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Diurnal variation of monsoon rainfall in central India

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सार — मध्य-भारत में दैनिक परिवर्तन जानने के लिये ग्रीष्मकालीन मानसून अवधि सन् 1979 से 1983 तक 17 स्वतः अभिलेखी केन्द्रों के दैनिक प्रति घण्टे की वर्षा का अध्ययन किया गया । इन परिवर्तनों को स्पष्ट करने का प्रयास भी किया गया ।

ABSTRACT. The daily three hourly rainfall for 17 self recording stations during summer monsoon for the period 1979 to 1983 has been studied to bring out its diurnal variation in central India. An attempt is also made to explain these variations.

1. Introduction

It is believed that rainfall occurs in the tropical region during some preferred hours of the day. This is attributed to the well known phenomenon of diurnal cycle of convection. However, there is an enough evidence to show that in tropics maximum rainfall incidence can occur at any time of the day, and that timing can vary considerably over short distances. The knowledge of diurnal variation of rainfall can be useful for outdoor functions and road communication when the roads are unpaved. It also influences the efficiency of rains for agricultural purposes, because rainfall during hot hours of the day are subjected to heavy losses by evaporation.

The diurnal variation of rainfall for individual stations have been done by various authors in the past. Recent studies are at Nagpur by Mulky (1958) and Hyderabad by Rao (1960). A few studies, on collective stations, of diurnal variation of rainfall have also been done. Rao and Raman (1958) and Prasad (1970) studied the diurnal variation of rainfall over India for selected stations. Jagannathan (1968) studied the climatological aspects of Indian rainfall as the same were considered useful for a short range weather forecasting to meet the need of multifarious interest. In his discussion of diurnal pattern during monsoon season he observed that Rajasthan had its maximum rainfall in noon hours, 09 to 15 IST. The west coast and practically the entire north India excluding the Bengal plains received their maximum between 3 and 9 IST. Madras state received its intense falls between 21 and 03 IST. while the adjoining region of Andhra coast up to Bengal plains experienced their maximum during 15 to 21 IST. He did not comment the diurnal pattern over central India. Prasad (1974) in his study of Brahmaputra valley found, marked maximum in rainfall from midnight to morning 6 hours. Bhattacharjee and Bhattacharjee (1980) in their study of upper catchment of north Bengal rivers found that there was marked tendency of occurrence of heaviest fall during night/early morning hours from June to September.

The diurnal variations of rainfall during monsoon season in central India is considered in the present study, as 80 to 90 per cent of rainfall in central India occurs in monsoon season alone.

2. Data

The hourly values of rainfall during each hour of the day from June to September have been collected from self recording tabulation sheet for following 17 stations from 1979 to 1983 : (1) Nagpur (21° 06′ N, 79° 03′ E, 310 m), (2) Akola (20° 42′ N, 77° 04′ E, 309 m), (3) Brahmapuri (22° 36′ N, 79° 51′ E, 227 m), (4) Chandrapur (19° 58′ N, 79° 18′ E, 191 m), (5) Satna (24° 14′ N, 80° 50′ E, 315 m), (6) Pendra (22° 46′ N, 81° 54′ E, 624 m), (7) Raipur (21° 14′ N, 81° 39′ E, 296 m), (8) Jagdalpur (19° 05′ N, 82° 02′ E, 553 m), (9) Jabalpur (23° 12′ N, 79° 57′ E, 397 m), (10) Gwalior (26° 14′ N, 78° 15′ E, 205 m), (11) Guna (24° 39′ N, 77° 19′ E, 477 m), (12) Bhopal (Bairagarh) (23° 17′ N, 77° 21′ E, 523 m), (13) Indore (22° 43′ N, 75° 48′ E, 561 m), (14) Pachmarhi (22° 28′ N, 78° 26′ E, 1068 m), (15) Bagratawa (22° 38′ N, 77° 59′ E, 331 m), (16) Khandwa (21° 50′ N, 76° 22′ E, 317 m), (17) Gondia (21° 28′ N, 80° 12′ E, 311 m).

For Pendra only, available data for four years have been utilised.

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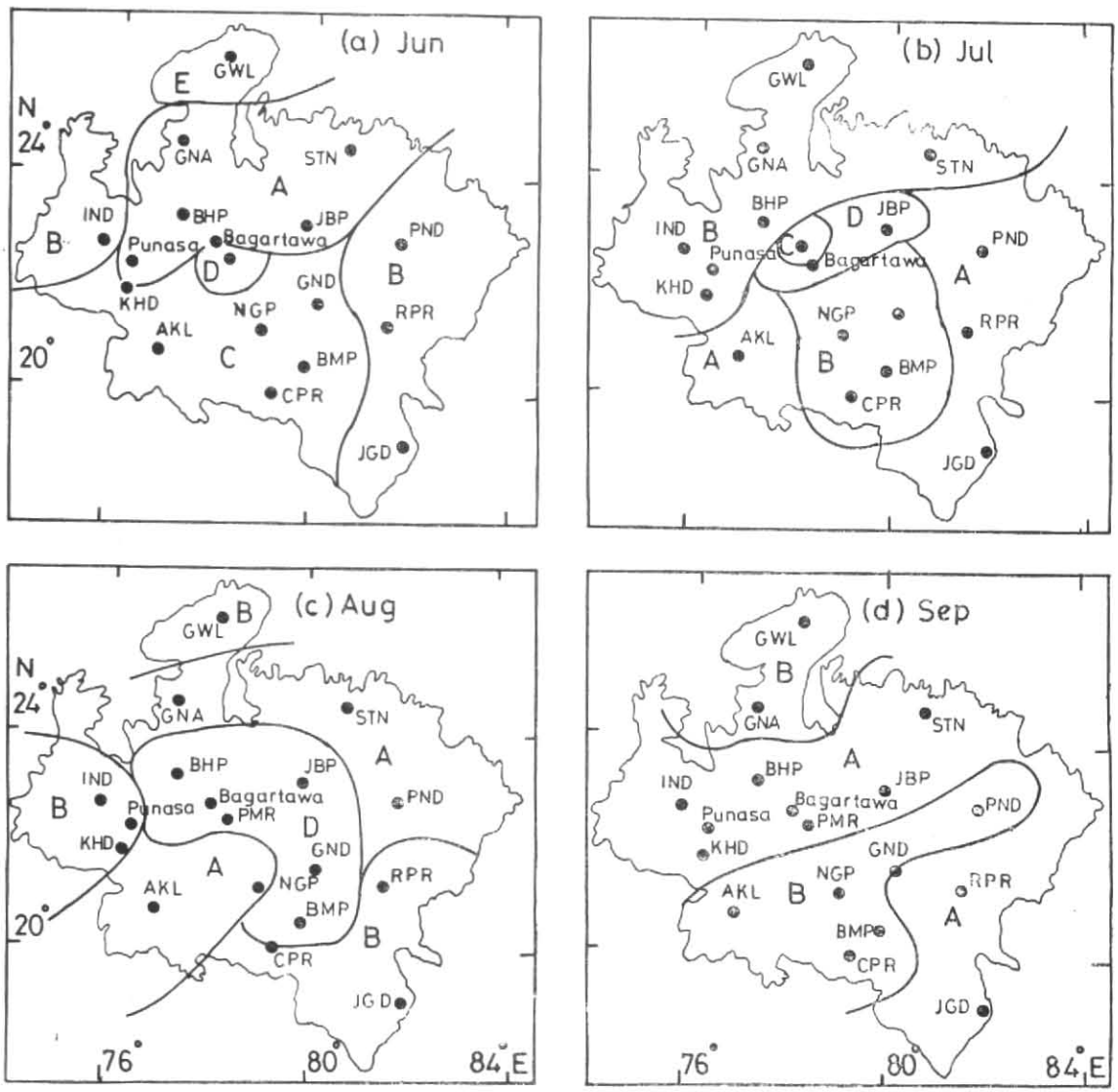

Figs. 1(a-d). Diurnal pattern of rainfall over central India during June-September

3. Physical features

The central India consists of Madhya Pradesh and Vidarbha portion of Maharashtra State. It is generally a plain area with elevations near about 300 m a.s.l. The Vindhya and Satpura mountain ranges run east to west across the region and in the hilly tracks the individual peaks are between 1000 and 1500 m a.s.l. In this region, there are two rivers *Narmada* and *Tapti* and both are flowing east to west into Arabian Sea while river *Mahanadi* is running west to east and flowing into Bay of Bengal.

4. Method of analysis

To reduce irregularities in the diurnal pattern, the three hourly mean daily rainfall of each of the monsoon month, *i.e.*, June to September have been calculated and are shown in the Table 1.

In order to study the diurnal variation, a day has been divided into 8 periods of 3 hours duration as detailed below: Late night (00-03 IST), Early morning (03-06 IST), Morning (06-09 IST), Late morning (09-12 IST), Early afternoon (12-15 IST), Late afternoon (15-18 IST), Evening (18-21 IST) and Night (21-24 IST).

5. Classification of rainfall areas

The diurnal pattern varied with the location. The area may be grouped under five types with following characteristics :

A — Rainfall maximum in the afternoon/evening,

B — Well defined maximum in the afternoon/evening with feeble maximum in the late night/early morning,

C — Well defined rainfall maximum between evening to late night,

D — Well distributed rainfall throughout the day and

E — No well marked maximum.

TABLE 1

Mean 3 hourly daily rainfall (mm)

	Hours (IST)							
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
Nagpur								
Jun	0.9	0.4	0.3	0.1	0.6	1.2	1.2	1.3
Jul	1.2	0.9	0.6	0.3	1.7	1.6	2.4	1.4
Aug	0.7	1.3	1.6	0.7	1.6	1.4	1.2	1.3
Sep	0.5	0.4	0.7	0.6	1.8	2.2	1.2	0.6
Akola								
Jun	0.9	0.3	0.3	0.0	0.2	0.5	0.9	1.3
Jul	0.3	0.3	0.4	0.3	0.8	2.0	1.5	1.0
Aug	1.5	0.5	0.7	1.0	0.9	1.4	0.7	1.0
Sep	0.5	0.2	0.3	0.3	0.0	0.6	1.3	1.1
Bramhapuri								
Jun	1.0	1.1	0.7	0.6	0.5	0.8	1.0	1.0
Jul	1.8	1.5	0.8	0.8	1.0	1.7	1.8	1.5
Aug	0.9	1.5	1.5	1.2	1.6	2.1	1.6	1.0
Sep	1.7	1.0	0.6	1.0	0.7	1.0	1.5	0.6
Chandrapur								
Jun	1.0	0.6	0.8	0.3	0.2	1.0	1.1	1.1
Jul	2.0	1.3	0.7	0.6	0.6	1.9	1.8	1.3
Aug	1.6	1.7	0.9	1.5	2.6	1.8	1.0	1.5
Sep	0.6	0.4	0.4	0.4	1.0	2.4	1.2	0.4
Guna								
Jun	0.3	0.3	0.5	0.4	0.5	0.4	0.0	0.1
Jul	0.6	1.2	1.3	1.0	1.4	0.8	0.5	0.1
Aug	1.0	1.0	2.1	1.4	2.6	1.8	0.7	0.6
Sep	0.5	0.4	0.6	0.2	0.5	0.6	0.6	0.7
Pendra								
Jun	0.4	0.1	0.0	0.4	1.4	1.2	1.3	0.3
Jul	0.7	0.7	0.5	0.8	1.2	1.8	1.4	0.9
Aug	1.2	0.4	1.5	0.4	1.7	3.7	2.1	1.8
Sep	0.8	0.6	0.2	0.2	0.5	0.6	1.6	1.1
Bairagarh								
Jun	0.2	0.3	0.3	0.2	1.1	1.5	1.3	0.6
Jul	0.9	0.5	0.4	0.5	0.6	2.2	1.3	0.7
Aug	1.1	1.5	1.1	1.0	1.4	1.5	1.2	1.7
Sep	0.2	0.0	0.0	0.0	0.4	0.4	0.1	0.3
Jagdalpur								
Jun	1.5	0.9	0.7	0.3	0.7	2.2	1.3	1.5
Jul	0.5	0.7	1.0	1.5	2.1	2.8	0.6	0.8
Aug	1.4	1.1	0.8	0.8	1.3	2.5	1.1	0.9
Sep	0.3	0.2	0.1	0.4	1.3	2.0	1.7	0.9
Indore								
Jun	0.6	0.7	0.2	0.2	0.4	1.0	1.2	0.8
Jul	1.1	0.8	0.6	0.5	0.9	1.5	1.5	0.9
Aug	1.5	1.4	1.3	0.8	0.8	1.9	1.1	0.9
Sep	0.1	0.2	0.0	0.0	0.4	1.7	0.5	0.4

	Hours (IST)							
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
Raipur								
Jun	0.8	0.4	0.4	0.1	0.3	0.8	1.2	1.0
Jul	0.3	0.2	0.6	1.0	1.9	1.3	1.5	1.2
Aug	1.6	1.7	0.6	0.9	0.9	1.5	2.2	1.0
Sep	0.6	0.5	0.7	0.4	1.0	1.7	1.9	1.7
Jabalpur								
Jun	0.1	0.5	0.6	0.4	1.1	1.4	0.4	0.4
Jul	0.5	0.7	0.5	0.7	0.8	1.9	1.7	0.9
Aug	1.2	1.8	1.4	2.1	1.3	1.8	1.3	1.6
Sep	0.8	1.0	1.0	0.4	1.4	1.5	0.8	0.3
Pachmarhi								
Jun	0.5	0.3	0.5	1.0	0.8	0.8	0.7	0.4
Jul	1.5	2.0	1.2	1.2	1.1	1.3	1.4	1.0
Aug	2.4	2.3	2.0	1.9	1.4	2.4	2.2	1.7
Sep	0.6	0.5	0.7	0.3	1.5	1.4	0.8	0.4
Satna								
Jun	0.2	0.3	0.3	0.2	1.1	0.8	0.6	0.5
Jul	0.7	1.9	0.8	1.6	1.9	1.9	1.2	0.7
Aug	1.1	0.9	1.4	1.0	1.5	1.5	2.1	0.9
Sep	0.1	0.1	0.3	0.7	0.8	0.8	0.5	0.2
Gwalior								
Jun	0.2	0.2	0.3	0.5	0.2	0.1	0.2	0.3
Jul	0.9	0.3	0.1	1.3	2.0	1.8	0.5	0.5
Aug	1.3	0.9	1.1	1.0	1.7	1.4	0.8	0.4
Sep	0.4	0.5	0.1	0.4	0.3	0.6	0.5	0.0
Khandwa								
Jun	0.5	0.5	0.5	0.4	0.4	0.6	1.5	0.7
Jul	0.4	1.4	0.6	0.3	0.7	1.4	1.5	1.3
Aug	1.1	0.9	0.5	0.5	1.2	2.1	1.3	1.2
Sep	0.3	0.2	0.1	0.3	0.1	1.1	1.1	0.3
Bagratawa								
Jun	0.2	0.1	0.2	0.1	0.9	0.9	0.6	0.4
Jul	0.6	0.4	0.5	0.5	0.6	2.1	1.6	1.9
Aug	1.1	1.2	1.8	1.1	1.5	0.8	1.8	0.7
Sep	0.5	0.3	0.3	0.6	0.9	0.9	0.7	0.3
Gondia								
Jun	1.0	0.5	0.2	0.6	0.7	1.0	0.9	0.8
Jul	1.0	0.9	0.6	0.8	1.1	1.7	1.7	1.3
Aug	1.4	1.4	1.2	0.9	1.5	1.8	1.3	1.1
Sep	0.6	0.7	0.8	0.1	1.3	1.8	0.8	0.7

The diurnal variation of rainfall from June to September is given in the Figs. 1 (a-d) July is the rainiest month followed by August.

6. Synoptic disturbances

The mechanism leading to mass convergence in central India depends upon the travelling synoptic disturbances. During monsoon season central India receives rainfall mainly due to (1) Semi-permanent trough in the lower troposphere over Gangetic plain and (2) Low pressure systems, *i.e.*, cyclonic storm or depression or low pressure area or cyclonic circulation or E-W shear zone. The low pressure system may form over Bay of Bengal or over land and moves westnorthwestwards/northwestwards. According to Mooley and Shukla (1987), the frequency distribution of the number of low pressure systems is about 13. About 63 per cent of the low pressure systems form in the longitudinal sector 85° to 90° E and 88 per cent form east of 80° E. Percentages of the systems which form over Bay and over the land area are 64 and 30 respectively.

7. Discussion

Attempt has been made to explain the cause of diurnal variation as far as possible. The diurnal pattern of rainfall in the month of June is shown in the Fig. 1 (a). In the month of June, rainfall maximum is seen in the afternoon/evening over north Madhya Pradesh. The area is nearly coinciding with the highest normal maximum temperature zone, *i.e.*, ground heating is playing major role for afternoon/evening shower. The east Madhya Pradesh is also getting maximum peak in the afternoon/evening with feeble maximum in the late night/early morning. The maximum peak in the east Madhya Pradesh in afternoon/evening is due to orography and day's maximum temperature. Cloud top cools due to radiation causing inter instability in the night giving maximum peak in the late night. Banerjee (1961) suggested drifting of thunderstorm cell towards northwest/southeast in his pre-monsoon study from hills. Mulky (1958) in his study of diurnal variation of rainfall in Nagpur also suggested early morning peak due to slow drifting of thunderstorm. Vidarbha and adjoining Madhya Pradesh is getting maximum peak between evening and late night. In this month depression or low pressure system generally moves in a northwesterly direction and mostly becomes less marked after reaching east Madhya Pradesh. Southwestern sector ahead of depression is generally coinciding with Vidarbha and adjoining Madhya Pradesh area. Extreme northwest Madhya Pradesh does not show any marked diurnal pattern as monsoon reached there at the end of June. Around central point, near Pachmarhi, the highest elevation in central India, a well distributed rainfall is observed throughout the day.

The diurnal pattern in the month of July which is the rainiest month in the monsoon season is given in the Fig. 1 (b). The east Madhya Pradesh is characterised by maximum peak in the afternoon/evening. The central portion of Madhya Pradesh is having well distributed rainfall throughout the day while the remaining portions have maximum peak in the afternoon/evening with feeble maximum in the late night/early morning.

The diurnal pattern in the month of August is given in the Fig. 1 (c). We have seen that in the month of July a portion of central region is having well distributed rainfall throughout day. But in this month, there is a large extension of the area covering central parts of Madhya Pradesh and east Vidarbha having well distributed rainfall throughout the day. This is probably due to the fact that in the month of August, most of the depressions or the low pressure systems pass through north Madhya Pradesh, *i.e.*, northwest of the area forming convergent zone and, hence, is getting well distributed rainfall throughout the day. The movements of these systems are rather slow over Madhya Pradesh.

While in the month of September, the cloud amounts decrease and ground heating plays a major role for afternoon/evening maximum peak in the entire area which is shown in Fig. 1(d). But it is seen that northwest Madhya Pradesh, Vidarbha and adjoining northeast Madhya Pradesh is getting feeble maximum peak in the late night/early morning.

8. Summary

From this study, the following results could be obtained :

(*i*) North Madhya Pradesh is getting maximum peak in the afternoon/evening in the month of June while in July it is east Madhya Pradesh. In August it is northeast Madhya Pradesh and west Vidarbha and in September it is southeast and central Madhya Pradesh.

(*ii*) Maximum peak in afternoon/evening with feeble maximum in late night/early morning is observed in east Madhya Pradesh and western parts of west Madhya Pradesh during June while in July it is north Madhya Pradesh and east Vidarbha and adjoining central Madhya Pradesh. It is southeast and extreme northwest Madhya Pradesh and western parts of west Madhya Pradesh in August and in September it is northwest Madhya Pradesh and Vidarbha and adjoining northeast Madhya Pradesh.

(*iii*) The well defined rainfall maximum between evening to early morning is observed in Vidarbha and adjoining Madhya Pradesh in the month of June while in July it is confined to small pocket around Bagratawa.

(*iv*) Well distributed rainfall throughout the day is observed around Pachmarhi in June and in July it is central parts of Madhya Pradesh. In August the area is further extended and it covers central parts of Madhya Pradesh and east Vidarbha.

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