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Forecasting heavy rainfall over Delhi and neighbourhood

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ABSTRACT. The wind field and the convergence pattern over Delhi have been examined with a view to develop criteria for forecasting heavy rainfall over Delhi and neighbourhood. The study reveals that on many occasions there is a passage of a wave trough or rise in the rate of convergence in the lower levels 24 to 36 hours prior to the occurrence of heavy fall. It is suggested that these can be taken as guide to heavy rainfall forecasting.

1. Introduction

Forecasting heavy rainfall over a wide area during monsoon season have generally been associated with the location and depth of the monsoon trough, the movement of upper air troughs, depressions etc but these are of little help for giving a local weather forecast. The local weather forecast for Delhi assumes special importance due to various reasons. This study was undertaken to develop criteria for forecasting heavy rainfall over Delhi and neighbourhood.

One mechanism for heavy rainfall may be due to convergence in the lower levels with superimposed divergence aloft (Mull and Rao 1949, Koteswaram and George 1960). Examination of wind field over Delhi during the monsoon season has revealed on many occasions the development of wave troughs in the lower levels in advance of active weather. These are regions of strong convergence. The study of wind field and the horizontal convergence along the vertical over Delhi was, therefore, undertaken with a view to aid heavy rainfall forecasting.

2. Study

Delhi and neighbourhood have been considered to have received heavy rainfall when any one of the raingauge station in Delhi State reported rainfall of 6 cm or more. The various rainguage stations are shown in Fig. 1.

During monsoon season of 1963—65 heavy falls were experienced on many occasions. The distribution of rainfall in Delhi State on these occasions showed wide variation. Bose (1960) has attributed the extremely localized spatial distribution of heavy falls due to the showery nature of precipitation. He has shown that the core of heaviest fall is hardly few kilometres across. This may be generally true. But to explain on the whole the incidence of higher rainfall in a particular region the nature of topography has to be taken into account. This influence has also been observed by Mooley (1959), Agarwala (1961) and Saha (1968). In this context the results of project 'Pluvious' started by Bergeron (1960) in the environment of Uppsala in Sweden is worth mentioning. This project was carried out with a very dense network of stations (1000 raingauges in an area of 400 sq. miles). From the analogy between the precipitation pattern during successive nights, Bergeron concluded that towns, hills not higher than 50 metres and forests have a considerable influence on the precipitation pattern. A town can be considered a local source of heat and condensation nuclei, forests excercise an influence *via* the frictional effects. According to Bergeron the precipitation on the leeward side of a town is about 20 per cent higher than that on the windward side. Difference of the same order are found around forested areas. Small hills of the order of 50 metres give an increase of precipitation of 1-2 mm in case of rain of 5 mm and an increase of 2 to 5 mm in rains of about 15 mm. Riehl (1962) has also pointed out that the variation of summer rain on the Florida peninsula which is shaped as regularly and is topographically as simple as one can find, has to be explained amongst other things by minute topographic variations.

Delhi State has a network of 35 raingauge stations. An annual average of five years (1961—65) of these stations (Fig. 1) indicates that areas adjoining Chandrawal and Delhi University is a region of comparatively higher rainfall. This shows that the topographic features in the area which consists of ridge (highest area in the

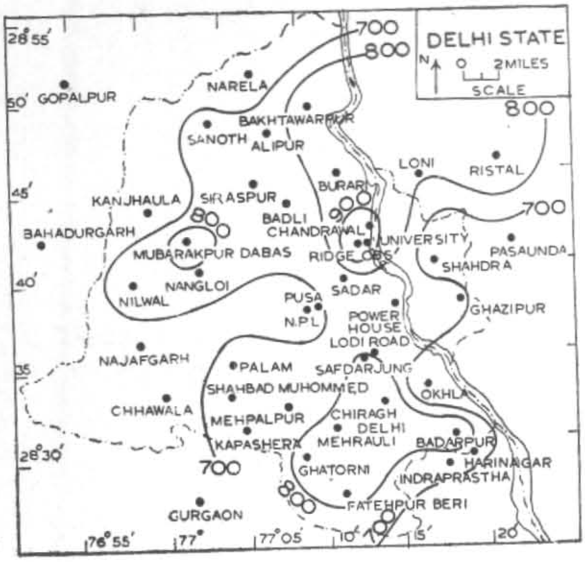

Fig. 1. Annual Rainfall
(Isohyets are labelled in mm)

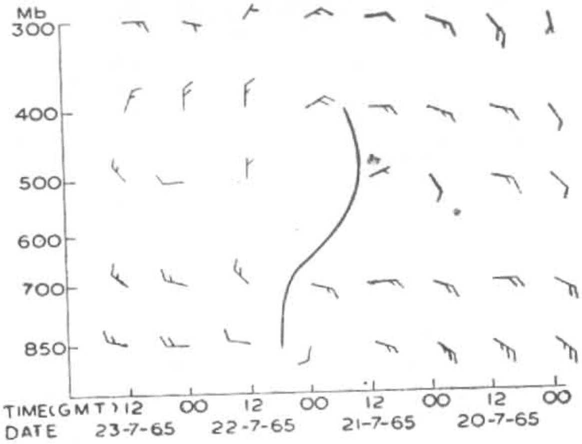

Fig. 2. Heavy fall on 23 July 1965

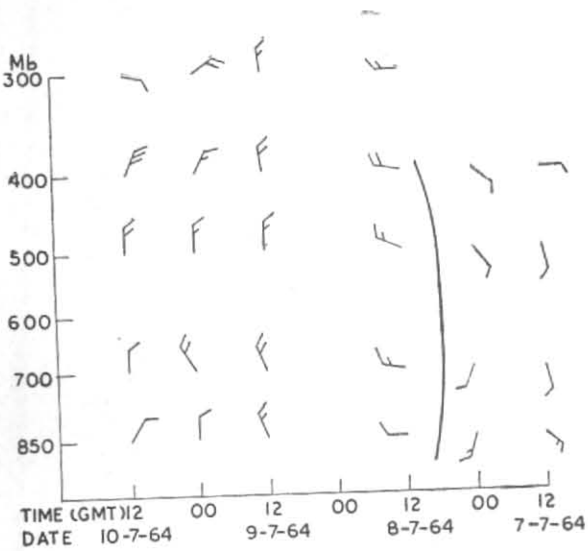

Fig. 3. Heavy fall on 10 July 1964

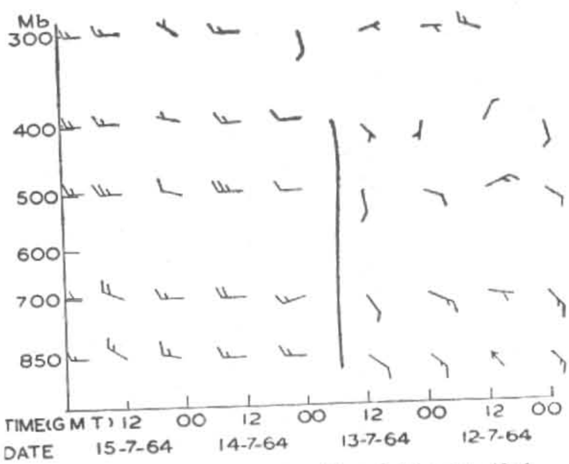

Fig. 4. Heavy fall on 15 and 16 July 1964

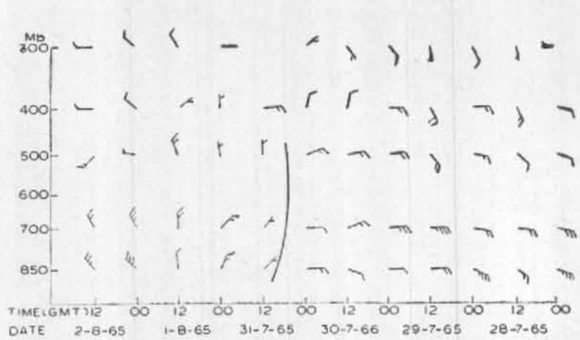

Fig. 5. Heavy fall on 1 and 2 August 1965

State) plays an important role in deciding the distribution of rainfall in Delhi.

Wind field — The 00 and 12 GMT wind observations of Delhi were plotted in vertical time section charts. The wind field revealed on some occasions the passage of wave trough prior to the occurrence of heavy fall (Figs. 2 to 5). This is indicated by wind shift from easterly to northwesterly or westerly. It is found that generally the wave trough appeared in levels between surface to 400 mb or less. The heavy rainfall normally occurred 24 to 36 hours after the appearance of the trough.

In 1963 heavy fall was recorded on twelve occasions between the months of June to September. The wave trough was located on 6 and 30 August and 14 September prior to heavy falls on 9 August, 1, 2, 14, 15 and 16 September. For other days of heavy fall there was no passage of wave trough.

In 1964 the monsoon period recorded heavy falls on eleven occasions. The wave trough was located on 3, 8, 13 July and on 13 August prior to heavy falls on 5, 10, 15, 16 July and 14 and 15 August. No passage of wave trough was found prior to the falls on 2 and 16 September.

In the year 1965 heavy fall was reported on five occasions only. The wave trough were located on 22 and 30 July accounting for the heavy falls on 23 July and on 1 and 2 August. No troughs were found for the falls on 3 and 4 September. In all we find that on 64 per cent occasions we get prior indication of heavy fall.

3. Horizontal convergence pattern

Having seen that the convergence in the lower levels play an important role in giving rise to heavy fall it was decided to determine the changes in the convergence pattern in the vertical associated with heavy rainfall.

3.1. *Calculation of convergence*

The convergence and divergence values were calculated by making use of Bellamy's graphical method (Bellamy 1949). A triangular area formed by the pilot balloon stations of Bareilly, Jaipur and Ambala were chosen for the purpose. Delhi lay approximately at the centre of this triangle. Since the space bounded by the triangle was small and the investigation was being made for the monsoon season the field under study could be taken synoptically homogeneous. It is assumed that variation in wind direction and speed from one vertex to another vertex of the triangle is on the average linear. This type of assumption is common in meteorology (Cocheme 1965).

To facilitate routine computation numerical tables were prepared giving the partial convergence of the respective stations for different wind speed and direction. The partial divergence D_x per sec values for point x were calculated from the following formula —

$$D_x = (V/h_x) \sin (\beta_{yz} - \alpha)$$

where, V is the wind speed in ft per sec, α is the wind direction, h is the perpendicular distance in feet from the point x to the opposite side yz of the triangle, β_{yz} is the azimuth of the side opposite to the vertex x. Similarly partial divergence values for the other two points of the triangle were calculated. The algebraic sum of these gave the total convergence. The positive values represent divergence and the negative convergence, according to as the wind is directed out or into the triangle. Wind data for the above mentioned stations were collected upto a height of 6 km. The missing data were made up from the stream line

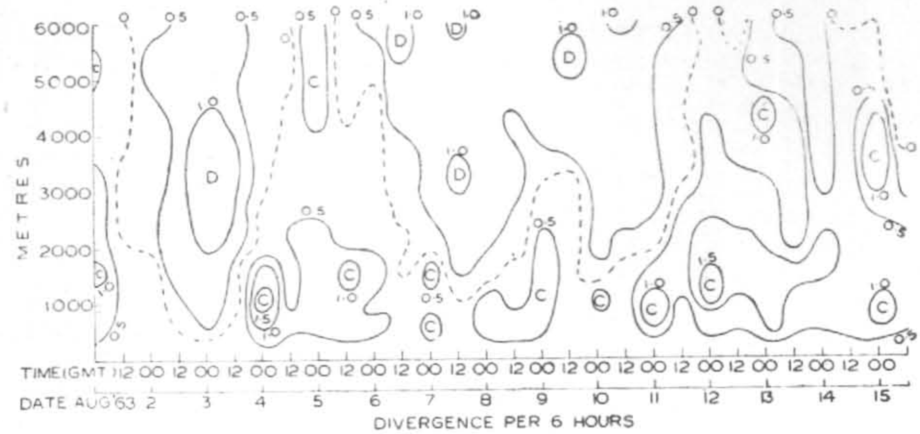

Fig. 6. Convergence pattern at 00 and 12 GMT upto a height of 6 km for the period 1-15 August 1963

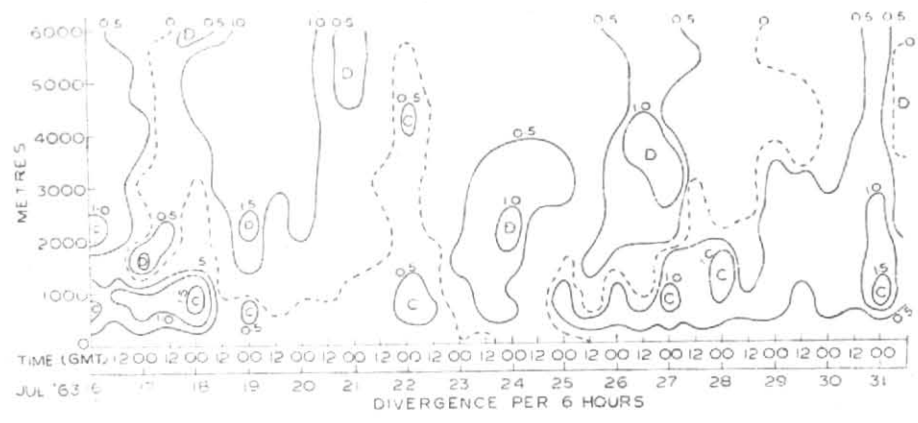

Fig. 7. Convergence pattern at 00 and 12 GMT upto a height of 6 km for the period 16-31 July 1963

Fig. 8. Convergence pattern at 00 and 12 GMT upto a height 6 km for the period 16-30 September 1963

chart. Both the 00 and 12 GMT observations were recorded and partial divergence values noted from the prepared numerical table. Thus the convergence values for all the monsoon months, *i.e.*, June to September of 1963 to 1965 were computed.

3.2. *Results*

The convergence pattern at 00 and 12 GMT upto a height of 6 km for the period under investigation were plotted (Figs. 6–8). In general it is found that the air is convergent from surface to 2 to 3 km having a maximum rate of change near about 900 metres and this is followed by divergent field aloft. A day before occurrence of heavy fall the pattern shows a markedly increased rate of convergence in the lower levels. This rate of increase can be seen either at 00 or 12 GMT pattern or in both.

In 1963 apart from three occasions all other days of heavy fall showed the above indications. In 1964 except for the heavy fall on 16 July; 23, 24 August and 2 September all other showed an increase in the rate of convergence prior to heavy fall. In 1965 the exception is only 2 August.

4. Diurnal variation of horizontal convergence

We digress here a while and discuss some aspects of the diurnal variation of the horizontal convergence in the vertical. The plot of horizontal convergence in the lower levels from day-to-day showed a diurnal variation. The data have been plotted as divergence per 6 hours. These are shown in Figs. 6 to 8. These indicate that divergence increases around 12 GMT and decreases around 00 GMT. However, it is not concluded from this that the peak values lie around these times. Determination of this will require closer observations. The above is in consonance with the fact that cloudiness and rainfall over Delhi shows a marked peak near dawn with suppression indicated during midday hours. It is also observed in these diagrams that the magnitude of convergence in the lower levels gradually increases before a heavy fall. After the heavy fall has occurred a sharp decrease in convergence is also noticed.

Another feature which comes out is that the field is markedly divergent even in the lower levels in the later half of September. This can be associated with fair weather period.

The intensity of rainfall in relation to the magnitude of convergence divergence pattern was also studied. But this does not show a direct relationship. This is understandable since the pattern of convergence are influenced by the properties of the basic current along with local orography and not dependent on the moisture content of the air. As a consequence, the configuration of rainfall in relation to this pattern remains variable.

5. Conclusion

From the study of the wind field over Delhi it is concluded that under favourable synoptic situations an examination of the vertical time section might show an appearance of wave trough. This is indicated by a change in wind direction from easterly to northwesterly or westerly. This can be taken as a fair indication of expected heavy rainfall about 24 to 36 hours later.

The second part of the study reveals that the depth of convergence extends from surface to 3-km level followed by divergence aloft. A day before the occurrence of heavy rainfall the pattern shows an increased rate of convergence in the lower levels. The increase can be seen either in 00 and 12 GMT pattern. Along with the increased rate of convergence, the level of non-divergence increases. We may, therefore, summarise the indication prior to heavy fall thus,

(1) Appearance of wave trough 24 to 36 hours in advance,

(2) An increased rate of convergence at the lower levels,

(3) An increased depth of convergence from surface upward, and

(4) The conditions (1) and (2) building up in advance usually a 24-hr period.

It is suggested that if day-to-day convergence values for each pibal ascents are plotted with help of ready made partial convergence tables for the three pibal stations as mentioned earlier it car give an indication of the weather which likely to occur over Delhi soon after.

Some other aspects of heavy rainfall are under study.

6. Acknowledgement

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