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Rainfall around monsoon depressions over India

P. R. PISHAROTY and G. C. ASNANI

Meteorological Office, Poona

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ABSTRACT. Rainfall that occurred for 2 to 3 days within a radius of 350 miles from the centre of a depression along its track has been combined using the data of all raingauge stations within that area. Such 'composite' charts of rainfall were prepared for a sample of three mid-monsoon depressions in the year 1944. Falls of heavy rain of 3″ and above in 24 hours are confined to an area lying to the left-hand side of the track. On any particular morning, the heavy rainfall area extends to about 300 miles ahead and to about 300 miles behind the centre of the depression on that morning, measured respectively along the expected and past track of the depression. The width of the area is about 250 miles and extends to the left of the track. It is further noticed that out of this belt, about 30 per cent of the area is almost the maximum over which there may be rainfall of 3″ or more in 24 hours. The results are discussed from a forecaster's point of view.

1. Introduction

The distribution of rainfall around depression and cyclonic storms over India has been the subject of numerous studies by Roy and Roy (1930), Ramanathan and Ramakrishnan (1933), Sur (1933), Mull and Rao (1949), Malurkar (1950), Desai (1951) and others. These studies have described the distribution of rainfall around individual storms and depressions. It is fairly well known that the southwest sector of a monsoon storm is liable for heavy rains of 3″ and above in a period of 24 hours. But no attempt has been made so far to determine the extent of this southwest sector which is liable for heavy rains. In any such study, we have to ignore for the present the effect of orographic features on the storm rainfall and consider only the hydrodynamical effects. The present study outlines a method of preparing 'composite' rainfall charts for monsoon depressions, moving more or less westnorthwestwards across the central parts of India, taking into consideration rainfall reports from all rainfall recording stations.

2. Data used

Three monsoon depressions of the year 1944 were selected, which, at one stage or another, were of sufficient intensity to be called 'cyclonic storms'. Their tracks and day-to-day positions, shown in Fig. 1, were taken from the *India Weather Review*, Annual Summary, Part C, 1944. Rainfall amounts reported in the publication *Daily Rainfall of India*, 1944 were plotted on a map (scale 1″ = 32 miles), over an area of 500 miles around the depression centres, for the following eleven dates—

25, 26, 27 and 31 July 1944

1, 2, 19, 20, 21, 22 and 23 August 1944

The depression centres referred to 0900 IST of each day, and the rainfall referred to the amount recorded during the preceding 24 hours (During the year 1944 the IST was one hour ahead of the present IST).

3. Preparation of Composite Charts

The 24-hr rainfall amounts plotted within a circle of 350 miles radius, drawn around the centre of the depression on a particular morning, were transferred to a transparent overlay. The limit of 350 miles was chosen because there were only a few isolated instances of heavy rainfall occurring between the 350 and 500 miles range. The centre and the tangent to track of the storm were also marked on the overlay. This overlay was then superposed on the rainfall chart

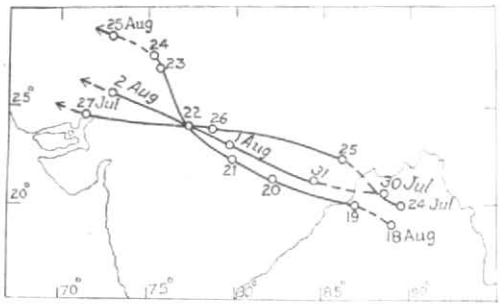


Fig. 1. Positions of depression centres at 0900 IST (July and August 1944)

plotted for the subsequent day, with the centres and the tangents to the tracks at the respective centre of the depression coinciding. The rainfall amounts for the second day were then transferred to the overlay in a different colour. The process was repeated for a third day. Thereby, rainfall amounts registered around depression centres on three consecutive days were transferred to the same overlay. Isopleths were then drawn irrespective of the days on which the rainfalls were recorded. It is felt that such a composite chart would have the advantage of high-lighting the common features attributable to the physical hydro-dynamics of the depression.

The combination of the rainfall has been carried out for the following days—

(*i*) 25, 26 and 27 Jul 1944

(*ii*) 31 Jul and 1 and 2 Aug 1944

(*iii*) 19, 20 and 21 Aug 1944

(*iv*) 22 and 23 Aug 1944

Thus 11 days' data were combined into 4 charts. The charts give the general distribution of past 24 hrs rainfall within a range of 350 miles from the centre of a depression moving nearly westnorthwestwards, across the central parts of India, during the monsoon months.

4. Main features of the Composite Charts

Isohyets for 3″ and 5″ of rain on the composite charts are shown in Figs. 2 to 5. Figs. 6 to 9 give the composite charts of pressure departure, and Figs. 10 to 13 the 24-hr pressure tendency (from 0900 IST of previous day to 0900 IST of date), corresponding to the four composite rainfall charts, Figs. 2 to 5, worked out similarly by using the pressure departures and pressure tendencies around the depression centres instead of 24-hr rainfalls.

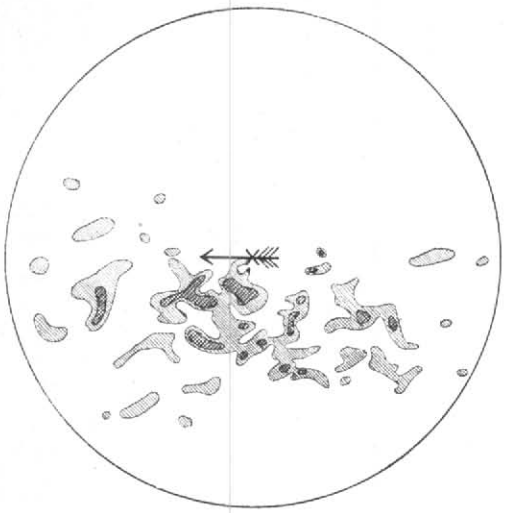
A comparison of the composite charts of rainfall and the composites of pressure departures and of pressure tendencies is interesting. The pressure departures and pressure tendencies have a certain degree of symmetry about the centre of the depression; the negative values in both cases extend well to the left and right of the track of the depressions. However, the rainfall distribution appears to be distinctly asymmetric. There is no instance (out of the 11 situations) when a 5″ or 3″ isohyet lies to the right of the track of the depression.

If P is the centre (Fig. 14) of the monsoon depression over the central parts of India, moving nearly westnorthwestwards, regions of heavy rainfall of 3″ and above in 24 hours, are generally found within the area ABCD, where PA is the direction of movement of the depression. The distances PA and PD are each nearly 300 miles, while the width PQ is about 250 miles.

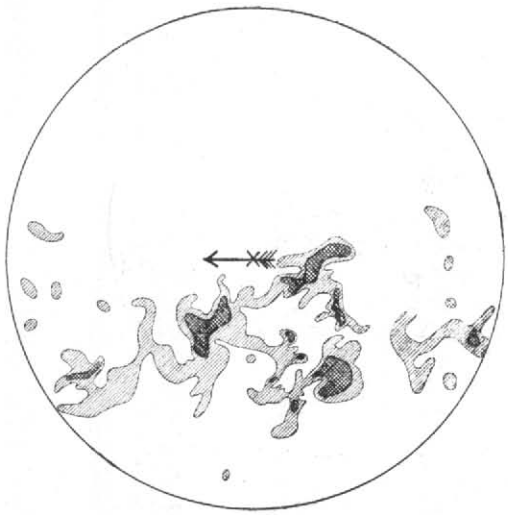
The area ABQP is part of the southwest sector of the depression and is well known to be the area of heavy rains, and for which there are quite a few theoretical explanations. What this study reveals is the approximate dimensions of this area when the pressure departure is of the order of 10 millibars at the centre of the depression.

With respect to the spatial distribution of heavy rainfall, it will be realised that the shaded area in Figs. 2 to 5 represents the area where heavy precipitation occurred on *at least one* of the days for which the combination has been made. From that point of view, it represents the upper limit of the area of heavy precipitation which may occur during 24 hours preceding the morning on which the depression centre has been located. Measurement shows that the shaded area is of the

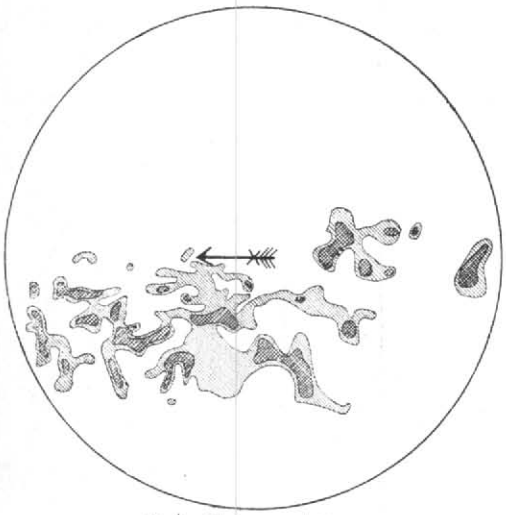
Composite charts of Rainfall for area
350 miles around depression centres



25 to 27 July 1944
Fig. 2



31 July to 2 August 1944
Fig. 3



19 to 21 August 1944
Fig. 4

22 to 23 August 1944
Fig. 5

Rainfall 3.00 to 4.99 inches in 24 hours
Rainfall 5.00 inches or more in 24 hours

Composite charts of Pressure Departure (mb) for area 350 miles around depression centres

25 to 27 July 1944

Fig.6

31 July to 2 August 1944

Fig.7

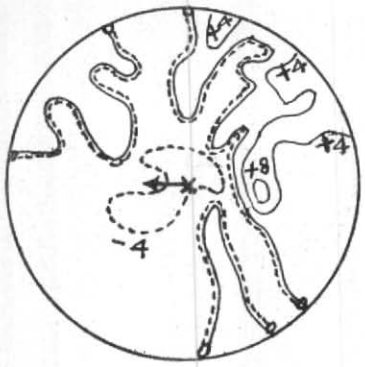
19 to 21 August 1944

Fig 8

22 to 23 August 1944

Fig. 9

Composite charts of Pressure Tendency (*mb*) for area 350 miles around depression centres

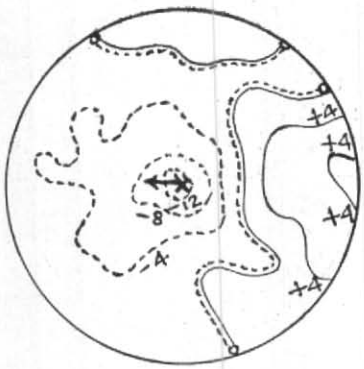


25 to 27 July 1944

Fig.10

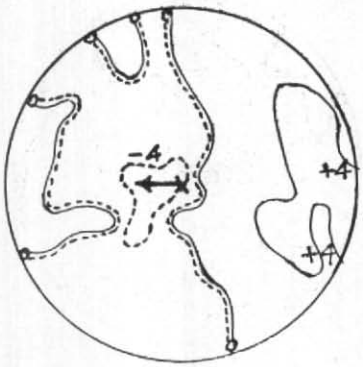
31 July to 2 August 1944

Fig.11



19 to 21 August 1944

Fig.12



22 to 23 August 1944

Fig.13

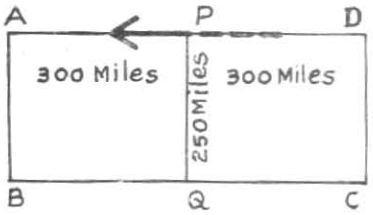


Fig. 14

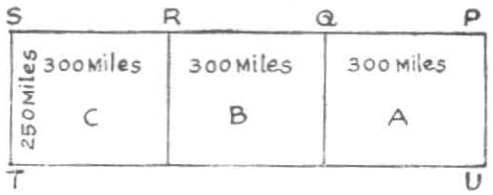


Fig. 15

order of 25 per cent of the total area ABCD (600 × 250 sq. miles, Fig. 14). If, however, PQ is made 200 miles instead of 250 miles, the length AD continuing to be the same 600 miles, the shaded area is of the order of 30 per cent of the total area (600×200 sq. miles). One may, therefore, make a statement that about 30 per cent of the area liable for heavy rainfall, is almost the maximum area over which there may be rainfall of over 3″ in 24 hours.

5. Application to Forecasting

A forecaster with the responsibility of issuing routine heavy rainfall warnings for the next 48 hours has to cover an area up to at least 300 miles ahead of the expected centres of the depression 48 hours hence. The eleven days' study gave the average movement of such monsoon depressions to be very nearly 300 miles a day. If P (Fig. 15) be the centre of a depression on any particular morning, R is the expected position of the storm 48 hours later, heavy rainfall may occur over an area PSTU, nearly 900 miles long and about 250 miles wide. Denoting the hour at which the depression is centred at P, by t, the periods during which the heavy rain may occur over the different areas of Fig. 15, will be somewhat as follows—

Area A : From $t-24$ hrs to $t+24$ hrs
Area B : From t hrs to $t+48$ hrs
Area C : From $t+24$ hrs to $t+72$ hrs

It may be emphasized that these conclusions are based on a small sample of eleven depression days of the monsoon period, when these were moving more or less westnorthwestwards across the central part of India. The conclusions are, therefore, necessarily tentative, but appear to be significant. However, they cannot be applied to depressions of other seasons, or to depressions which have a northerly or northeasterly movement. Further study of the rainfall distributions during different storms is contemplated.

6. Acknowledgement

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