·0	1·6	0·0	2·2
		Total	5·5	2·3	11·5	0·8	20·1
14	Rajputana, West	Few falls	1·3	0·5	5·5	0·5	7·8
		Local	1·3	2·0	15·3	0·7	19·3
		Widespread	1·2	0·8	8·5	0·4	10·9
		Total	3·8	3·3	29·3	1·6	38·0
15	Rajputana, East	Few falls	4·5	2·5	19·2	2·6	28·8
		Local	2·4	2·0	27·6	1·4	33·4
		Widespread	0·2	0·3	15·0	0·5	16·0
		Total	7·1	4·8	61·8	4·5	78·2
16	Gujarat	Few falls	2·9	2·2	33·9	5·3	44·3
		Local	0·2	0·1	25·7	1·8	27·8
		Widespread	0·1	0·2	12·8	0·1	13·2
		Total	3·2	2·5	72·4	7·2	85·3
17	Central India, West	Few falls	3·6	3·3	19·7	2·7	29·3
		Local	1·6	1·0	21·5	1·7	25·8
		Widespread	0·6	0·2	33·1	1·7	35·6
		Total	5·8	4·5	74·3	6·1	90·7
18	Central India, East	Few falls	..	..	..	..	..
		Local	4·6	3·4	34·0	2·7	44·7
		Widespread	2·3	0·6	28·7	1·1	32·7
		Total	6·9	4·0	62·7	3·8	77·4
19	Central Provinces, West	Few falls	10·1	7·3	24·0	4·4	45·8
		Local	3·4	2·6	34·0	3·6	43·6
		Widespread	1·3	0·7	42·9	2·9	47·8
		Total	14·8	10·6	100·9	10·9	137·2
20	Central Provinces, East	Few falls	9·6	10·5	23·0	9·0	52·1
		Local	4·7	4·6	41·0	5·3	55·6
		Widespread	1·2	1·2	38·1	2·1	42·6
		Total	15·5	16·3	102·1	16·4	150·3
21	Konkan	Few falls	0·8	2·8	10·9	7·3	21·8
		Local	0·3	2·2	19·0	4·4	25·9
		Widespread	0·4	1·2	80·0	6·2	87·8
		Total	1·5	6·2	109·9	17·9	135·5
22	Bombay Deccan	Few falls	6·4	11·7	44·4	10·8	73·3
		Local	0·8	4·0	39·4	9·2	53·4
		Widespread	0·3	0·5	14·2	2·8	17·8
		Total	7·5	16·2	98·0	22·8	144·5
23	Hyderabad, North	Few falls	..	..	..	..	..
		Local	6·4	5·6	32·6	6·9	51·5
		Widespread	1·4	1·5	40·2	4·5	47·6
		Total	7·8	7·1	72·8	11·4	99·1
24	Hyderabad, South	Few falls	4·8	7·6	27·4	6·5	46·3
		Local	1·5	2·4	24·5	3·6	32·0
		Widespread	0·6	1·0	19·8	4·3	25·7
		Total	6·9	11·0	71·7	14·4	104·0

NOTE—The type of rainfall distribution having the highest frequency in the different seasons and the year is given in bold types

TABLE 1 (*contd*)

S. No.	Meteorological sub-divisions	Rainfall distribution	No. of days				
			Winter	Pre-monsoon	Monsoon	Post-monsoon	Whole year
25	Mysore	Few falls	4·7	8·5	5·5	6·2	24·9
		Local	1·4	7·7	33·0	7·7	49·8
		Widespread	0·6	4·5	22·3	9·4	36·8
		Total	6·7	20·7	60·8	23·3	111·5
26	Malabar	Few falls	13·7	14·6	17·9	14·5	60·7
		Local	2·4	8·2	19·5	10·3	40·4
		Widespread	0·9	9·8	71·9	13·9	96·5
		Total	17·0	32·6	109·3	38·7	197·6
27	Madras, Southeast	Few falls	23·7	19·9	56·9	23·1	123·6
		Local	7·1	3·0	13·1	16·9	40·1
		Widespread	2·7	1·1	1·0	8·4	13·2
		Total	33·5	24·0	71·0	48·4	176·9
28	Madras, Deccan	Few falls	2·6	6·7	24·1	9·2	42·6
		Local	2·0	3·8	19·6	7·1	32·5
		Widespread	0·4	1·9	11·8	5·0	19·1
		Total	5·0	12·4	55·5	21·3	94·2
29	Madras Coast, North	Few falls	7·7	5·4	36·0	11·8	60·9
		Local	2·9	3·7	34·9	11·5	53·0
		Widespread	0·4	0·7	9·8	8·1	19·0
		Total	11·0	9·8	80·7	31·4	132·9

NOTE—The type of rainfall distribution having the highest frequency in the different seasons and the year is given in bold types

During the southwest monsoon there is a large increase in the days of widespread or local rain for most of the areas outside West Pakistan and Kashmir where there is an increase in the days of few falls of rain. The areas having the higher frequencies of widespread precipitation are Kashmir and the Northwest Frontier Province during the winter period, Assam and Malabar in the pre-monsoon period and the southern parts of the Peninsula in the post-monsoon period. During the southwest monsoon period, the west coast of the Peninsula, northeastern parts of India and the central parts of India and the adjoining parts are the areas of predominantly high incidence of widespread rainfall.

4. Type of rainfall distribution having maximum frequencies

The type of rainfall distribution which has the highest average in the different seasons for the meteorological sub-divisions has been indicated in bold figures in Table 1.

There is a predominance of the few falls of rain or local rain in most of the areas in most of the seasons. In the case of Malabar, the Konkan, north Hyderabad, the west Central Provinces, west Central India, Chota Nagpur, Orissa and Assam, the frequency of widespread rain, however, becomes higher than the other two types of rainfall distribution during the southwest monsoon. Chota Nagpur and Mysore have also higher occasions of widespread rain in the post-monsoon period.

5. Three types of rainfall distribution for the year as a whole

Distribution of the three types of rainfall for the year as a whole is shown diagramatically in Fig. 1. East Central India and north Hyderabad have not been included in the diagram as no significant information regarding the three types of rainfall distribution could be derived due to the paucity of the rainfall stations over these areas.

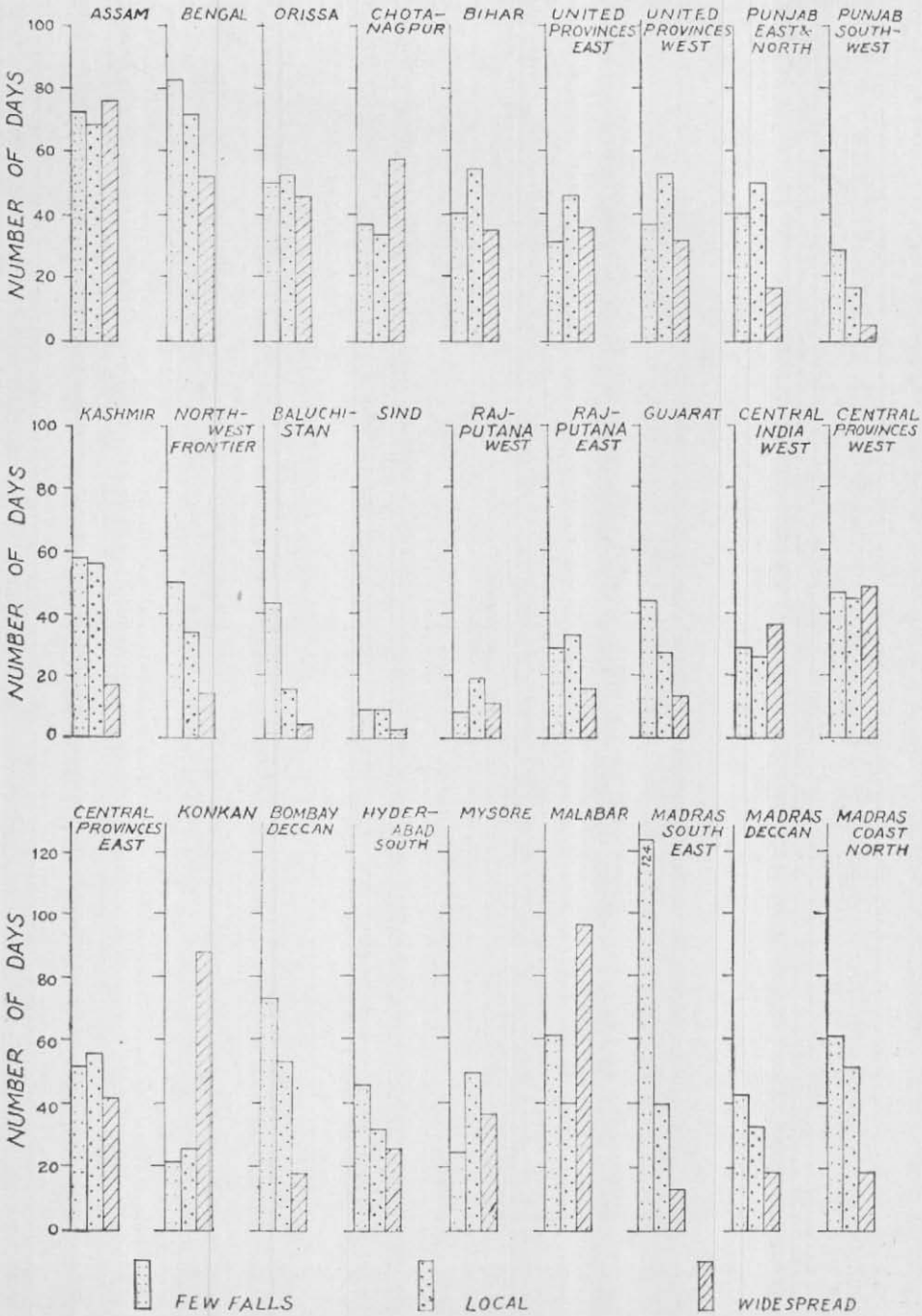

Fig. 1. Three types of rainfall distribution for the year

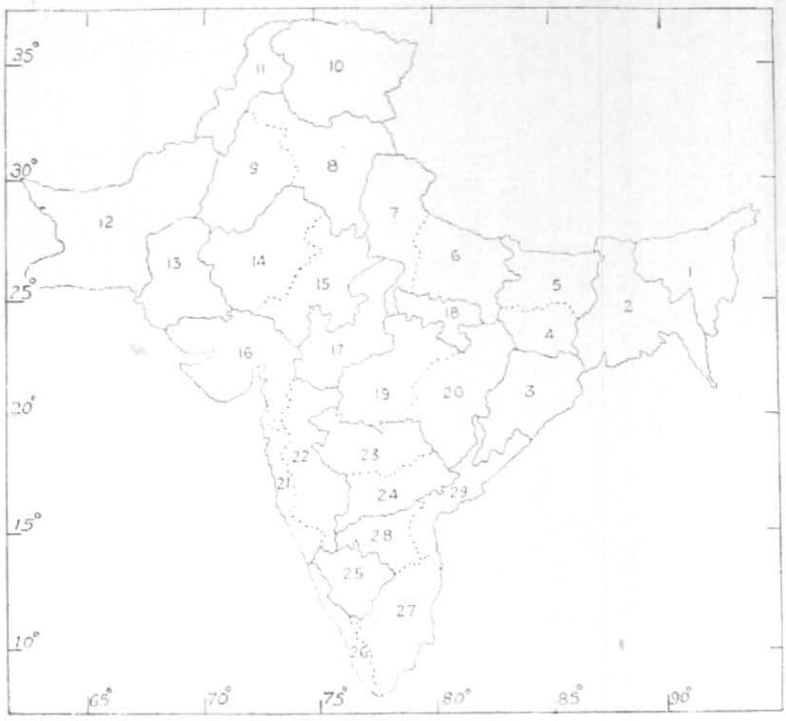

Fig. 2. Map showing Meteorological sub-divisions

1. Assam
2. Bengal
3. Orissa
4. Chota Nagpur
5. Bihar
6. United Provinces, East
7. United Provinces, West
8. Punjab, East and North
9. Punjab, Southwest
10. Kashmir
11. N.W. Frontier Province
12. Baluchistan
13. Sind
14. Rajputana, West
15. Rajputana, East
16. Gujarat
17. Central India, West
18. Central India, East
19. Central Provinces, West
20. Central Provinces, East
21. Konkan
22. Bombay Deccan
23. Hyderabad North
24. Hyderabad South
25. Mysore
26. Malabar
27. Madras, Southeast
28. Madras, Deccan
29. Madras Coast, North

Assam, Orissa and the west Central Provinces form a group where the numbers of days of widespread, local and few falls of rain are equal to each other during the year. Chota Nagpur, west Central India, north Hyderabad, the Konkan and Malabar form another group where widespread rain has the highest frequency during the year, while the southwest Punjab, Kashmir, the Northwest Frontier Province, Baluchistan, Sind, Gujarat, the Bombay Deccan, south Hyderabad, the Madras Deccan, southeast Madras and the north Madras Coast form the largest group where the annual frequencies of few falls, local and widespread rain are in the descending order of magnitude.

6. Seasonal and annual distribution of total number of days of rainfall of the meteorological sub-divisions

Distribution of the total number of days of rainfall of the meteorological sub-divisions for different seasons and the year as a whole are shown on the maps in Fig. 3. A reference map, showing the different meteorological sub-divisions is also given under Fig. 2. The main features of the distribution in relation with the chief meteorological factors are noted below.

Winter period (*December-March*)—The rainfall in this season is due to the (*i*) west to

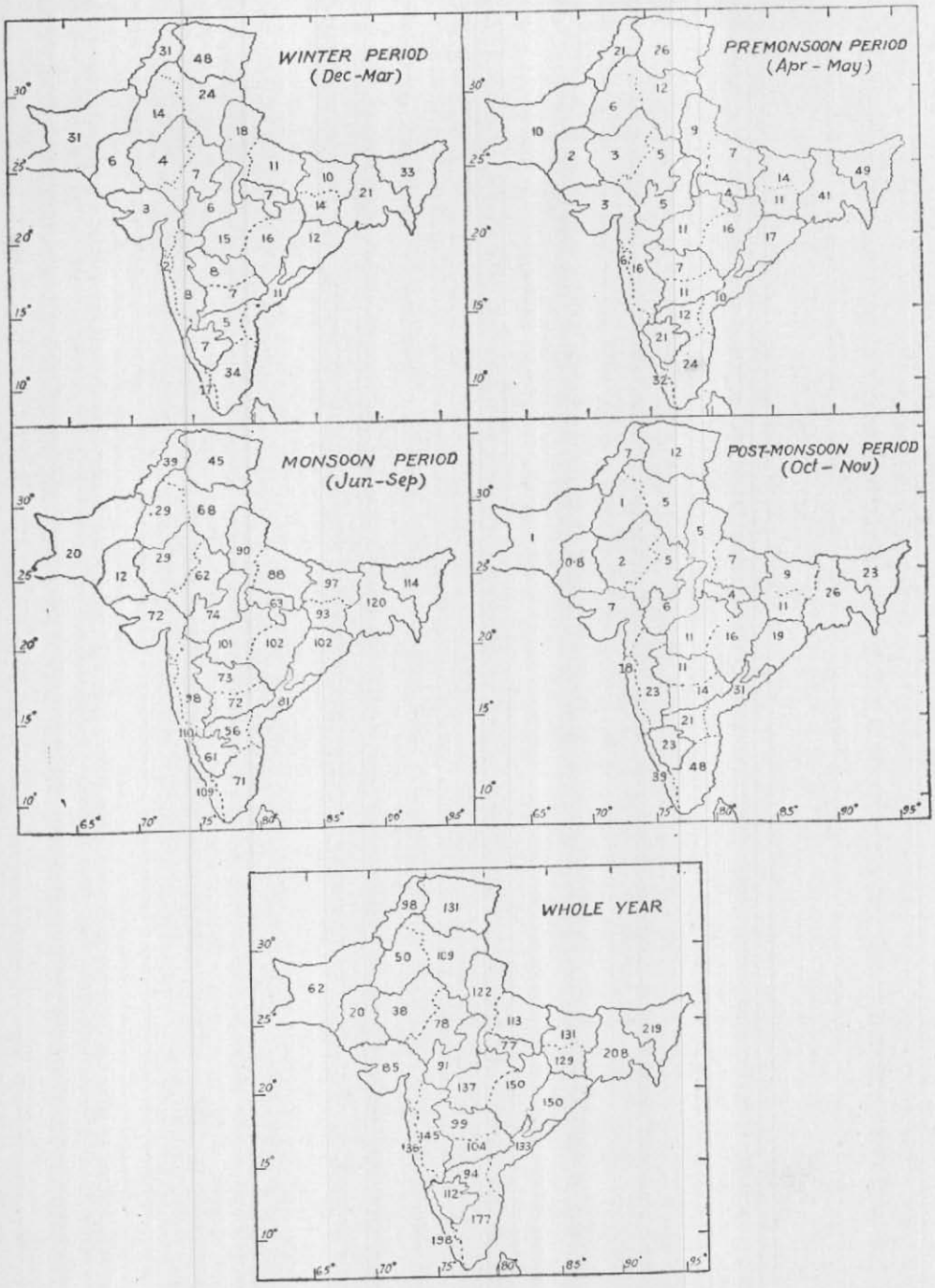

Fig. 3. Number of days of rainfall for different Meteorological sub-divisions for different seasons and the year as a whole

east movement of the lows or low pressure waves in the north of the country, (*ii*) west to east movement of the induced lows from the central parts of the country and (*iii*) east to west movement of the lows or low pressure waves along a belt in the extreme south of the country or further down to the south of the country. Corresponding to the three sets of lows as mentioned above, there are three regions of higher numbers of days of rainfall—one in the northern parts of the country, the second extending from the Central Provinces eastwards and the third in the southern part of the country.

The principal regions of higher frequencies of the days of rainfall are more or less same in January, February and March. The number of days of rainfall of the meteorological sub-divisions, however, increases during February in the above mentioned first two regions (excluding Kashmir) due to the increased activity of the western disturbances and their secondaries. The number of days of rainfall during February on the other hand, decreases in southeast Madras due to the eastern lows following more southern track. It is worth mentioning that Assam gets higher number of days of rainfall than any other sub-division during February due to the western disturbances or their secondaries passing through both northern and central parts of the country.

During March, there is a decrease in the number of days of rainfall of the United Provinces and Bihar and from the Central Provinces eastwards, while there is an increase in Malabar, Mysore and the Bombay Deccan due to west to east movement of feeble lows or low pressure waves and occasional penetration of the moist air from the Indian seas.

It is interesting to note that if the number of days of rainfall of the meteorological sub-division is represented on the map for the different months, it will be found that during the months of January, February and March, the Konkan is the centre where the days of rainfall are practically absent and that the number of days of the meteorological sub-division increases radially outwards from that centre.

Absence of rainfall or the very small number of days of rainfall in the Konkan during this period of active western disturbances indicates that the lows or low pressure waves in the latitudes of the Konkan in connection with the western disturbances either form or become active on the east of Konkan area.

The total number of days of rainfall of the season is highest in Kashmir and lowest in the Konkan where rainfall occurs only on one or two days during this period.

Pre-monsoon period (*April-May*)—Frequent passage of low pressure waves through different latitudes of the country is observed in this season. In addition there is the effect of the seasonal low over Chota Nagpur and neighbourhood and a relatively low pressure area over the Peninsula, which cause incursion of moist air over hot land from the Peninsula northeastwards to Assam, resulting in increased number of days of thunderstorm-rain over this area with an eye of the increased frequencies over Assam and Bengal and the other over the south Peninsula. One or two depressions or cyclonic storms from the Bay of Bengal or the Arabian Sea also increase the rainfall activity over this area.

The centre of the least number of rainy days shifts from the Konkan to Gujarat in April and to Sind in May.

The highest number of rainfall days is for Assam where rainfall occurs on about fifty days during this period and the lowest number is for Sind where rainfall occurs on about two days only.

Southwest monsoon period (*June-September*)—The stationay low or the seasonal low which is now over the northwestern parts of the country helps the moist monsoon current to invade practically the whole of the country. Thus, there is an extension of

the rainfall activity both in space and in frequency. Frequent east to west travels of the depressions from the north Bay of Bengal through the central parts of the country also cause an increase in the intensity of rainfall and extension of the rainy area into the northwestern parts of the country.

There are three regions of high number of rainfall days, one over the west coast of the Peninsula, where the Arabian Sea branch of the southwest monsoon first comes from the sea area over the land and also meets the transverse orographic barrier there, the second over the northeastern parts of the country where the Bay branch of the monsoon current first enters inland and is interrupted by two rectangular mountain ranges of Assam and Burma and of the Himalayas, and the third over Orissa and the Central Provinces through which the monsoon depressions frequently travel westwards.

There are two regions of relatively low number of days of rainfall. One is over Sind and Baluchistan, recording the lowest number of days of rainfall, and the other is over the southeastern parts of the Peninsula, which is the shadow region of the Western Ghats with respect to the westerly monsoon current.

Post-monsoon period (October-November)—The seasonal low which was over the northwestern part of the country disappears from there and appears over the south Bay of Bengal which causes the northeast monsoon in southeast Madras. Thus, whereas there is an increase in the number of days of rainfall over southeast Madras, there is a very much decrease in the number of days of rainfall generally over the country, particularly in the northern parts. The storms or depressions which forming in the south Bay of Bengal recurve either in the Bay itself, or near the Peninsula or through the southeast Arabian Sea, cause extension of rainfall over an area, the northern extremity of which extends in the extreme cases from Gujarat eastwards.

This is the season when the divisions of the northwestern parts of the country have their least number of rainy days. Because, neither the seasonal lows nor the travelling lows are of any significant help in producing rain there at this time of the year. The seat of the lowest number of days of rainfall is over Sind and neighbourhood. The number of days of rainfall for different divisions increases outwards radially from this central region.

The area of relatively high number of days of rainfall extends from the Peninsula to Assam. In the northern part of the country, the highest number of rainfall days is recorded in Kashmir where rainfall occurs on 11 to 12 days during this period.

Year as a whole—The monsoon season contributes most towards the yearly total number of days of rainfall for different sub-divisions. Thus the pattern of distribution of the days of rainfall is like that of the southwest monsoon period, modified in the extreme north due to the increased effect of the western disturbances and in southeast Madras due to the considerable effect of the northeast monsoon there.

The regions of high annual frequencies of rainfall days of the meteorological divisions are (*a*) the southern and western parts of the Peninsula, (*b*) Assam, Bengal and neighbourhood, (*c*) the Central Provinces and Orissa and (*d*) Kashmir.

The three corners of the country, *e.g.*, (*i*) southeast Madras, (*ii*) Assam and (*iii*) Kashmir and the Northwest Frontier Provinces, record days of rainfall in all the months of the year. In the Konkan on the other hand, there is practically no rainfall during the three to four winter months during the year. In other parts of the country there are one or two months, when the number of days of rainfall is negligibly small.

During the year, the highest number of days of rainfall, taking the meteorological sub-divisions as a whole, is for Assam where rainfall occurs on about 220 days and the least

number is for Sind where it occurs on about 20 days.

7. Summary

There is a predominance of the few falls of rain or local rain in most of the areas and seasons. During the southwest monsoon, however, a marked increase occurs in respect of the days of widespread or local rain for most of the meteorological sub-divisions outside the northwestern parts of the country. In the case of the meteorological sub-divisions, lying in the active fields of the southwest monsoon, widespread rain has predominance over the other two types of rainfall distribution at least in the peak monsoon month when a corresponding drop is noticeable in respect of the number of days of few falls of rain.

Assam, Orissa and the west Central Provinces form a group where the numbers of days of widespread, local and few falls of rain are equal to each other during the year. Chota Nagpur, west Central India, north Hyderabad, the Konkan and Malabar form another group where widespread rain has the highest frequency during the year while the largest group is formed by the northwestern regions of the country and the southeastern parts of the Peninsula where the annual frequencies in respect of the few falls, local and widespread rain are in the descending order of magnitude.

Regarding the distribution of the total number of days of rainfall of the meteorological sub-divisions the following features are significant. Days of rainfall are recorded in the southern, eastern and northern corners of the country in all the months of the year. During the non-monsoon periods, excluding April and December, there is practically one centre which records no days or very small number of days of rainfall and the number of days of rainfall of the meteorological sub-divisions increases radially outwards from that centre. In the southwest monsoon period there is another area of relatively low number of days of rainfall in the southeastern parts of the Peninsula. The seat of the least rainfall activity or the least number of days of rainfall shifts from the Konkan to Gujarat, Sind, Baluchistan, the southwest Punjab and west Rajputana and then back to the Konkan during the course of the year.

Assam records the highest number of days of rainfall and Malabar the highest number of days of widespread rainfall during the year. In the Konkan, on the other hand, there is no rainfall practically in the three or four winter months of the year. Absence of rainfall in the Konkan during the period of marked activity of the western disturbances indicate that induced lows or low pressure waves in the latitudes of the Konkan in connection with the western disturbances either form or become active on the east of the Konkan area.

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