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A study of Climatological and other Rainfall Patterns over Central India

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ABSTRACT. The study is divided into three parts, *viz.*, (a) The normal monthly rainfall charts during monsoon months for Madhya Pradesh and Vidarbha have been presented and the results of the analysis discussed; (b) The spatial distribution of rainfall associated with monsoon depressions moving across Central India has been depicted and a method to forecast the same has been described ; and (c) The character of rainfall at different places in and around a low-level convergence zone occurring over the above area has been brought out with the help of self-recording raingauge charts and its usefulness in local forecasting has been indicated.

1. Introduction

The preparation of the normal monthly rainfall charts for the monsoon months was done by using the data based on 50-year records (1901 to 1950) from all the 40 departmental and 350 State raingauge stations within Madhya Pradesh and Vidarbha. For the study of the rainfall patterns associated with a depression moving across the central parts of the country, the isohyetal patterns of twelve depressions pertaining to the period 1952—63, have been used. In a previous study by Pisharoty and Asnani (1957), data for three depresssions during July and August 1944 had been used, while in a recent study by George and Datta (1965) data for only one depression in September 1963 had been examined in detail with reference to the character of the rainfall and other synoptic features. Analysis of heavy rainfall patterns associated with six selected depressions in the present study, has enabled preparation of more representative composite rainfall charts. In the present study the composite charts prepared can be used directly on the surface chart for ascertaining expected areas of heavy rainfall. The present charts bring out finer details of the heavy rainfall patches in the field of the depression. Character of rainfall occurring at different stations within a convergence zone has been studied with reference to self-recording rainguage charts of 9 stations in the region for a period of 12 years. In all ten cases of occurrence of convergence zones have been looked into and the observed patterns brought out accordingly.

2. Normal rainfall patterns during monsoon

Rainfall data for the departmental as well as the State raingauge stations were plotted on a map monthwise for the monsoon period, June to September and the isohyets were drawn (Fig. 1).

In June, isohyetal pattern shows a progressive decrease in rainfall from southeast to northwest direction across the region. In July the pattern gets completely changed, with higher isohyetal values. It is observed that there is a prominent belt of concentrated rainfall (50 cm) in the longitudinal belt 80°-81°E with a small additional patch covered by the 50-cm isohyet in Raigarh district. In August, the pattern is more or less similar to July and the prominent belt of rainfall (40 cm) lies in the same longitudinal belt as in July. Two small patches enclosed by the 40-cm isohyet, one in Raigarh district and another in Sagar-Hoshangabad districts are also seen. In September the isohyetal pattern again gets completely changed. There is again a progressive decrease of rainfall, broadly from southeast to northwest and thus it seems to correspond generally to the June pattern of isohyets.

The June pattern of isohyets can be understood with reference to the dates of onset of the monsoon over the region. As is well known, the monsoon sets in first on the southern parts of the region and then gradually extends northwards. The isohyetal patterns are thus in conformity with this progressive onset of monsoon.

The July and August patterns, however, present some peculiarities. Apart from the samll patches of concentrated rainfall observed in the normal charts of July and August, there is the prominent belt broadly between Long. 80°E and 81°E and between Lat. 18°N and 24°N during both these months where relatively high rainfall persists. While the small patches can be attributed to local orographic effects, it is difficult to explain this extensive longitudinal belt of concentrated rain on this account as the main hill ranges, *viz.*, the *Satpuras* and the *Vindhyas* run in an east-west direction.

An explanation for the existence of such a belt of concentrated rainfall, however, becomes feasible

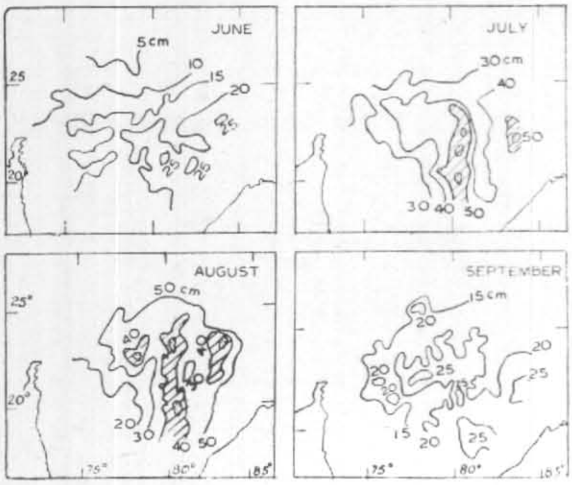

Fig. 1. Monthly normal isohyetal pattern for June, July, August and September

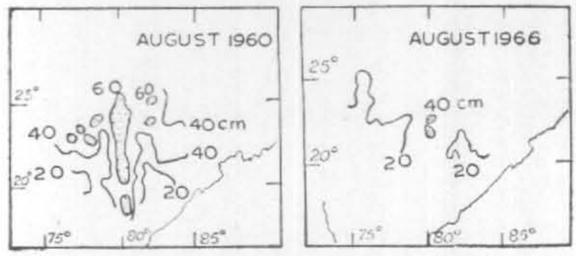

Fig. 2(a). Monthly rainfall charts for August 1960 and August 1966

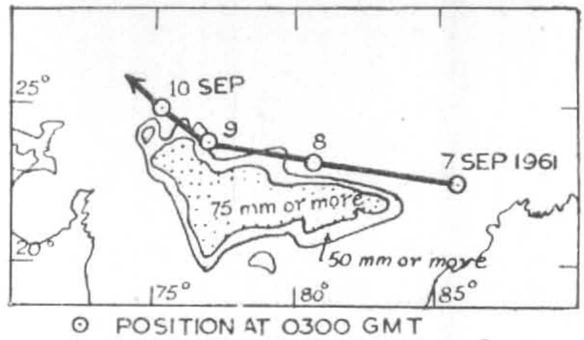

Fig. 2 (c). Track of depression (thick line with arrow) between 7 and 10 September 1961 and the areas where heavy rainfall (24-hr period) occurred during its passage

Rainfall recorded at various stations in the region on the mornings of 8, 9 and 10 September 1961 have been utilised

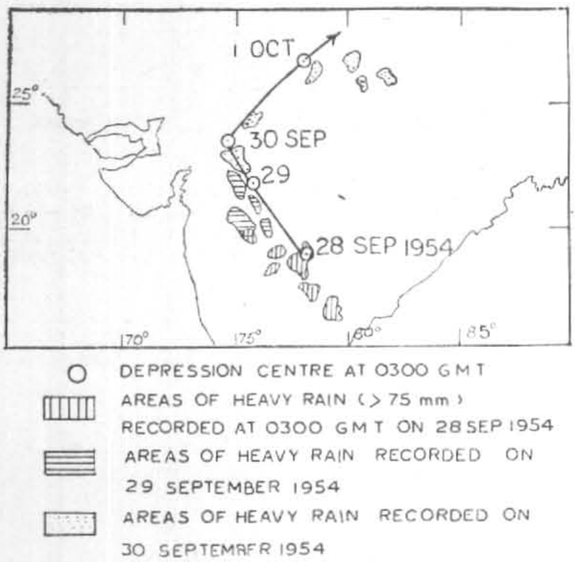

Fig. 2(b). Principal heavy rainfall areas in the field of a recurving depression of September 1954

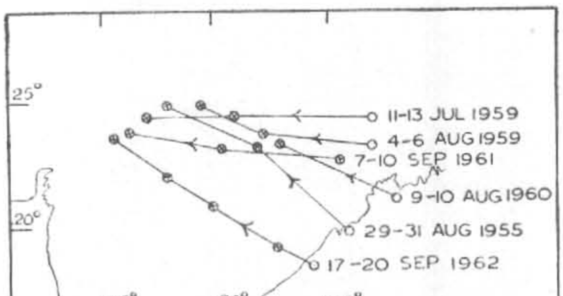

Fig. 3. Tracks of depressions

Depression positions at 0300 GMT only have been indicated by small circles. Positions for which rainfall data have beed utilised for preparing composite charts are shown with cross within the circle

when the synoptic aspects are taken into consideration. It is generally observed that on most occasions when a depression originates in the Bay in latitudes above and near 18·5°N, a low-level convergence zone giving concentrated rainfall also develops over the Central India right from the time of formation of the depression. These zones are also seen to lie partly or wholly within the longitudinal belt 80° to 81°E on many occasions (Figs. 6 to 8). With a view to examine this aspect, monthly rainfall charts for August 1960 and August1966 have been analysed (*see* Fig. 2a). It is seen from these charts that in the former case, anchoring of heavy rainfall along 80°-81°E did occur as 3 depressions and 2 lows (covering 28 days of of Dep./Low) formed during the month and moved across the country,

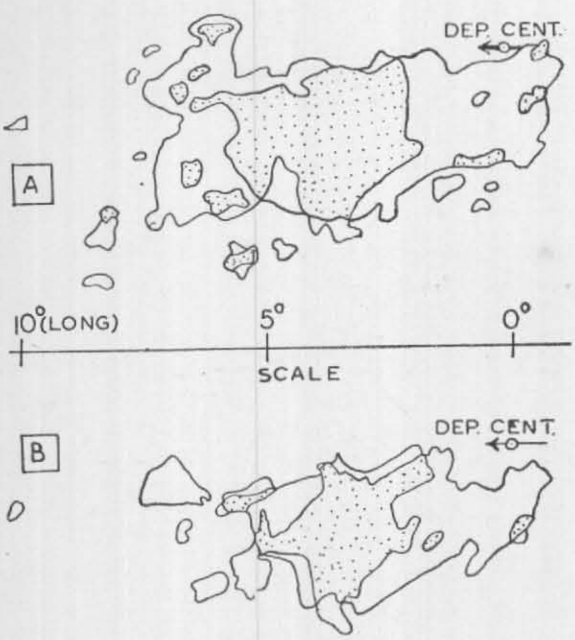

Fig. 4. Composite maps depicting "Probable areas" around depression centre (shown by continuous line) for 50 mm of rain (top) and 75 mm of rain (bottom). "More probable areas" are stippled

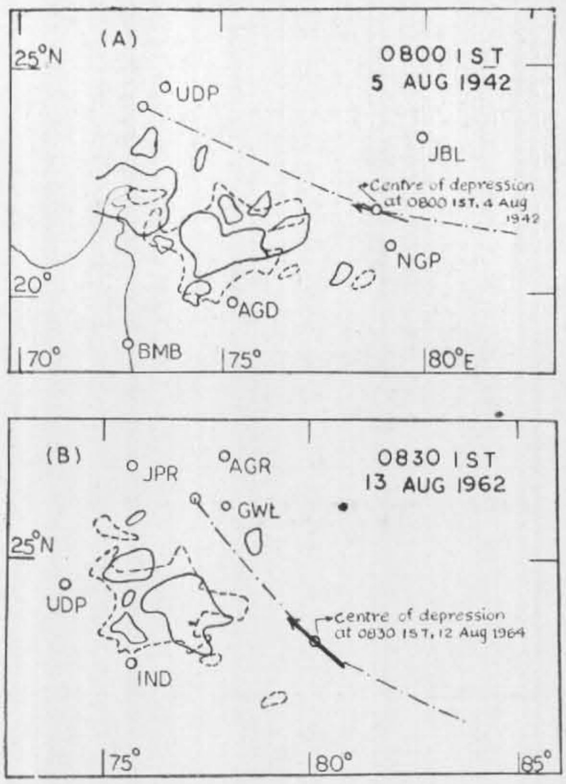

Fig. 5. Actual and expected areas of heavy rain around a depression centre

(A)—Actual areas (enclosed by continuous lines) of heavy rain recorded at 0800 IST on 5 August 1942 and the expected areas (enclosed by dotted lines) of heavy rainfall for the subsequent 24 hours with respect to that depression centre at 0800 IST on the previous day.

(B)—Actual areas of heavy rain recorded at 0830 IST on 13 Aug 1962 and the expected areas of heavy rain for the subsequent 24 hours with respect to the depression centre at 0830 IST on the previous day.

But, in the latter case no such anchoring is observed as only 1 depression and 2 feeble lows (covering only 8 days of Dep./Low) formed in the Bay and moved across the country. Thus, it is evident that the normal monthly frequency of depressions forming in the Bay north of Lat. 18½°N is of importance in this context since the low-level convergence zones where concentrated rainfall occurs and which develops over the region in association with these depressions will have direct influence in shaping the normal monthly isohyetal pattern of the region.

The climatological records of 70 years (1891—1960) show that in June 43 out of 52, in July 82 out of 108, in August 82 out of 117 and in September 49 out of 113 of the Bay depressions formed north of Lat. 18½°N (India met. Dep. 1964). Thus, the percentage frequency is significantly greater in June, July and August than in September. The normal movement of these depressions is westnorthwest or northwestwards and hence during July and August, the average number of depressions originating in the Bay in latitudes north of 18½°N and then moving across the region is also significantly greater compared to that in September. Now, as these depressions form in the Bay and get intensified, a cyclonic circulation develops around them over a wide area and on the western/southwestern periphery of the circulation, a convergence zone invariably develops in lower levels (Figs. 6 and 7). As mentioned earlier, this zone lies either partly or wholly along the longitudinal belt 80°-81°E on many occasions. When the depression moves westnorthwest/northwestwards and crosses overland, it weakens but the convergence zone continues to persist more or less where it formed in the initial stages as the

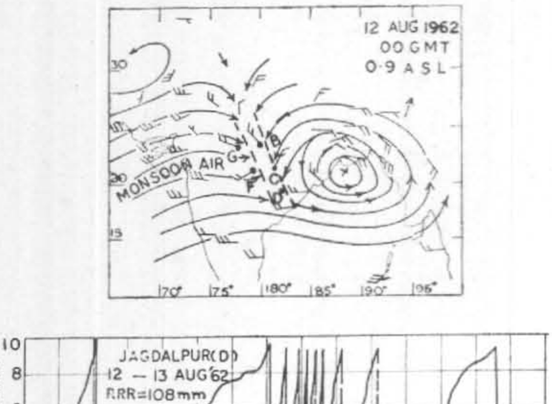

Fig. 6. Streamflow chart at 0·9 km a.s.l. for 00 GMT of 12 August 1962 and relevant intensity rainfall charts of Jagdalpur, Bhopal, Nagpur, Jabalpur and Raipur

extent of the circulation reduces due to the weakening of the system. Thus, due to the favourable positioning of the low/depression centres in the Bay and their WNW/NW movement in July and August, the longitudinal belt 80°-81°E over the region is subjected to an early spell of heavy rains right from the formation of the lows/depressions and this spell is maintained during the subsequent movement of the system till it crosses the coast and moves a little inland. However, when the system further moves W/NW beyond the belt (80-81°E), the associated convergence zone also shifts westwards with it. But the rainfall within the convergence zone is now associated with a system which has progressively weakened with its movement. Hence concentration of heavy rain does not occur in other parts of the region as in the 80°-81°E belt. This appears to be the most plausible reason for the formation of the belt of concentrated rainfall as observed in the isohyetal patterns for July and August over the region.

The reasoning given above is not, however, applicable for June although almost an equally high percentage of depressions from above 18½°N in this month also, as in July and August. This is because, the southwest monsoon normally begins to set in over the region only from the second half of June in association with the formation of lows/depressions in the head Bay and finally gets established towards the end of the month by the progressive movement of these lows/depressions across the country. Hence, due to absence of monsoon current in lower levels over the region during a major period in this month, very few effective low-level convergence zones develop over the region in particular. Secondly, the annual frequency of Bay depressions forming above 18½°N latitude in this month is almost half of that for the month of July and August. Consequently, the concentrated rainfall belt is not observed in the normal monthly isohyetal pattern of June as in July and August.

In September, the isohyetal pattern is more or less similar to the June pattern and the belt of concentrated rain is not observed. As stated above, majority of the depressions (about 60 per cent) during this month originate in latitudes much lower than 18½°N and then traverse in a WNW or NW-ly direction. Hence, the probability of formation of low-level convergence zones over the region right from the time of formation of depressions in the Bay gets much reduced in September unlike July or August. Further, it is also seen from the climatological data for the 70-year period that whereas on an average one depression per year forms in the Bay above 18½°N during July and August, only one in two years forms in September. Thus, on this account the probability of formation of low-level convergence zones in the region gets still further reduced in this month. Consequently, in September, the concentrated rainfall belt is not seen in the normal isohyetal pattern. The usual decrease in rainfall associated with progressive weakening of the low/depression system during their movement across the region is, therefore, reflected in the normal isohyetal pattern of September. The normal rainfall pattern of this month therefore exhibits in

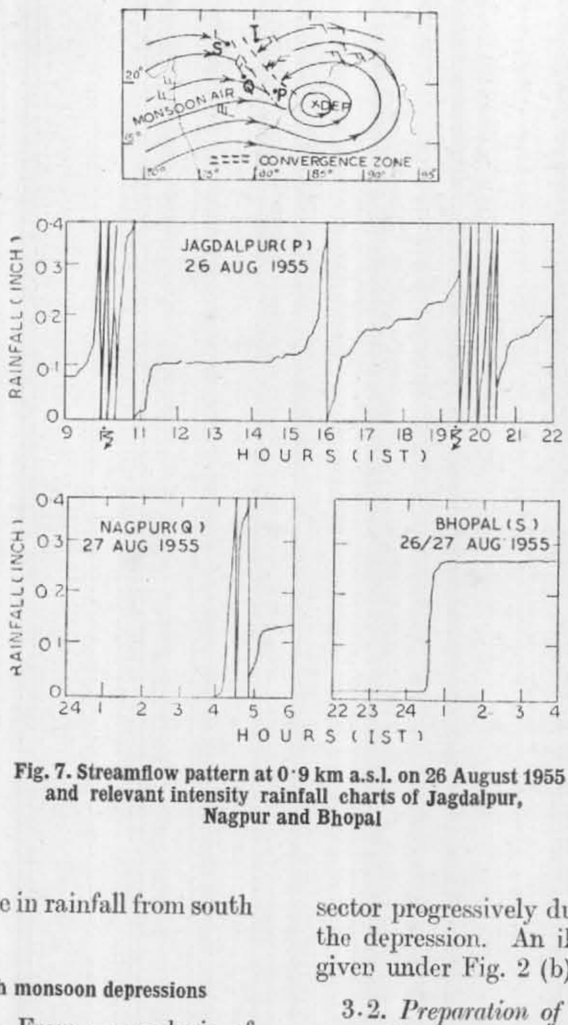

Fig. 7. Streamflow pattern at 0·9 km a.s.l. on 26 August 1955 and relevant intensity rainfall charts of Jagdalpur, Nagpur and Bhopal

general a progressive decrease in rainfall from south to north.

3. Rainfall patterns associated with monsoon depressions

3.1. *Spatial distribution* — From an analysis of 32 rainfall charts (associated with different locations of the centres of 12 depressions), each depicting 24-hr isohyetal pattern for the region, it is observed that heavy rain (75 mm or more) generally occurs in patches. On an average about 8 individual patches of heavy rain are generally observed in the field of each depression position. Each patch, on the average, covers an area of about 4800 sq. km.

It is further observed that rainfall amount exceeding 50 and 75 mm in 24-hr are invariably concentrated to the left of the depression track and within a comparatively narrow belt of 2 to 3 degree latitude from the track (Fig. 2c). Heavy rain rarely occurs to the right of the track except in cases when the depression shows some tendency to recurve north/northeastwards. In most of such cases, the heavy rainfall belt which normally remains confined to the left forward sector of the depression partly shifts to the right forward sector progressively during the recurving phase of the depression. An illustration of this feature is given under Fig. 2 (b).

3.2. *Preparation of composite charts* — In order to study the spatial distribution of heavy rain associated with the depressions, composite rainfall charts in respect of six selected depressions for July, August and September which moved across the region in directions varying from W to NW were prepared. The depressions were so chosen that the central pressure defects were between 4 and 8 mb during the course of their movement across the region. The composite rainfall charts were prepared on the lines adopted by Pisharoty and Asnani (*loc. cit.*) with a view to obtain a picture of rainfall arising mainly due to the hydrodynamical processes operating in the depression system. The tracks of the depressions selected are indicated in Fig. 3.

In all, six composite charts were obtained and areas where rainfall of more than 50 and 75 mm occurred during the subsequent 24-hr period were demarcated. From each of these composite charts, areas around the depression centre covered by 50-mm isohyet on each occasion were transferred

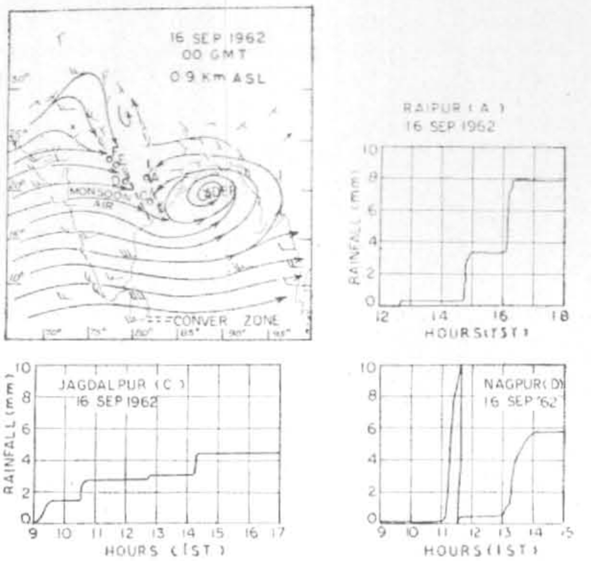

Fig. 8. Streamflow pattern at 00 GMT on 16 September 1962 at 0·9 km a.s.l. and character of precipitation at stations near and within a weak convergence zone

(The confluent monsoon and the easterly streams are rather weak in this case)

to one single map in six different colours. Now in this single composite map so prepared with six different colours, the areas where two, three or more colours overlapped were marked out. The areas around the depression centre where two colours overlapped were taken as the 'Probable areas' for occurrence of more than 50 mm rain during the subsequent 24-hr period. Similarly, areas where three or more colours overlapped were taken as 'More probable areas' for the occurrence of more than 50 mm of rain (*see* Fig. 4a). One more such single composite map (from the six composite charts) was prepared for the 75-mm isohyet exactly in the same manner as indicated above (Fig. 4b). These two single composite maps have been reduced to the scale of surface chart ($1 : 10^7$).

3.3. *Utility for forecasting heavy rain* — These maps can be utilised for forecasting expected areas of heavy rainfall around the depression centre for a subsequent 24-hr period by carrying out the following operation.

First coincide the centre of depression shown in the composite map (for 75-mm isohyet) with the actual centre of the depression on the 0300 GMT surface chart. Then, keeping the centre fixed, orient the composite map in a manner such that the arrow coincides with the expected direction of movement of the depression centre. Now, trace out the 'More probable areas' of heavy rainfall on the surface chart from the composite map (shown in Fig. 4b).

The expected areas of heavy rainfall for a subsequent 48-hr or 72-hr period can also be assessed by the single composite map (for 75-mm isohyet) by shifting the depression centre indicated on it to the anticipated positions of the centre of the actual depression 24 or 48 hours later respectively and then marking out the 'More probable areas' of heavy rain swept out in this operation on the surface chart.

A striking feature that has been noticed in all the six composite charts is the absence of heavy rain in a belt of about 60 km around the depression centre. This observation corroborates the view of Mull and Rao (1949) that the areas of maximum convergence and consequently heavy rainfall is somewhat away from the depression centre.

The average picture of distribution of 75 and 50-mm isohyets with respect to the depression centre (depicted in Fig. 4), obtained on the basis of rainfall data for the period 1952–63, was put to test in cases of two depressions (one in August 1942 and another in August 1964) which moved across the region. These two test cases are shown in Fig. 5. It will be seen that the areas over which the heavy rainfall may be forecasted on the basis of composite charts, generally encompass the different patches of heavy rainfall areas actually observed. Thus, it is felt that these composite maps can be fruitfully utilised for the purpose of forecasting heavy rain in the region associated with depressions.

4. Rainfall patterns in and near low-level convergence zones

(*a*) *Special features* — It is interesting to see from the self-recording rainfall charts, the marked contrast in the character of rainfall which occurs at stations within low-level convergence zone and at other stations situated in the monsoon-air sector slightly away from the periphery of the zone. A fairly strong north-south low-level convergence zone, which formed between the monsoon current and the easterly current associated with a Bay depression centred near 21°N/88½°E at 0000 GMT on 12 August 1962, is depicted in Fig. 6 along with the intensity rainfall charts of some stations. It can be seen from the rainfall charts of Jabalpur, Raipur and Jagdalpur which are situated in or at the periphery of the convergence zone, that the rainfall at these places was fairly heavy and was generally characterised by one or two very intense spells of concentrated rain accompanied by thunder. At Nagpur, a station situated in the monsoon-air sector and about 80 km (50 miles) to the west of the (western) periphery of the convergence zone in this case, the precipitation was rather showery in the beginning but was more of a continuous type later with much diminished intensity. At Bhopal, a station situated in the same monsoon-air sector, but still further away from the convergence zone, there was only a brisk shower.

Another strong low-level convergence zone (strength of monsoon current and easterlies at 0·9 km a.s.l. greater than 15 kt near the zone) which formed on 26 August 1955 is shown in Fig. 7 along with the self-recording raingauge charts of the relevant stations. This convergence zone was associated with a Bay depression centred near 18½°N/85½°E in the morning on this day. In this case, Jagdalpur situated inside the convergence zone experienced two spells of very intense rain accompanied by thunder. The character of rainfall at Jagdalpur was, therefore, more or less akin to that of Jabalpur, Raipur and Jagdalpur of the previous case (*see* Fig. 6) which were also situated inside a similar convergence zone. Again in this case also Nagpur, situated in the monsoon-air sector and slightly away from the western periphery of the convergence zone, experienced only a brisk shower for a short while. Thus, the nature of precipitation at Nagpur, in both these cases, being similarly situated with respect to the convergence zone was more or less identical except that in the former case continuous type of precipitation followed the initial brisk shower. The nature of precipitation at Bhopal on both the occasions was also more or less identical, being similarly situated in relation to the convergence zone.

When, however, the strength of the monsoon current as well as the easterly current is feeble (less than 15 kt), the low-level convergence zones which form on such occasions are also rather weak in character and the distinguishing features in the nature of rainfall at stations situated within and slightly away from the convergence zones no longer exist. It will be seen from the self recording charts of Raipur, Jagdalpur and Nagpur (Fig. 8) situated in and near a weak convergence zone that the rainfall at these stations is characterised by one or two showers only. The total amount of precipitation at each of these individual stations is also considerably less as compared to that of similarly situated stations of a strong convergence zone.

(*b*) *Utility in local forecasting* — From the special characteristics of rainfall described above, their utility for local forecasting becomes immediately apparent. For aerodrome stations where short term accurate forecast is of particular importance for guiding the flying activity at the station it will be seen from this study, that the duty forecaster will be able to form a picture about the trend of weather at his station depending on the location of the station with reference to the convergence zone. Thus, at a station situated 100 to 200 km to the west of a strong north-south convergence zone which is moving, say westwards, one can expect light showers in the beginning but after a few hours heavy or very heavy showers can be expected at the same station. However, in the case of the weak convergence zone when the strength of the monsoon current and the easterlies does not exceed 15 kt, the forecaster will be able to infer that the location of his station with reference to the zone will not make much difference to the character of rain which can occur at the station. The rainfall in this case will be light and characterised by one or two showers only.

This study shows that a watch on the synoptic development and movement of low-level convergence zones gives one a clue to the character of rainfall that can be expected at a station depending on its location with respect to the convergence zone.

5. Acknowledgement

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