

Is the number of cyclonic disturbances traversing India during a monsoon season related to the rainfall in that season ?*

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ABSTRACT. There is a general belief that in the monsoon season (June to September) if more cyclonic disturbances, such as depressions, deep depressions and storms, traverse the country, more rainfall will be received in that season. In order to investigate this, the statistics of cyclonic disturbances traversing the land area of the country during the 60-year period from 1901 to 1960 has been examined. Monsoon season rainfall of the country as a whole has also been worked out for each year of the 60-year period using the data of more than 3,000 rainfall stations distributed uniformly over the country. The study has shown that the number of these disturbances or the number of days spent by these disturbances in traversing the land area of the country during the monsoon season is not a reliable index of monsoon rainfall over the country.

1. Introduction

It is a common belief that cyclonic disturbances (which include depressions, deep depressions and storms) cause most of the rains in India during the summer monsoon season. It has been said that but for the influence of these disturbances, the monsoon rain would tend to be just orographic or localised along the hills and mountains of this country (Ramdas 1960). Rao (1976) has stated that the monsoon depressions have a profound influence on the rainfall over most of the country, much more than their number would suggest. An attempt has been made here to assess the rainfall potential of these cyclonic disturbances over the country as a whole after they cross inland from the neighbouring seas of Bay of Bengal and Arabian Sea and move through the country during the monsoon months of June to September. As the summer monsoon is also called the southwest monsoon, it will be referred here as 'the monsoon'.

2. Data used

Dhar and Ghose (1972) have studied the space-time distribution of depressions and storms over the country using the 80-year data of these disturbances from 1891 to 1970. Fig. 1 shows the spatial distribution of these disturbances during the monsoon seasons of the 80-year period. The present study is based upon the data of these disturbances during the monsoon season of the 60-year period from 1901 to 1960 and the corresponding rainfall of the country. The

data of cyclonic disturbances have been compiled from the *Storm Track Atlas* (India Met. Dep., 1964) and the rainfall statistics has been worked out on the basis of about 3,000 rainfall stations distributed uniformly over the country (India Met. Dep. 1901-1960).

On the basis of 60-years' rainfall data, Dhar *et al.* (1974), have found that the mean annual rainfall of the contiguous Indian areas is about 119 cm and that monsoon rainfall is about 75 per cent of the mean annual rainfall with the coefficient of variability of 9 per cent Table 1 shows the mean monsoon rainfall of each of the 31 contiguous sub-divisions of the country outside the island sub-divisions of Bay of Bengal and Arabian Sea. Mean monsoon rainfall for each sub-division has been calculated from the available rainfall data of all the stations in a sub-division from 1901-1960. Table 1 also shows for each sub-division the percentage of the mean monsoon rainfall to the mean annual rainfall and the coefficient of variability of the monsoon rainfall. It is seen from Table 1 that excepting Tamil Nadu, a sub-division located in the southeastern part of the Indian Peninsula, all the remaining sub-divisions of the country receive 50 per cent to 95 per cent of the mean annual rainfall during the monsoon.

2.1. Cyclonic disturbances during the monsoon season

In this study all those cyclonic disturbances have been considered which crossed inland from

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TABLE 1

Sub-divisional monsoon rainfall statistics of the contiguous Indian area (1901—1960)

S. No.	Name of met. sub. divisions (*)	Mean monsoon rainfall		Coeff. of variability (%)
		(Jun-Sep) (cm)	Mean of annual (%)	
1	North Assam	154.1	65	8
2	South Assam	209.2	66	12
3	Sub-Himalayan West Bengal	225.7	78	13
4	Gangetic West Bengal	106.9	75	15
5	Orissa	110.9	77	15
6	Bihar Plateau	111.5	82	12
7	Bihar Plains	102.6	85	16
8	East Uttar Pradesh	89.4	88	20
9	West Uttar Pradesh	86.6	85	23
10	Haryana	45.5	83	30
11	Punjab	47.9	75	30
12	Himachal Pradesh	109.0	72	21
13	Jammu & Kashmir	52.5	50	27
14	West Rajasthan	26.4	89	34
15	East Rajasthan	62.5	91	26
16	West Madhya Pradesh	93.4	90	18
17	East Madhya Pradesh	120.1	88	12
18	Gujarat	92.6	95	29
19	Saurashtra & Kutch	48.4	93	37
20	Konkan	273.7	94	17
21	Madhya Maharashtra	79.6	83	17
22	Marathwada	68.1	84	25
23	Vidarbha	93.8	87	19
24	Coastal Andhra Pradesh	58.1	57	19
25	Telangana	74.4	81	22
26	Rayalaseema	37.7	55	27
27	Tamil Nadu	35.0	34	19
28	Coastal Karnataka	288.5	87	14
29	North Interior Karnataka	45.6	65	19
30	South Interior Karnataka	78.6	66	20
31	Kerala	193.5	67	24
	Contiguous Indian area	89.7	75	9

*Meteorological sub-divisions as defined on 1 January 1971.

TABLE 2

Number of cyclonic disturbances which traversed the country during the monsoon season and the corresponding monsoon rainfall obtained during each year of the 60-year period from 1901—1960

Year	No. of cyclonic disturbances	Total No. of depressions days	Year's monsoon rainfall	
			Average (cm)	% of mean monsoon rainfall
1901	1	3	77.8	87
1902	7	28	82.8	92
1903	7	19	92.2	103
1904	6	26	78.7	88
1905	7	29	76.0	85
1906	7	29	93.0	104
1907	8	22	81.6	91
1908	5	22	94.2	105
1909	3	12	93.6	104
1910	3	13	96.6	108
1911	4	19	77.8	87
1912	5	17	85.0	95
1913	6	32	79.8	89
1914	4	21	96.8	108
1915	4	15	81.8	91
1916	5	22	100.0	111
1917	5	20	106.4	119
1918	5	16	69.9	78
1919	7	26	94.5	105
1920	8	27	74.8	83
1921	5	23	92.1	103
1922	6	21	91.6	102
1923	9	40	87.4	97
1924	4	24	93.4	104
1925	11	39	85.0	95
1926	7	38	95.6	107
1927	11	39	91.4	102
1928	6	25	81.0	90
1929	8	38	84.1	94
1930	4	12	85.4	95
1931	5	7	91.9	103
1932	6	25	86.0	96
1933	11	42	102.4	114
1934	8	26	94.8	106
1935	8	16	88.3	98
1936	8	24	93.2	104
1937	10	31	87.8	98
1938	4	9	94.5	105
1939	11	45	82.4	92
1940	8	34	87.8	98
1941	10	41	78.4	87
1942	8	38	102.0	114
1943	8	32	92.4	103
1944	11	47	94.9	106
1945	8	26	94.2	105
1946	9	31	95.2	106
1947	9	29	94.8	106
1948	10	20	92.3	103
1949	6	23	91.9	103
1950	11	36	94.1	105
1951	8	17	74.3	83
1952	7	23	83.1	93
1953	5	11	96.8	108
1954	8	16	90.8	101
1955	6	13	97.5	109
1956	8	25	99.4	111
1957	3	10	84.5	94
1958	5	18	96.3	107
1959	10	29	99.5	111
1960	6	20	90.2	101
Total	413	1481	—	—

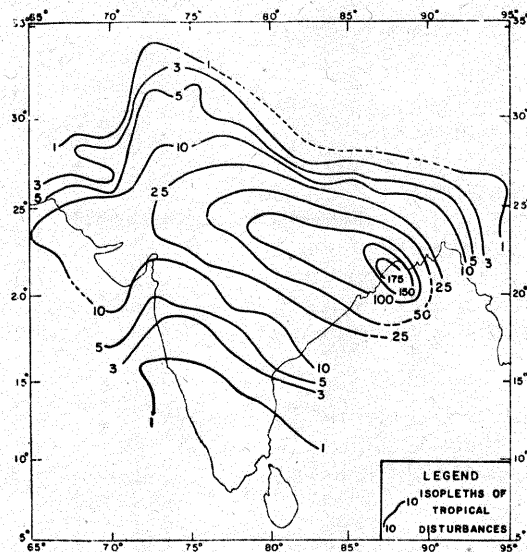


Fig. 1. Distribution of tropical disturbances in monsoon season (Jun-Sep) during the period 1891-1970

the Bay of Bengal and the Arabian Sea during the four monsoon months of June to September. Land depressions which sometimes develop over northeast India and neighbourhood during this season have also been taken into consideration as these disturbances also give a fairly large amount of rainfall during their passage through northern India. The total number of cyclonic disturbances which traversed the country during the monsoon season of each year have been determined and are given in Table 2.

It is seen from Table 2 that during the monsoon seasons of the 60-year period, the highest number of cyclonic disturbances which moved through the country was 11, this happened in 1925, 1927, 1933, 1939, 1944 and 1950. The lowest number of disturbances was 1 in 1901. The next lowest number of cyclonic disturbances were 3 each in the years 1909, 1910 and 1957. The average number of these disturbances traversing the country during the monsoon season is about 7 while the annual average is about 10.

2.2. Number of cyclonic disturbance days

The total rainfall received from a cyclonic disturbance during the course of its travel over the land area of the country to a large extent depends upon the number of days spent by the disturbance in moving through the country. In order to have this data, the total number of days (or say depression-days) on which disturbances were traversing the land area after crossing the coast were also determined for each monsoon season of the 60-year period. In counting the depression-days, both the days when a disturbance moved inland and the day when its track

ceased to exist on the land area were taken into consideration. The total number of depression-days in the monsoon season of each year is given in Table 2. The highest number of depression-days during a monsoon season was 47 which occurred in 1944 when the number of cyclonic disturbances was 11. The second highest number of 45 depression-days was experienced in the monsoon season of 1939, when 11 cyclonic disturbances moved through the country. The lowest number of depression-days was 3, in the monsoon season of 1901 when only 1 cyclonic disturbance traversed through the country.

2.3. Average yearly monsoon rainfall for the period 1901 to 1960

Average rainfall received during each monsoon season of the 60-year period was worked out on the basis of available rainfall data for (i) the country as a whole, and (ii) for each of the 31 meteorological sub-divisions. Table 2 gives average monsoon rainfall for the country as a whole for each year of the 60-year period. For want of space subdivisational rainfall for each year of the 60-year period under study has not been included.

3. Relation between monsoon rainfall and monsoon disturbances

In order to find whether there is any direct relationship between the number of monsoon disturbances/depression-days and the country's monsoon rainfall, correlation coefficients were worked out. It was found that correlation coefficients between country's rainfall and the frequency of monsoon disturbances was 0.08 and between rainfall and depression-days was 0.05,

thereby suggesting that no direct correlation exists between them.

This exercise was repeated in the case of each of 31 sub-divisions of the country. The results are given in Table 3. This study has shown that of the sub-divisions which are directly influenced by these disturbances, Orissa is the only sub-division which showed significant correlation at 5 per cent level while rest of the sub-divisions showed insignificant correlations. More or less, similar results were obtained in the case of depression-days also.

A careful study of Table 2 also reveals the following interesting facts about relationships between number of disturbances/depression-days and rainfall of the country:

- (a) In monsoon seasons of each of the years 1925, 1927, 1933, 1944 and 1950, which experienced the largest number of 11 disturbances per season, the country received rainfall of 85 cm, 91 cm, 102 cm, 82 cm, 95 cm and 94 cm respectively. These correspond to percentage departures of -5 , $+2$, $+14$, -8 , $+6$ and $+5$ per cent respectively.
- (b) The monsoon seasons of the wettest year of 1917 and the driest year of 1918 experienced the same number of 5 cyclonic disturbances. In 1917 the rainfall was 19 per cent in excess while in 1918 the rainfall received was 22 per cent in deficit.
- (c) The smallest number of 1 cyclonic disturbance was experienced in the monsoon season of 1901 but the rainfall experienced by the country in this season was 13 per cent in deficit. The monsoon seasons of the years 1905, 1918 and 1920 experienced cyclonic disturbances of the order of 7, 5 and 8 respectively and the corresponding monsoon rainfall over the country were in deficit by 15, 22 and 17 per cent respectively.
- (d) The largest number of 47 depression-days occurred in 1944. The rainfall over the country during this monsoon season was only 6 per cent in excess. On the other hand, in the 1917 monsoon season, the total number of depression-days was 20 and only 5 disturbances traversed the country, yet rainfall was 19 per cent in excess which is a record during the 60-year period.

TABLE 3

Relationship between rainfall and cyclonic disturbances/depression-days over different meteorological subdivisions

(Data used 1901-1960)

Sub-divisions	C.C. between monsoon rainfall and No. of	
	Cyclonic disturbances	Depression days
North Assam	-.092	-.271*
South Assam	-.031	-.085
Sub Himalayan West Bengal	-.030	-.119
Gangetic West Bengal	.115	.319*
Orissa	.270*	.328*
Bihar Plateau	.160	.291*
Bihar Plains	-.168	-.115
East Uttar Pradesh	-.185	-.246
West Uttar Pradesh	-.114	-.044
Haryana	-.124	-.025
Punjab	.074	.032
Himachal Pradesh	.126	.210
Jammu & Kashmir	-.174	-.116
West Rajasthan	.004	.057
East Rajasthan	.120	.178
West Madhya Pradesh	.237	.165
East Madhya Pradesh	.244	.213
Gujarat	.202	.237
Saurashtra & Kutch	.108	.126
Konkan	-.053	-.177
Madhya Maharashtra	-.119	.046
Marathwada	-.192	-.251*
Vidarbha	.037	-.066
Coastal Andhra Pradesh	-.148	-.265*
Telangana	-.085	-.259*
Rayalaseema	-.238	-.190
Tamil Nadu	-.107	-.054
Coastal Karnataka	.199	.092
North Interior Karnataka	-.062	-.161
South Interior Karnataka	.301*	.125
Kerala	.102	.203
Indian rainfall	0.08	0.05

*Significant at 5 per cent level

- (e) In the monsoon of 1901, the smallest number of 3 depression-days was experienced but monsoon rainfall over the country was in deficit by 13 per cent. On the other hand during the monsoon season of 1911 and 1941, 19 and 41 depression-days respectively were experienced but the rainfall over the country was of the same magnitude.
- (f) The average number of days with cyclonic disturbances during the monsoon season was found to be about 25, which is nearly one-fifth of the total monsoon period.
- (g) During the monsoon season the life-span of a cyclonic disturbance over the land area of the country was on an average 3 to 4 days

4. Discussion of the results

Cyclonic disturbances in the monsoon season activate the monsoon currents and carry them to different parts of the country but these disturbances do not by themselves contribute a major portion of the country's monsoon rainfall. This suggests that monsoon rainfall over the country depends upon several other factors besides cyclonic disturbances. It has been seen that in the absence of cyclonic disturbances, if other factors are favourable, the rainfall over the country can be normal or even in excess. In the principal monsoon month of July of the years 1908, 1924, 1931 and 1953 no cyclonic disturbances moved through the country but the rainfall received was 11, 9, 1 and 9 per cent in excess of the mean July rainfall respectively. From the above it is quite evident that the absence of cyclonic disturbances does not result in the decrease of rainfall over the country.

There is, however, no denying the fact that localized heavy rainfall occurs along and near the tracks of cyclonic disturbances. Das (1968) has described the progress of the rain belt over the land areas associated with the westward movement of depressions from the head Bay of Bengal during the monsoon season. According to Pisharoty and Asnani (1957), the heavy rain belt of 400 km width lies to the left of depression tracks for a distance of about 500 km from the centres of disturbances. But it has been found that only 30 per cent of this area actually records heavy rain (Rao 1976). Besides this, during the passage of these cyclonic disturbances, there are certain parts of the country, especially the subdivisions along and near the northeastern and central Himalayas, which receive very little rainfall (Raghavan 1967, Dhar and Rakhecha 1976). Dhar *et al.* (1973, 1974) have shown that over the *Ganga* and the *Godavari* river

basins, these disturbances hardly contribute 8 per cent and 12 per cent of their respective mean annual rainfall.

According to Ramaswamy (1967) the statement that the history of the monsoon is the history of its depressions is an over simplified description of the behaviour of the monsoon. There is, however, no doubt that these depressions constitute a very potent agency for producing intense lower tropospheric convergence which leads to heavy rainfall. The heavy rainfall occurs over a localized area during a short interval of time say from 1 to 3 days. As such, these disturbances have a large potential for causing floods over a region through which they travel. The localized heavy rains and consequent flooding give an impression that these disturbances cause most of the monsoon rainfall in this country but this is not the case in fact.

5. Conclusion

During the monsoon season, neither the number of cyclonic disturbances traversing the country nor the number of depression-days are a reliable index of the monsoon rainfall over the country. Thus, the common belief that more cyclonic disturbances or depression-days during a monsoon period mean more rainfall over the country does not appear to be correct.

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References

- Das, P. K., 1968, *The Monsoons*, published by National Book Trust, India, New Delhi.
- Dhar, O.N. and Ghose, G.C., 1972, On some hydrometeorological aspects of space-time distribution of depressions and storms over major river basins in India, *Vayu Mandal*, Bulletin of Indian met. Soc., 2, 2.
- Dhar, O.N. and Bhattacharya, B.K., 1973, Contribution of tropical disturbances to the water resources of Ganga Basin, *Vayu Mandal*, Bulletin of Indian met. Soc., 3, 2.
- Dhar, O.N., Parthasarathy, B. and Ghose, G.C., 1974, A study of mean monthly and annual rainfall of contiguous Indian area, *Vayu Mandal*, Bulletin of Indian met. Soc., 4, 2.
- Dhar, O.N., Bhattacharya, B.K. and Ghose, G.C., 1974, Contribution of tropical disturbances to the water potential of Godavari basin. Proc. of the International Tropical Met. Meeting held at Nairobi, Am. met. Soc. publication.

- Dhar, O. N. and Rakhecha, P. R., 1976, Does the absence of tropical disturbances cause deficient rainfall in north Indian sub-divisions during the monsoon months ?, *Proc. Indian Nat. Sci. Acad.*, **42**, Part A, 1.
- India met. Dep., 1901-1960, *Rainfall of India*, Compiled by India met. Dep.
- India met. Dep., 1964, *Tracks of storms and depressions in the Bay of Bengal and the Arabian Sea*, India met. Dep. publ.
- Pisharoty, P.R. and Asnani, G.C., 1957, Rainfall around monsoon depressions over India, *Indian J. Met. Geophys.*, **8**, 1.
- Raghavan, K., 1967, Influence of Tropical Storms on monsoon rainfall in India, *Weather*, **22**, 6.
- Ramaswamy, C., 1967, The problem of the Indian Southwest monsoon, Prince Mukarram Jah Lectures held under auspices of Indian Geophysical Union, Hyderabad.
- Ramdas, L A , 1960, The establishment, fluctuations and retreat of the southwest monsoon in India, *Prcc. Symp. Monsoons of the World*. Published by IUGG, WMO, IAMAP and India met. Dep.
- Rao, Y.P., 1976, *Southwest Monsoon*, Meteorological Monograph Synop. Met. No. 1/1976, India met. Dep. publ.