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## LATITUDINAL VARIATION OF RAINFALL DURING THE MONTH OF JULY IN RELATION TO THE AXIS OF THE MONSOON TROUGH OVER INDIA

1. The salient features of rainfall variations during the southwest monsoon season over India are well known and can be easily seen from the rainfall atlases published by the India Meteorological Department (IMD) [IMD 1971(a), 1981]. However, the information about the variation of monsoon rainfall with latitude across India and the locations of maximum and minimum rainfall in relation to the axis of the monsoon trough is not readily available from the diagrams in the published literature. This aspect is briefly highlighted in this short communication.

2. *Data and analysis*—The weather and meteorological conditions prevailing over the Indian monsoon area during the month of July are considered to be fairly representative of the southwest monsoon season. Hence, the rainfall variations during the month of July can be regarded as typical for the southwest monsoon season. To study the variation of rainfall with latitude and to find out the locations of raifall maximum and minimum in relation to the axis of the monsoon trough during the month of July over Indian longitudes, monthly normal rainfall data of a large number of raingauge stations distributed along and around the different Indian longitudes have been obtained for the month of July from the publication of the India Meteorological Department (IMD 1962).

Monthly rainfall values of stations within half a degree of the selected longitude are picked up and plotted against the latitudes of the individual stations along the longitude. The number of raingauge stations varied from 30 to 100 for different longitudes. The curves depicting the variations of rainfall with latitude across India along six longitudes 75.0°, 77.5°, 80.0°, 82.5°, 85.0° and 87.5° E for the month of July are given in Fig. 1. The plots of the individual station values are shown by dots for the rainfall curve in the diagram. The scatter of the dots gives the extent of rainfall variation at different stations. The mean curve passing through the dots of the plotted rainfall values is drawn as a solid continuous curve to show the average rainfall variation with latitude along the particular longitude. The mean latitudinal location of maximum rainfall is shown as a continuous line across the mean curves for different longitudes. The location of minimum rainfall is also shown as a broken line in a similar way. The normal position of the axis of the monsoon trough at the mean sea level for the month of July (obtained from Fig. 2) is indicated in the diagram by double dashed lines for reference.

### 3. *Results and discussion*

3.1. *Latitudinal variation of rainfall*—The rainfall curves in Fig. 1 exhibit largest amplitude (maximum-minimum) over the region north of 20°N. The main feature brought out by the curves is the rainfall maximum over latitudes of central India and minimum over latitudes of north India. Along 87.5°E longitude, the rainfall variation is less pronounced than at the other longitudes. The rainfall cross-section along 77.5°E covers the entire stretch of the country from the extreme south of the peninsula to the foothills of the Himalayas. The rainfall curve for this section shows a secondary maximum around the latitude of 13°N with a minimum around 9°N towards the south of the peninsula and another minimum around 15°N (Rayalaseema area).

3.2. *Rainfall maximum and minimum in relation to the position of the monsoon trough*—The semi-permanent synoptic system "monsoon trough" running from Head Bay of Bengal across Gangetic plains towards northwest India has a vital control on the monsoon rainfall. The locations of ranfall maximum and minimum are associated with the position of the monsoon trough. To bring out this association, the normal position of the monsoon trough as revealed by the mean monthly sea level isobaric pressures and prevailing wind field over India for the month of July based on 0300 UTC data for the 30-year period 1931-1960 [IMD 1971(b)], is shown in Fig. 2. As seen from Fig. 2, the axis of the trough at the mean sea level (msl) runs northwestwards from about 22°N at the Head Bay of Bengal to 28.5°N at 75°E longitude. The locations of the rainfall maximum and minimum over the region north of 20°N with respect to the normal position of the axis of the monsoon trough are indicated in the Figure. The latitudes of the rainfall maximum and minimum and also of the axis of the monsoon trough along six longitudes as estimated from Figs. 1 and 2 are given in Table 1.

TABLE 1

**Latitudinal locations of rainfall maximum and minimum in relation to the axis of the monsoon trough over Indian longitudes**

| | Longitude | | | | | |
|---|---|---|---|---|---|---|
| | 75.0 | 77.5 | 80.0 | 82.5 | 85.0 | 87.5° E |
| Rainfall minimum | 29.5 | 28.5 | 27.0 | 25.5 | 25.5 | 24.0° N |
| Monsoon trough axis | 28.5 | 27.5 | 26.0 | 25.0 | 24.0 | 22.0° N |
| Rainfall maximum | 24.0 | 23.0 | 22.0 | 22.0 | 22.0 | ——° N |

It is observed from Table 1 that the rainfall minimum lies about 1 to 2 degrees to the north of the axis of the monsoon trough. The rainfall maximum is about 2 degrees to the south of the axis of the trough at its eastern end and 4 to 5 degrees to its south at its western end.

3.3. *Physical causes responsible for rainfall maximum south of the monsoon trough*

(a) *Westward moving low pressure systems (LPS)*—Low pressure systems (LPS) including monsoon depressions and low pressure areas moving westwards along the monsoon trough are the synoptic systems that cause most of the monsoon rains. The rainfall maximum to the south of the trough axis is largely associated with the monsoon depressions and low pressure areas which traverse across the central parts of the country from the Head Bay of Bengal. Numerical studies by Rao and Rajamani (1970, 1975) show maximum ascending motion in the southwest sectors and comparatively less ascending motion in the northwest sectors of the

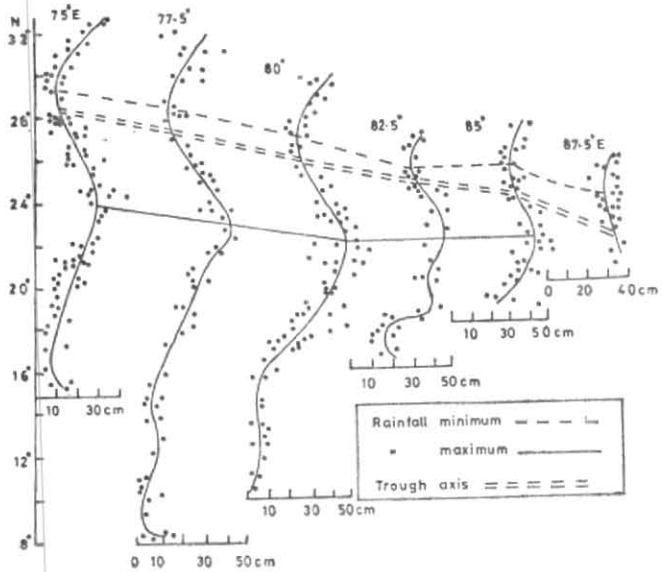


Fig. 1. Latitudinal variation of rainfall during the month of July along six longitudes 75.0°, 77.5°, 80.0°, 82.5°, 85.0° and 87.5°E (with location of rainfall maxima marked with respect to the axis of the monsoon trough)

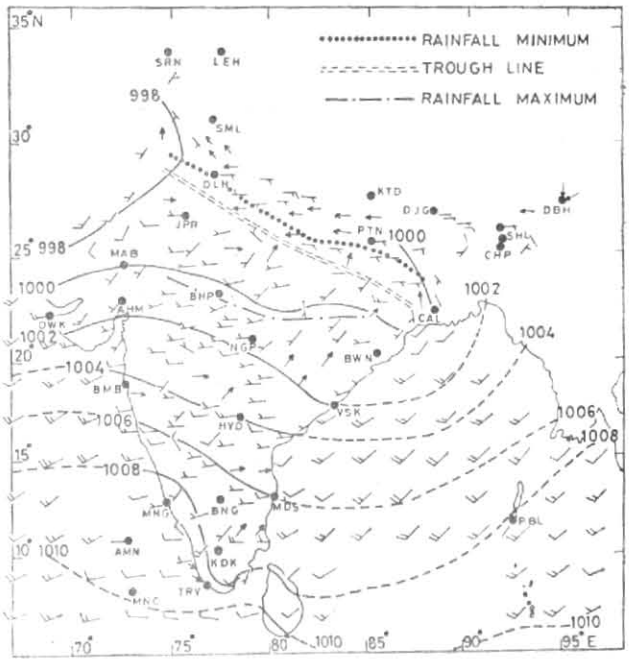


Fig. 2. Msl isobars and winds over India for July (0300 UTC) indicating locations of rainfall maxima and minima in relation to the position of axis of the monsoon trough [adopted from IMD 1971 (b)]

monsoon depressions. This causes the largest rainfall amounts in the southwestern quadrant and less rainfall in the northwest quadrant of the monsoon depressions. However, the number of low pressure systems formed is not significantly related to the monsoon rainfall over India except for a weak relationship with central India monsoon rainfall [Mooley and Shukla 1989(a)].

(b) *The monsoon trough and its southward tilt with elevation*—The dominant factor controlling the southwest monsoon rainfall over the country is the monsoon trough. No other semi-permanent system has such a control on monsoon activity (Rao 1976). While studying the index of activity of the monsoon trough over India, Mooley and Shukla [1989(b)] have observed that on majority of the days (about 56%) during the monsoon season, the seasonal monsoon trough is the only synoptic scale system contributing to the rainfall over the Indian region. The normal monsoon trough tilts southward with height from surface to mid-troposphere, because of decrease of temperature from north to south at tropospheric levels during the southwest monsoon season. An examination of possible relationship between the vertical slope of the monsoon trough and the distribution of rainfall over India by Saha and Saha (1981) indicated that the rainfall associated with the normal southward slope of the trough is distributed mainly to the south of the msl position of the trough.

While investigating the circulation changes that lead to break-monsoon over the plains of northern India (20-29°N, 75-85°E), Raghavan (1973) has given latitudinal variation of mean July rainfall at 80° E. The pattern of rainfall variation along 80°E brought out in Fig. 1 of the present study is in agreement with that of Raghavan. However, the rainfall variation obtained in the present study appears to differ in amplitude from that of Raghavan, particularly in the region 20-24°N. The difference may be due to more number of stations considered in the present study compared to Raghavan's study.

In his study, Raghavan noted that the seasonal monsoon trough and its associated upward motion are mainly responsible for the typical monsoon rainfall variation in the area. Further he stated that the location of the maximum rain belt roughly coincides with the position of the trough axis at 700 hPa level. It would be interesting to compare the location of the 700 hPa trough with that of the maximum rainfall. For this purpose, the position of monsoon trough axis brought out by the normal upper winds over India at 700 hPa level for the month of July based on the data for the period 1951-1970 obtained from the India Meteorological Department (IMD), is given in Fig. 3. It is apparent from Fig. 3 that the trough axis has approximately east-west orientation about 22°N at 700 hPa level. The zone of maximum rainfall brought out in Fig. 1 coincides nearly with the position of the trough axis at 700 hPa level.

## 4. *Conclusion*

The diagrammatic presentation of the latitudinal variation of rainfall during the monsoon month of July over Indian longitudes in relation to the axis of the monsoon trough on the msl isobaric chart revealed a rainfall minimum 1 to 2 degrees to the north of the axis of the monsoon trough and a rainfall maximum about 2 degrees to the south of the trough axis at its eastern end and 4 to 5 degrees to its south at its western end. The zone of maximum rainfall coincides nearly with the position of the monsoon trough at 700 hPa level.

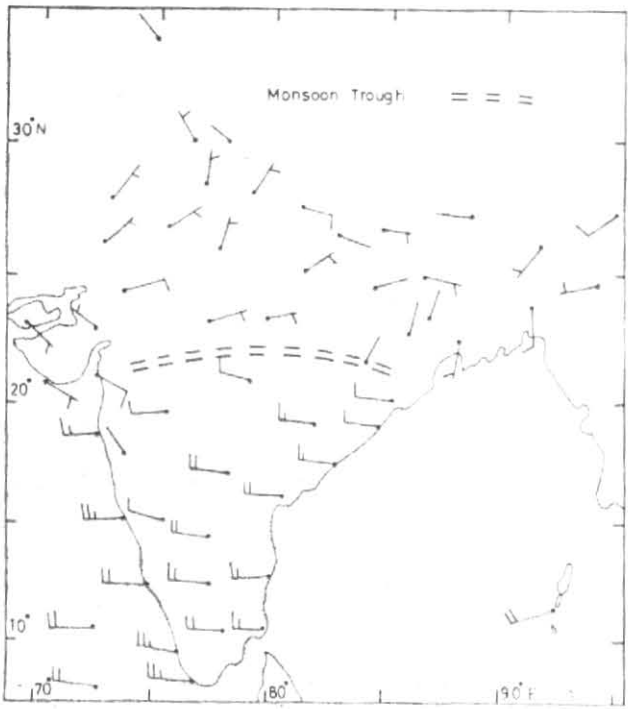


Fig. 3. Normal upper winds at 700 hPa level (position of the monsoon trough marked with parallel double dashed lines)

It is hoped that the information contained in this brief communication will be of interest; since such an information is not readily obvious through the conventional published maps and charts.

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