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# ROLE OF LOW PRESSURE AREAS IN THE ABSENCE OF TROPICAL DISTURBANCES DURING MONSOON MONTHS IN INDIA

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## ABSTRACT

In this study an effort has been made to find out the contribution of low pressure areas (or lows) towards the rainfall of northern and central India during the monsoon months of June to September in the absence of more intense cyclonic disturbances such as depressions, deep depressions and cyclonic storms. 15 years of data from 1983 to 1997 has been used to study this aspect. This study has shown that the occurrence of moderate to heavy rainfall mainly depends upon their frequency, life span, track followed and origin of these disturbances provided there are no inhibiting meteorological factors like 'break' monsoon situations. Copyright © 1999 Royal Meteorological Society.

KEY WORDS: north and central Indian region; low pressure areas; monsoon depressions; cyclonic storms; seasonal monsoon trough; mid-latitude westerly troughs; 'break' monsoon situations; upper air circulations

## 1. INTRODUCTION

During the summer monsoon months of June to September, the Indian sub-continent is affected by cyclonic disturbances like low pressure areas (abbreviated as lows), depressions, deep depressions and cyclonic storms from the neighbouring seas of the Bay of Bengal and the Arabian Sea. Besides these, there are other regional and local rain producing systems which interact with the prevailing monsoon circulations over the country causing fair to moderate rainfall over different parts of the country during a monsoon season. Some of these are of a semi-permanent nature, like the seasonal monsoon trough over the Indo-Gangetic plains, mid-tropospheric cyclones, offshore troughs along the west coast of India, easterly waves, mid-latitude westerly troughs, upper air circulations, etc.

The contribution to monsoon rainfall by depressions and other cyclonic disturbances has been studied by a large number of workers in the past as well as in the recent times. Notable among the recent workers are Pisharoty and Asnani (1957), Raghavan (1967), Dhar and Mhaiskar (1973), Venkataraman *et al.* (1974), Dhar and Rakhecha (1976), Sikka (1977) and Dhar *et al.* (1978, 1980, 1981, 1984), to mention only a few. In recent years, Mooley and Shukla (1987) prepared a comprehensive monograph on the characteristics of westward moving low pressure systems (which include all the cyclonic disturbances from lows to cyclonic storms) that affected the Indian region during the monsoon periods of 1888 to 1983. Besides dealing with their other characteristics, the monograph has also studied their relationships with monsoon rainfall.

In the present study an effort has been made to find out the contribution of only lows to the monsoon rainfall of India in the absence of other stronger cyclonic disturbances like depressions and cyclonic storms. There is however, a general feeling among the meteorologists of this country (Sikka, 1977; Mooley and Shukla, 1987) that these weak cyclonic disturbances (i.e. lows) because of their frequent occurrence during monsoon months of June to September, contribute substantially to the monsoon rainfall of the

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country. As no study concerning the contribution of these lows alone has so far been made, it is felt that the present study may help in throwing some light on this subject.

## 2. LOWS AND THEIR BROAD CHARACTERISTICS

A low is an atmospheric vortex with a central region of low pressure. In the northern hemisphere, the wind blows round the centre in a counter clockwise direction (Das, 1988). On the other hand a depression or a cyclonic storm is a deep low pressure area with two or more closed isobars at 2 hPa intervals covering an area of about a 5 degree square (Rao, 1976). The intensity of a cyclonic disturbance is measured by the strength of its winds. The India Meteorological Department (IMD) uses the following classification in defining these disturbances (Das, 1988):

| Type of disturbance | Range of winds (speed m $s^{-1}$) |
|---|---|
| Low pressure areas or lows | 8.5 |
| Depression | 8.5–13.5 |
| Deep depression | 14.0–16.5 |
| Cyclonic storm | 17.0–23.5 |
| Severe cyclonic storm | 24.0–31.5 |
| Hurricane | $>32.0$ |

Lows are therefore weaker disturbances compared to depressions or cyclonic storms, having only one closed isobar with wind speeds of less than 8.5 m $s^{-1}$. These disturbances cause less intense rainfall when compared to other stronger cyclonic disturbances, like monsoon depressions and cyclonic storms. Rainfall associated with a low covers a relatively much larger area and heavy rainfall occurring in the field of a low is scattered in character (Mooley and Shukla, 1987). There is, however, no denying the fact that passage of lows across the country maintains the normal location and activity of the seasonal monsoon trough which results in fairly good rainfall activity over northern and central parts of the country. It is also said that but for these disturbances, monsoon rainfall would have been mainly orographic in nature and confined to hilly areas of the country.

During monsoon months, lows form both in neighbouring seas and over land areas. They frequently form in the northwest Bay of Bengal and the adjoining central Bay and travel west/northwestwards after crossing the east coast of India. They rarely form in the Arabian Sea and if and when they form there, they cross the west coast and travel in a northeasterly direction over the Saurashtra–Gujarat region and move occasionally up to Punjab and Haryana in the extreme northeast. Well-marked lows from the Bay which are more intense, after crossing the east coast move up to Uttar Pradesh and West Madhya Pradesh or even travel up to Rajasthan and Punjab under favourable meteorological situations. On the other hand, often after moving inland some of these disturbances recurve and move northwards towards north Bihar and occasionally move eastwards towards north Bengal, Sikkim and the neighbourhood. Rao (1976) in his treatise on 'Southwest Monsoon' has stated that during the 20-year period from 1950 to 1969 about 87 lows moved through north India of which 51 had a land origin. According to him the behaviour of lows is more or less like that of monsoon depressions but their movement is less regular and slower although their life span and associated rainfall are more or less alike.

It has generally been seen that lows which form over land (also called land lows), generally form north of latitude 22°N to the west of longitude 85°E. Land lows are normally smaller in areal extent than those which originate from the sea. It has also been noticed that lows have no preferred sectors of rainfall as is normally found in the case of depressions while moving through northern India. Their life span, on average, is of the order of 3–4 days.

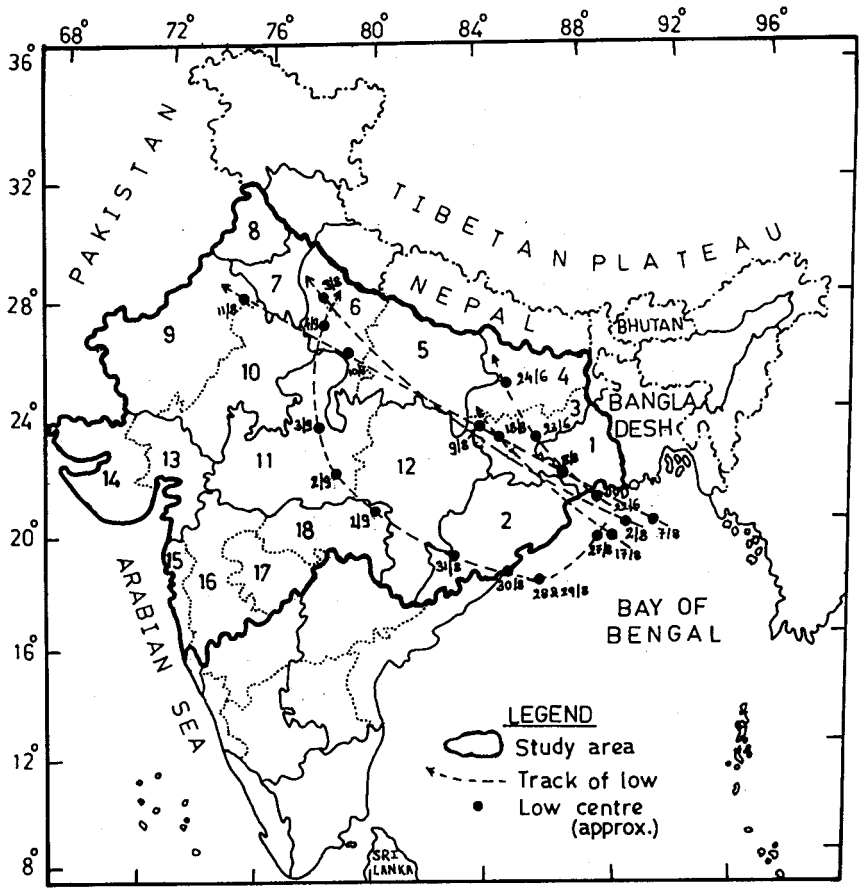
 

## 3. STUDY AREA

The area of the country considered for the present study is shown in Figure 1, after excluding the hilly sub-divisions in the north and northeast of India, where rainfall is augmented by the presence of orography. As lows mostly travel over the north Indian plains, say north of latitude 22°N, it is generally seen that their rainfall distribution over the country is confined to an area roughly between latitude 17°N to about latitude 33°N. This area is comprised of 18 contiguous sub-divisions of the country which are shown in Figure 1.

## 4. DATA AND METHODOLOGY USED

It has been experienced that during monsoon months, Indian weather is affected also by weather systems like upper air circulations, mid-latitude troughs, 'break' monsoon situations, etc., besides cyclonic




**1. Gangetic West Bengal** **2. Orissa** **3. Bihar Plateau**
**4. Bihar Plains** **5. East Uttar Pradesh** **6. West Uttar Pradesh (Plains**
**7. Haryana and Delhi** **8. Punjab** **9. West Rajasthan**
**10. East Rajasthan** **11. West Madhya Pradesh** **12. East Madhya Pradesh**
**13. Gujarat** **14. Saurashtra & Kutch** **15. Konkan**
**16. Madhya Maharashtra** **17. Marathwada** **18. Vidarbha**

Figure 1. Map of India showing the tracks followed by low pressure areas (lows) during the months of June 1995 and August 1995

Table I. Monsoon months which experienced only lows in the absence of other tropical disturbances during the period 1983 to 1997

| Year | June | | | | July | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1995 | 1983 | 1985 | 1987 | 1990 | 1993 | 1994 | 1995 |
| No. of LPAs (days) | 6 (48) | 2 (9) | 2 (10) | 1 (4) | 4 (28) | 1 (5) | 1 (8) | 3 (12) | 4 (19) | 6 (34) | 2 (9) |
| Sea originated LPAs (days) | 4 (39) | 1 (6) | 1 (3) | 1 (4) | 2 (12) | – | 1 (8) | 2 (7) | 1 (5) | 3 (19) | – |
| Land LPAs (days) | 2 (9) | 1 (3) | 1 (7) | – | 2 (16) | 1 (5) | – | 1 (5) | 3 (14) | 3 (15) | 2 (9) |
| Cyclonic circulations | 3 | 8 | 10 | 10 | 10 | 9 | 13 | 8 | 7 | 5 | 9 |
| Mid-latitude troughs (W.D.)[a] | 8 | 9 | 5 | – | 5 | – | – | 1 | 5 | – | – |
| Break monsoon situations (days) | – | – | – | – | (4) | – | – | – | (2) | – | – |
| Rainfall departures (%)[b] | +19 | −26 | +23 | −37 | −4 | −7 | −28 | +1 | −4 | +22 | +1 |

| | August | | | | September | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1992 | 1993 | 1995 | 1996 | 1984 | 1988 | 1989 | 1992 | 1993 | 1994 |
| No. of LPAs (days) | 5 (30) | 4 (21) | 4 (23) | 3 (12) | 3 (16) | 5 (28) | 2 (18) | 3 (21) | 3 (23) | 2 (16) |
| Sea originated LPAs (days) | 4 (29) | 1 (5) | 4 (23) | 2 (8) | 2 (14) | 3 (20) | 2 (18) | 2 (16) | 2 (18) | 1 (11) |
| Land LPAs (days) | 1 (1) | 3 (16) | – | 1 (4) | 1 (2) | 2 (8) | – | 1 (5) | 1 (5) | 1 (5) |
| Cyclonic circulations | 8 | 9 | 10 | 14 | 4 | 6 | 7 | 7 | 8 | 7 |
| Mid-latitude troughs (W.D.)[a] | 1 | 1 | – | 1 | 7 | 3 | 2 | – | – | 1 |
| Break monsoon situations (days) | – | – | 1 (4) | (8) | – | – | – | – | – | – |
| Rainfall departures (%)* | +20 | −12 | −14 | +4 | −25 | +12 | −16 | −8 | +40 | −6 |

[a] W.D., Western Disturbances.
[b] Note: Rainfall departures are based upon the monthly and normal weighted average rainfall of 18 sub-divisions shown in Figure 1 (Parthasarathy *et al.*, 1995).

disturbances like lows, depressions, deep depressions, etc., which are the main sources of widespread moderate to heavy rainfall. As such, the frequency of different synoptic systems affecting the weather of this country during different monsoon months of a given year were picked out from IMD publications such as: Weekly Weather Reports, Monthly and Annual Summaries, *Mausam* journal, etc., for the 15-year period from 1983 to 1997. From this data, monsoon months which were completely free from cyclonic disturbances like, depressions, deep depressions and cyclonic storms, were picked out. In other words, monsoon months which were affected only by lows were selected for this study so as to know what role these lows play in causing rainfall over the country in the absence of stronger systems like depressions, deep depressions, cyclonic storms.

From this exercise it was found that during the 15-year period (1983–1997), there were only four June, seven July, four August and six September months which experienced only lows. Of course, the other local and regional weather systems mentioned earlier, which usually occur during the monsoon months, did occur in these months also but the dominant effect as far as rainfall activity was concerned was due to lows. Table I gives the frequency of occurrence of lows and the low-days during the different monsoon months of the 15-year period which were affected by only lows. For each of these low affected months, average monthly weighted rainfall was calculated on the basis of 18 sub-divisions of the country (see Figure 1) which normally are affected by the passage of these lows through north India.

The normal monthly weighted rainfall for the region comprising the 18 sub-divisions (see Figure 1) was calculated using the long-period (1871–1990) normal monthly monsoon rainfall data of each of these

sub-divisions (Parthasarathy *et al.*, 1995). From the monthly monsoon rainfall normals of the region, percentage departures of rainfall were obtained in respect of months affected only by lows and this data are also given in Table I. Information regarding the frequency of occurrence of other weather systems which also affected the Indian region during these monsoon months is also shown in Table I, in order to know how far these systems were also instrumental in increasing or decreasing the rainfall over the region.

It may, however, be stated here that rainfall obtained from a low while moving over land depends upon their following characteristics:

(i) formation zone of the lows, i.e. sea or land origin,
(ii) track followed,
(iii) speed of movement over land,
(iv) strength of the low, i.e. well marked or of feeble intensity, and
(v) total life span of the low before it gets dissipated.

## 5. DISCUSSION

From a close study of Table I it is seen that the highest number of lows (i.e. six) occurred in the months of June 1984 and July 1994 whereas in the months of August and September the highest number of lows was five each in August 1992 and September 1988. The lowest number of lows (i.e. one) was recorded in June 1995, July 1985 and July 1987. The highest number of low days were experienced in June 1984 (48), Ju1y 1994 (34), August 1992 (30) and September 1988 (28).

In the following sections, five selected examples of low-affected months of different years are briefly discussed. More or less, similar synoptic situations were observed in the rest of the low-affected monsoon months of different years as given in Table I.

### *5.1. Some typical examples*

*5.1.1. June 1986.* The Arabian Sea branch of the monsoon struck the Kerla coast nearly 3 days late, i.e. on 4 June. It moved along the west coast and over the peninsula in a rather sluggish manner. The Bay branch of the monsoon ushered into Assam and the neighbourhood as late as 16 June and covered the entire north India up to Punjab and Rajasthan by 24 June. The seasonal monsoon trough over north India became established towards the third week of June. A well-marked low pressure area appeared in the northwest Bay on 19 June and moved up to central Madhya Pradesh by 22 June. Another land low appeared over Orissa and the neighbourhood and persisted over Gangetic West Bengal and the neighbourhood till 30 June.

Due to these synoptic systems, supported by ten upper air cyclonic circulations and widespread thundershower activities over central and northwest India, the monsoon was fairly active over the north India. Besides these, the movement of five western disturbances and a well-marked trough off the Maharashtra–Goa–Karnataka coast on most days during the month, enhanced rainfall activity over the study region. All these factors helped in causing well-distributed rainfall over the region. As per *Mausam* (IMD, 1987) rainfall during the month was above normal by + 23% (see Table I).

*5.1.2. June 1995.* During this month only one low formed over the northwest Bay off the south Orissa coast and its life span was of only 4 days duration (22–25 June) (see Figure 1). From its movement it was observed that after crossing the east coast, it moved over central parts of Bihar and became less marked there. Thus, due to the occurrence of only one low in this month, coupled with a short track of 4 low-days only, the rainfall over the region was below normal by − 37% (see Table I).

*5.1.3. July 1994.* As stated earlier July 1994 experienced the highest number of lows (i.e. six) during 3–6 July, 8–15 July, 14–17 July, 15–18 July, 19–25 July and 29 July–4 August. Rainfall received by the region (see Table I) during this month was + 22% above normal. This was due to the fact that out of six lows, five were of sea origin and one was formed over Gujarat and the neighbourhood. The lows of sea

origin formed over the northwest Bay and two of them (i.e. 8–15 July and 29 July–5 August) were well marked. However, it was observed that although these lows moved over the country in quick succession, three lows (out of five) of sea origin, had short tracks and moved over a limited area comprising the subdivisions of Orissa, West Bengal and Bihar Plateau. Similarly, the land low of 14–17 July had a short track and moved over southwest Rajasthan only. It is felt that due to their short tracks and the quick movements of the lows, the region received comparatively less rainfall although the month experienced six lows (see Table I).

*5.1.4. August 1995.* In August 1995, four lows were formed in the northwest Bay of Bengal off the Orissa–West Bengal coast. These were 2–6 August, 7–11 August, 17–19 August and 27 August–5 September. As far as the rainfall yielded by them is concerned, it was observed that in this month rainfall departure from the normal was $-14\%$. This deficiency in rainfall was mainly due to the fact that three out of four lows recurved in a northerly direction over Bihar Plateau and its neighbourhood. As such, their total life spans were comparatively short. In terms of rainfall distribution the major contribution was made by the low of 27 August–5 September which not only moved slowly but covered the entire north India from north Andhra to the south Orissa coast to Rajasthan. A 'break' monsoon situation occurred during 12–16 August which was responsible for causing deficient rainfall over the north and central Indian region. The combined effect of all these meteorological factors, caused negative percentage departure (i.e. $-14\%$) of rainfall in spite of two well-marked lows from the sea. In this case ten upper air cyclonic circulations were not of much help in contributing any substantial rainfall over the region.

*5.1.5. September 1993.* During September 1993, three lows formed in quick succession of which two were of sea origin and one formed over the land. These were 2–6 September (land), 6–14 September (sea) and 12–20 September (sea). The September 1993 month was unique in the sense that all meteorological situations responsible for causing fairly good rainfall were favourable, i.e. the two lows which formed in the northwest Bay of Bengal were well marked and they moved over north India from east to west along the normal track of monsoon disturbances. In other words, the two sea lows were quite intense in strength and had a long life span. The third low was of land origin which formed over northwest Madhya Pradesh and moved in a northwesterly direction covering the rest of the region. The occurrence of eight upper air cyclonic circulations by interacting with prevailing monsoon activity helped in obtaining the highest percentage departure of rainfall ($+40\%$) during the month.

Figure 1 also shows the tracks of lows which occurred during the months of June and August 1995 by way of illustration.

## 6. BROAD CONCLUSIONS

On critical examination of 15 years data (1983–1997) and tracks followed by individual lows, it was observed that the distribution of rainfall over the region (see Figure 1), only associated with lows, was due to:

(i) lows having a sea origin cause more rainfall than those which originate from land;
(ii) land lows when they form over Madhya Pradesh (east of longitude 85°E) and move across the country in a northwesterly direction cause fairly well-distributed rainfall compared to land lows which form over Gujarat or the Saurashtra–Kutch region (i.e. west of longitude 75°E);
(iii) lows originating from the Bay of Bengal and having westerly tracks up to west Madhya Pradesh/Uttar Pradesh or even up to Punjab–Haryana cause fairly well-distributed rainfall over northern and central India. Whereas, those travelling only up to the Vidarbha region cause less rainfall. In other words, lows having longer life spans and traversing the country from east to west cause well-distributed rainfall;
(iv) lows having northerly or northeasterly tracks (i.e. recurving north or northeastwards before longitude 85°E) cause deficient rainfall over the central and western parts of the country;

(v) like major cyclonic disturbances, slow moving lows cause fairly good rainfall compared to fast moving ones. Well-marked lows moving one after another in quick succession, generally cause a continuous spell of rain for a number of days which results in the flooding of rivers in the region. Most of the floods in the rivers of Narmada and Tapi (central Indian rivers) in this region are due to causes similar to the above;
(vi) frequency of occurrence of upper air cyclonic circulations or mid-latitude troughs, etc., appear to increase rainfall activity of the region to a certain extent only, and
(vii) 'break' monsoon situations cause deficient rainfall over the northern and central Indian region even though the concerned month may have experienced several lows.

Summing up, it can be said that in the absence of depressions and cyclonic storms during monsoon months, low pressure areas under favourable meteorological conditions can cause normal or even above normal rainfall over north Indian plains, central India and the northern half of peninsular India. Since the frequency of occurrence of these lows is much more than the frequency of monsoon disturbances like depressions and cyclonic storms, it may be said that under favourable meteorological conditions, these lows are instrumental in enhancing the monsoon rainfall of the country and are therefore quite beneficial from the point of view of agriculture, power generation and other developmental activities of the country.

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