WORST SUMMER MONSOON FAILURES OVER THE ASIATIC MONSOON AREA

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The summer monsoon (June to September) rainfall for a network of 39 stations well-distributed over the Asiatic monsoon area (Equator to 35°N and 70°E to 140°E) has been examined for the period 1890–1960. The years of worst monsoon failure have been brought out. Percentage departures of monthly rainfall during these years have been further examined to find out which months contributed maximum to these monsoon failures. Available data have been looked into to estimate the possible causes for these worst monsoon failures.

INTRODUCTION

The summer monsoon season (June to September) is the period in which 50 to 90 per cent of the annual rain over Southeast Asia including India occurs. Over a major portion of southeast Asia, the water needs have to be met by the rainfall that occurs during the summer monsoon season. In view of these factors it is of considerable interest to study large-scale failures of monsoon rainfall over the area and their possible causes. It is proposed to study the extent of these failures and their possible causes.

DATA

A network of 39 stations with a long-period rainfall record was selected from the area. The same is shown in Fig. 1. All the available record of monthly rainfall for these stations has been obtained from the World Weather Records (1927, 1934, 1947, 1959, 1967).

YEARS OF WORST MONSOON FAILURES

From the monthly rainfall, seasonal rainfall (June to September) was obtained for each year for each of the stations. The years in which the seasonal rainfall at a place was less than or greater than specified limits were classified as years of very scanty rain or years of highly excessive rain respectively. These specified limits are the first and the ninth deciles of the Gamma probability model applied to rainfall as tabulated by Mooley (1972). It has been shown by him that Gamma probability model is a good fit to monthly and seasonal rainfall over Southeast Asia. The probability distribution function, $p(x)$, of the Gamma model is given by

$$p(x) = \frac{x^{\gamma-1}\, e^{-x/\beta}}{\beta^{\gamma}\Gamma(\gamma)} \quad \text{for } x>0,\ \gamma,\ \beta>0$$
$$= 0 \quad \text{for } x \leqslant 0$$

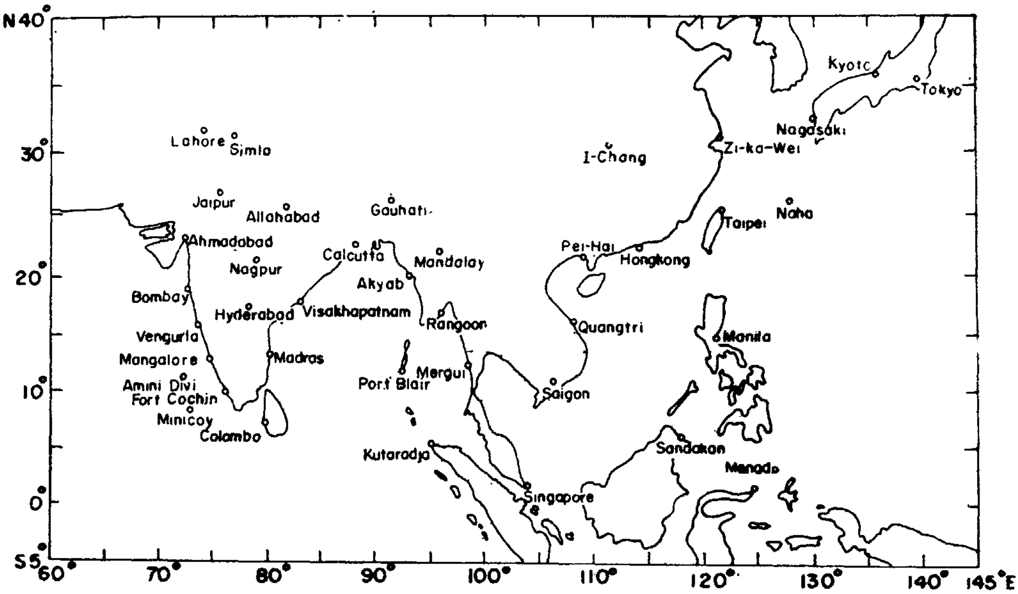


FIG. 1. Network of rain-gauge stations.

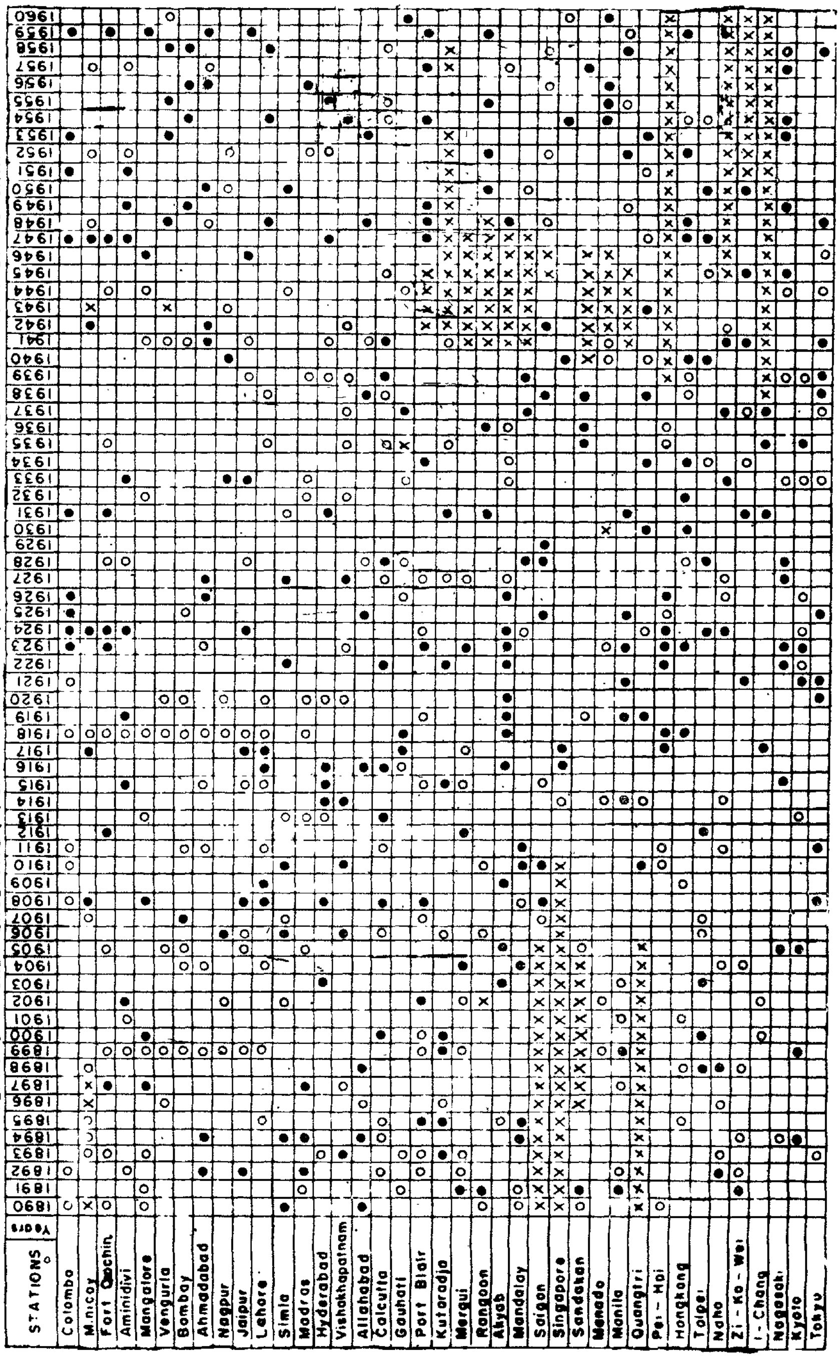
γ and β are respectively the shape and the scale parameters and $\Gamma(\gamma)$, the gamma function, is the first Eulerian integral $\int_0^\infty x^{\gamma-1} e^{-x} dx$.

Utilising the deciles tabulated by Mooley (1972), the seasonal rainfall in each year during the period 1890-1960, has been classified for each of the stations as highly excessive, very scanty, and neither highly excessive nor very scanty. This classification is given in Table I. The prominent feature of this table is the large-scale failure of the summer monsoon over the Indian Subcontinent during the years 1899 and 1918. For monsoon Asia, these are the years of the worst failures of the summer monsoon.

SEVERITY OF THE MONSOON FAILURES IN 1899 AND 1918

Fig. 2 shows for 1899 and 1918 the percentage departure of seasonal rainfall from normal i.e., $(x-\bar{x})\ 100/\bar{x}$ where x is rainfall for any individual season and $\bar{x}$ is the seasonal mean. These figures clearly bring out that during both of these years the impact of failure of the summer monsoon was severe over most part of western half (west of longitude 80°E) of the Indian Subcontinent where percentage deficiency exceeded 40, the impact being most severe over Gujarat, Saurashtra and Kutch where percentage deficiency was 70-80. During these years, the seasonal rainfall was also very scanty over Sulawesi (the Celebes Islands). However, in 1899 seasonal rainfall was highly excessive over western parts of Andalas (Sumatra) and north Philippines and in 1918 it was highly excessive over Southeast China. In Fig. 2(*a*), —80(40)80 denotes that isopleths are drawn, commencing with that for —80 and going upto that for 80 at intervals of 40.

TABLE I - YEARS OF HIGHLY EXCESSIVE (●) OR VERY SCANTY (○) SEASONAL RAINFALL. CROSS DENOTES NO DATA



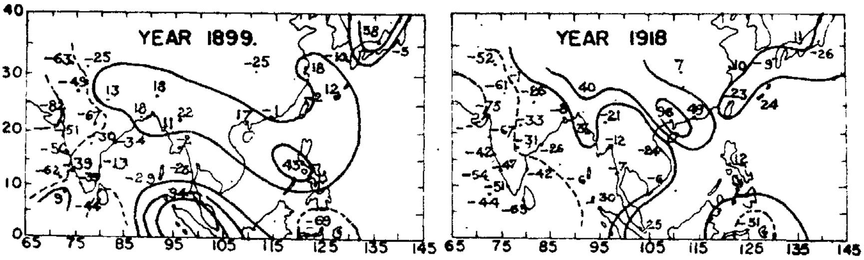


FIG. 2(*a*). Two cases of worst failure of summer monsoon. Percentage departure of seasonal rainfall from normal isolines : —80(40)80

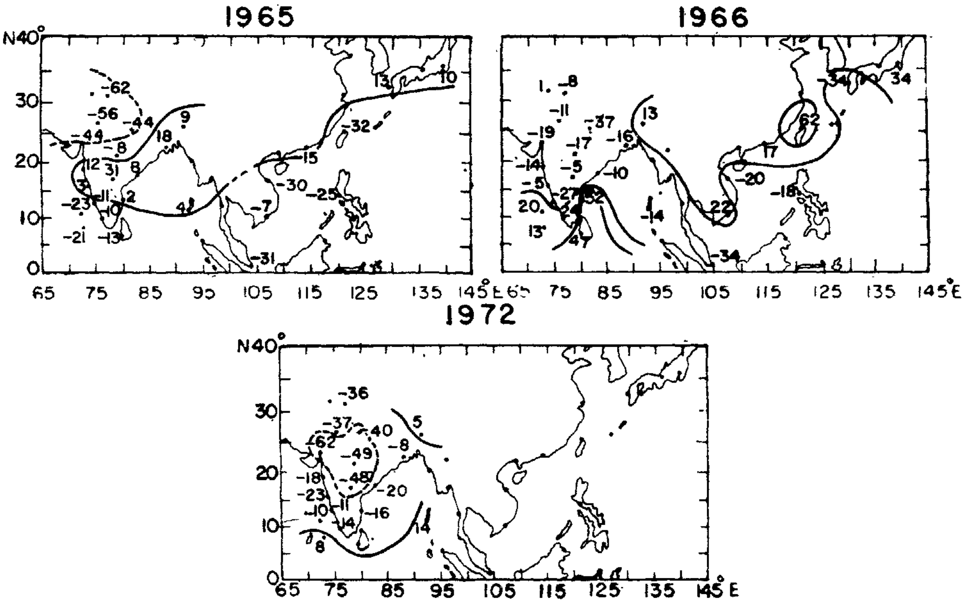


FIG. 2(*b*). Percentage departure of seasonal rainfall from normal isolines : —40(40)40.

It may be worthwhile to compare these two failures with post-1960 summer monsoon failure which occurred in 1965, 1966 and 1972 over the Indian subcontinent. Indian rainfall data are available and some extra-India data are available in the publication entitled *"Monthly Climate Data of the World"*. However, the publication, *Monthly Climate Data of the World* for June to September 1972, is not yet received. Utilising all available data, the percentage deficiency of seasonal rainfall has been calculated for 1965, 1966 and 1972. The same has been given in Fig. 2(*b*). On a careful examination, it is seen that the failure in each of the years 1899 and 1918 was worse than that in post-1960 years. However, amongst the post-1960 failures that in 1972 appears to be the worst.

MONTHLY RAINFALL DEFICIENCY

The monthly rainfall in each of the monsoon months during the two years 1899 and 1918 has been examined to find out the months that contributed maximum to the

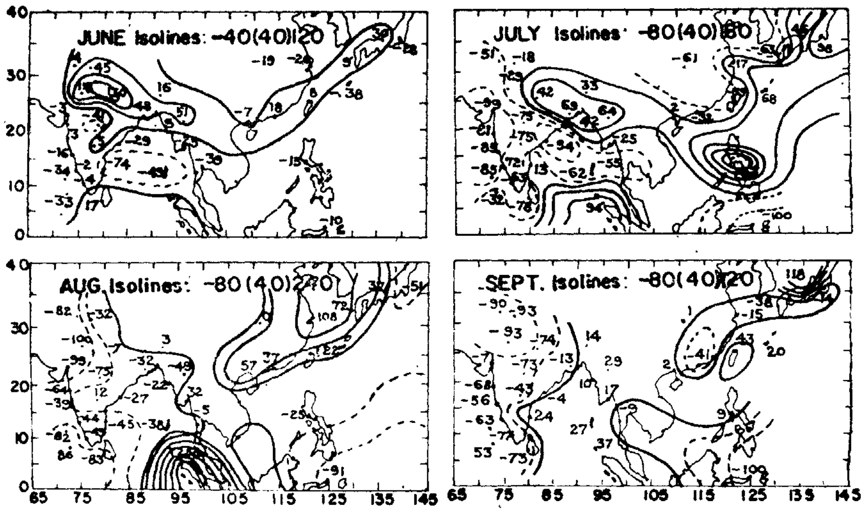


FIG. 3. Percentage monthly rainfall departure from normal during summer monsoon of 1899.

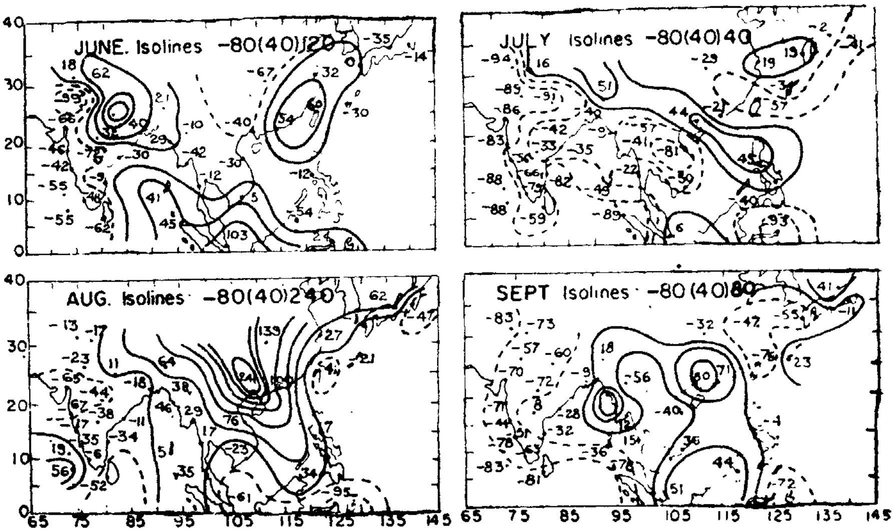


FIG. 4. Percentage monthly rainfall departure from normal during summer monsoon of 1918.

rainfall deficiency; Figs. 3 and 4 show the percentage monthly rainfall departure from the normal during 1899 and 1918 respectively.

During 1899, June rainfall was highly excessive over most parts of North India and deficiency was generally small elsewhere over India. The contribution of July to the deficiency was phenomenal. In each of the months July and August, the deficiency over Gujarat, Saurashtra and Kutch exceeded 90 per cent. Rainfall anomaly charts of July and August show highly contrasting features over Southeast Asia. Rainfall during July, though very deficient over most parts of the Indian Subcontinent, was highly excessive over Northeast India and northern parts of Burma, over the western parts of Andalas (Sumatra), and over the belt from north Philippines to eastern parts of South Japan. During August, the highly excessive rainfall over western parts of Japan, East China and western parts of Andalas (Sumatra) is in marked contrast to the very deficient rainfall over the Indian Subcontinent.

During 1918, June rainfall was highly excessive over Northeast India, over Taiwan and eastern parts of China and over the belt from Bay Islands to western parts of Kalimantan (Borneo) and very scanty over western India and Ceylon. The contribution of July to the seasonal rainfall deficiency over Southeast Asia was phenomenal in this year also, rainfall being very deficient over most of Southeast Asia. From July to August, the deficiency decreased substantially over many parts of Southeast Asia; however, rainfall continued to be very deficient in Saurashtra, Kutch, Gujarat, North Maharashtra and adjoining parts of Madhya Pradesh. The most prominent features of the August rainfall anomaly chart is the highly excessive rainfall over South and Central China, North Viet Nam, extreme Northeast India and northern parts of Burma. During September, rainfall was very deficient over western India, over Taiwan, easternmost parts of China and westernmost parts of Japan, over Sulawesi (the Celebes Islands), and over the area from north Burma to north Viet Nam and was highly excessive over Arakan coast, southeastern parts of China and Kalimantan (Borneo).

Possible Causes of the Monsoon Failures

The people of the Indian Subcontinent suffered extreme hardship in these two years of catastrophic monsoon failures. A failure of this magnitude is rare and it is suprising that the event should repeat in a short span of 20 years. Examination of the meteorological conditions that prevailed during these two years and inference therefrom of the possible causes of the dismal failures of the monsoon are of considerable interest.

A detailed study of the meteorological conditions during 1899 over India, Arabian sea, Indian Ocean and South Africa was made by Dallas (1900-1902). He observed the following important features :—

(*a*) Extraordinarily widespread and heavy rain over south Africa, Seychelles and Mauritius prior to June.

(*b*) Surface pressure anomaly over the Arabian Sea was persistently high and its magnitude increased with the advance of the season.

(*c*) Very small variation in wind direction and speed over the Arabian sea and western equatorial region. Wind was abnormally light and was most markedly light in August and September.

(*d*) An uninterrupted failure of rains over the Indian portion which ordinarily depends for its rainfall on the Arabian sea branch of the monsoon.

From the feature (*a*), Dallas (1900-1902) draws the inference that most of the southeast trades were deflected towards south Africa, south of the Indian monsoon area, presumably due to intensified cyclonic conditions over southern latitudes and that possibly this situation resulted in the positive pressure anomaly over the central

Arabian Sea during May. This anomaly increased progressively with the advance of the season. He believed that an area of excessive pressure which maintained the same character throughout, advanced northeastwards from near Cape of Good Hope to the north of Arabian Sea and felt that the causes of the monsoon failures originated in the region south of the equator and ultimately influenced the conditions north of the equator. Eliot (1900-1902) who examined the data in detail, could not find sufficient evidence for the existence of a high pressure in Indian Ocean and its march northwards across the equator.

Ramdas (1960) examined the mean sea level pressure distribution over the world for July 1918 and also for July 1917 which year was characterised by widespread floods in India. The chief features of the pressure distribution for the two years are, higher intensity (by about 5 mbs) of the southern hemispheric sub-tropical high pressure belt over the Indian Ocean and relatively weaker low pressure (pressure being higher by 5 mbs) over Northwest India and West Pakistan during July 1918 in comparison to that in July 1917.

The activity of the Asian summer monsoon can be considered to be primarily dependent on the following factors :—

(*i*) The intensity and location of the equatorial trough and the intensity of the low pressure area over West Pakistan. It is wellknown that over the Indian Subcontinent, when the trough in the lower troposphere (i.e., upto about 3 kms above mean sea level) shifts to the foot of the Himalayas and stays there, sub-Himalayan areas get heavy to very heavy rain and most parts of the Indian Subcontinent get very little rain and that such periods are referred to as 'breaks' in monsoon activity. These situations may persist from a few days to as much as 2 to 3 weeks. Ramamurthy (1969) studied the breaks during July and August for the period 1887-1967. According to Ramage (1967), the heat low system extending from Somalia to West Pakistan is maintained and intensified through the summer by subsidence of the air originally lifted and warmed by the release of latent heat in monsoon rain systems to the east and south.

(*ii*) Meteorological conditions within the tropical and sub-tropical latitudes in the southern hemisphere. From their study on Indian summer monsoon, Rao and Desai (1970) have concluded that the flow of air from southern hemisphere across the equator is most important for the development of the monsoon trough over India.

(*iii*) The intensity and location of the north Pacific anticyclone. This affects the monsoon activity over Japan and eastern China.

(*iv*) The character and movement of troughs in westerlies north of India. Their influence on monsoon activity over India has been brought out by Pisharoty and Desai (1956), Mooley (1957), Chakravorthy and Basu (1957) and Ramaswamy (1962).

(*v*) The activity and tracks of tropical storms and depressions. The depressions, moving across North India, maintain the activity of the monsoon trough by transporting heat and moisture upwards over the area of the trough.

All the above factors operate together with varying degree of influence and produce a variety in respect of monsoon activity over Asia. A severe imbalance in these factors would lead to large scale failure of monsoon. When all factors operate together it is difficult to locate precisely which factor has initiated the imbalance.

As available meteorological information is scanty it is rather difficult to find out the causes of these monsoon failures. The information that is available for these two seasons is the sea level pressure distribution over the Indian Subcontinent and the depression tracks during each of the months. This information has been examined and on the basis of this examination possible causes have been inferred.

The normal sea level monsoon trough in each of the monsoon months was divided into three sections, Calcutta to 85°E, 85°E to 80°E and 80°E to 75°E. For each of these sections mean monthly sea level pressure within the trough was obtained for each of the two years 1899 and 1918. Normal sea level pressure was obtained for each of these sections of the trough from the normals for the period 1931-60. For each section sea level pressure departure was obtained for each of the months June to September. In the same manner, pressure departure from normal was also obtained for North Rajasthan. This is given in Table II. It can be seen from this Table that the monsoon trough west of 80°E was, in general, substantially weaker than normal in each of the monsoon months. Particularly over North Rajasthan, the pressure was much higher than the normal in each of the two years.

TABLE II

Mean sea level pressure departure (Mbs) from normal within monsoon trough and over north Rajasthan during the months of summer monsoon of 1899 *and* 1918

Area	1899				1918			
	June	July	Aug.	Sept.	June	July	Aug.	Sept.
Trough between Calcutta and 85°E	0.5	0.0	0.0	1.4	0.0	0.0	0.0	—0.4
Trough between 85°E and 80°E	0.5	0.1	0.5	1.6	1.0	0.7	0.0	1.2
Trough between 80°E and 75°E	1.0	0.6	0.1	1.6	1.0	0.3	—1.2	1.3
North Rajasthan	0.0	3.5	2.3	2.2	2.0	1.8	1.0	2.4

The tracks of the monsoon depressions during 1899 and 1918 as taken from the atlas of tracks prepared by the India Meteorological Department (1964), are shown in Fig. 5. These tracks are unusual in that their influence was mostly confined to east of 80°E.

The prominent fact which emerges from this investigation is that in each of the monsoon months of these two years, the monsoon trough was substantially weaker west of 80°E and this is possibly the major cause for the disastrous failures over most parts of the Indian Subcontinent. The question arises, why the trough was much weaker in these two years! Perhaps (*a*) absence of active monsoon depression which could move west of 80°E, (*b*) larger activity of eastward-moving westerly troughs across northern parts of West Pakistan and of India and (*c*) the absence of a good flow of air from the southern hemisphere, appear to be the possible cause which might have acted jointly to produce the severe imbalance leading to large-scale monsoon failure particularly over western India. An examination of the daily weather reports and the monthly weather reviews of India for the monsoon months of these two years appears to suggest that eastward moving systems in westerlies affected the northern parts of India on a good number of days.

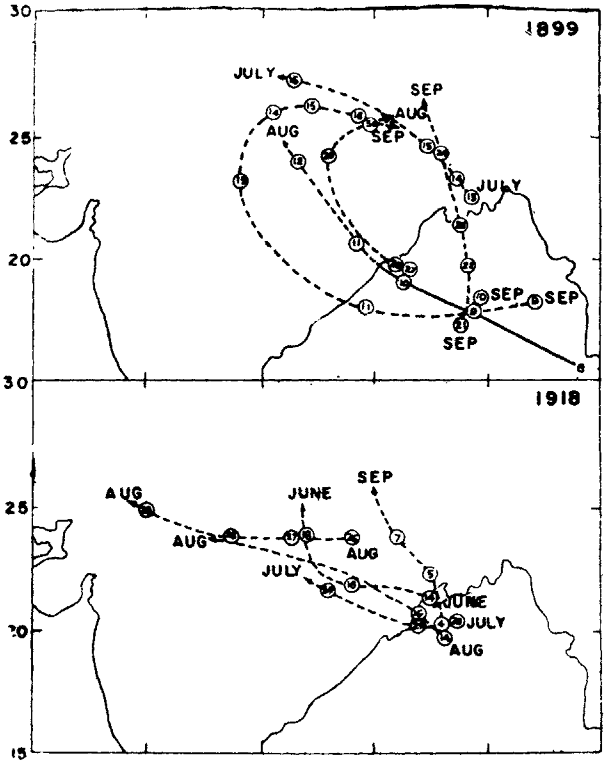


FIG. 5. Depression tracks during summer seasons of 1899 and 1918.

CONCLUSIONS

The worst summer monsoon failures over the Asiatic monsoon area occurred during the years 1899 and 1918.

A substantially weaker monsoon trough west of 80°E, resulting jointly from absence of active monsoon depression, larger activity of westerly troughs across northern parts of India and absence of a good air flow from across equator, appears to be the major cause of the monsoon failures over the Indian subcontinent during these two years.

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