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Summer monsoon low pressure systems over the Indian region and their relationship with the sub-divisional rainfall

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सार - इस शोध-पत्र में, हिंदमहासागर की निम्न दाब प्रणाली (एल.पी.एस.) की सहायता से उपक्षेत्रीय ग्रीष्मकालीन मानसून के दौरान मासिक वर्षा की मात्रा के संबंध में अध्ययन किया गया है। किसी स्थान विशेष में निम्न दाब बनने पर देश के कुछ निश्चित भागों में वर्षा की मात्रा में वृद्धि होती है जबकि कुछ अन्य भागों में वर्षा कम मात्रा में होती है। इस अध्ययन के लिए हिंदमहासागरीय क्षेत्र (5° - 35° उ. और 60° - 100° पू.) को 5° अक्षांश × 5° देशांतर के उपक्षेत्रों में बाँटा गया है। किसी विशेष उपक्षेत्र में निम्न दाब के ठहराव की अवधि की गणना दिनों में की गई है। 1891 से 1990 तक के वर्षों में ग्रीष्मकालीन मानसून ऋतु में जून से सितंबर के महीनों में प्रत्येक उपक्षेत्र में निम्न दाब के ठहराव के दिनों की गणना कुल मासिक दिनों में की गई है निम्न दाब प्रणाली 20° - 25° उत्तर की अक्षांशीय पट्टी के ठहराव के दिनों की संख्या अधिकतम कुल दिनों की आधी पाई गई है। इस क्षेत्र में निम्न दाब प्रणाली के ठहराव के कुल दिनों का प्रतिशत मानसून वर्षा की अधिकतम मात्रा वाले जुलाई और अगस्त के महीनों में अधिक होता है जबकि इसकी तुलना में जून और सितंबर के महीनों में यह प्रतिशत कम होता है। जब 20° - 25° उ. और 80° - 90° पू. की पट्टी में निम्न दाब बनता है तो मानसून माध्य द्रोणी के उपक्षेत्रों में वर्षा की मात्रा में उल्लेखनीय वृद्धि होती है जबकि जुलाई और अगस्त के महीनों में भारत के उत्तरी पूर्वी क्षेत्रों और दक्षिणी पूर्वी प्रायद्वीप भारत में वर्षा की मात्रा में आश्चर्यजनक ढंग से कमी पाई जाती है। जब निम्न दाब मध्य भारत से गुजरता हुआ पूर्व से पश्चिम की ओर बढ़ता है तो इसके फलस्वरूप उत्तरी पूर्वी भारत और दक्षिणी प्रायद्वीपीय भारत को छोड़कर देश के अधिकांश भागों में अच्छी वर्षा होती है और उपक्षेत्रों की मासिक वर्षा के बीच के विभिन्न उपक्षेत्रों में निम्न दाब के ठहराव के मासिक दिनों के संबंधों का अध्ययन करने के लिए इनका आंकलन किया गया है। उपक्षेत्रों में होने वाली वर्षा की मात्रा अधिकतर कुछ उपक्षेत्रों में निम्न दाब की अवस्थिति पर निर्भर होती है। विशेष उपक्षेत्रों में निम्न दाब की अवस्थिति के परिणामस्वरूप होने वाली वर्षा के बारे में कुछ उपयोगी सूचना सहसंबंध क्षेत्र मानचित्रों से प्राप्त हो सकती है।

ABSTRACT. In the present paper performance of the monthly sub-divisional summer monsoon rainfall is studied in association with the position of the Low Pressure System (LPS) over the Indian region. Existence of the LPS over a particular location increases the rainfall activities in certain parts of the country while decreases in some other parts. For this study, the Indian region (5°-35° N and 60° -100° E) is divided into 5° Lat. × 5° Long. grids. The duration of LPS is taken in terms of LPS days with respect to the location of LPS in a particular grid. Monthly total number of LPS days in each of the grids are computed during the summer monsoon season, June to September for the period 1891 – 1990. Maximum number of LPS days (more than half of the total) are observed in the latitude belt between 20°-25°N. The percentages of total LPS days in this area are higher in July and August which are peak monsoon months as compared to June and September. When there is a LPS are in the area 20°-25° N and 80°-90° E, there is significant increase in the rainfall activities in the sub-divisions along mean monsoon trough while northeast India and southeast peninsular India experience significant decrease in rainfall in the months of July and August. Owing to the movement of LPS from east to west through central India, most parts of the country, excluding northeast India and south peninsular India get good rainfall activity. Correlation coefficients between monthly LPS days over the different grids and monthly sub-divisional rainfall are computed to study the relationships. The performance of sub-divisional rainfall mostly related with the occurrence of LPS in certain grid-locations. The correlation field maps may give some useful information about rainfall performance due to LPS in a particular grid locations.

Key words – Low pressure system, Sub-divisional rainfall, LPS days.

1. Introduction

The existence of a closed low pressure area formed due to low, depression, cyclonic storm or severe cyclonic storm is termed as Low Pressure System (LPS). The LPS plays a very important role in distribution of rainfall during the period of summer monsoon season over India. Due to a cyclonic storm/severe cyclonic storm, very heavy

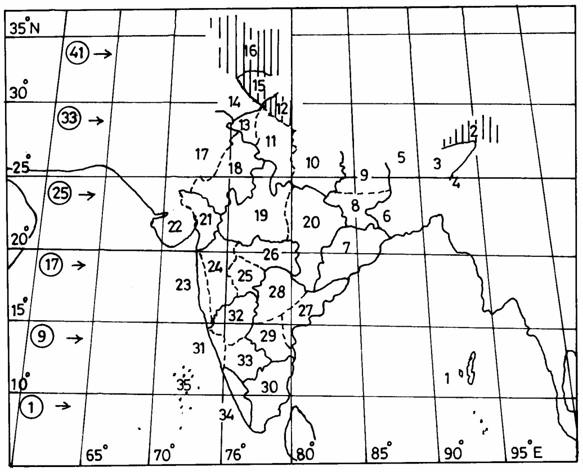

Fig. 1. The domain of study
(*i*) Meteorological Sub-divisions of India

No.	*Sub-division*	*No.*	*Sub-division*
1.	A & N Islands	18.	East Rajasthan
2.	Arunachal Pradesh	19.	West Madhya Pradesh
3.	Assam & Meghalaya	20.	East Madhya Pradesh
4.	Nagaland, Manipur, Mizoram and Tripura	21.	Gujarat, Daman, Dadra & Nagar Haweli
5.	Sub-Himalayan West Bengal & Sikkim	22.	Saurashtra, Kutch and Diu
6.	Gangetic West Bengal	23.	Konkan and Goa
7.	Orissa	24.	Madhya Maharashtra
8.	Bihar Plateau	25.	Marathwada
9.	Bihar Plains	26.	Vidarbha
10.	East Uttar Pradesh	27.	Coastal Andhra Pradesh
11.	West Uttar Pradesh	28.	Telangana
12.	Hills of west Uttar Pradesh	29.	Rayalaseema
		30.	Tamil Nadu and Pondicherry
13.	Haryana and New Delhi	31.	Coastal Karnataka
14.	Punjab	32.	North Interior Karnataka
15.	Himachal Pradesh	33.	South Interior Karnataka
16	Jammu & Kashmir	34.	Kerala
17.	West Rajasthan	35.	Lakshadweep

(*ii*) Griding of the Indian Region
5° Lat. × 5° Long. Grids of the Indian region (5° N-35° N and 60° E-100° E). Circled figure shows first grid of the 5° Latitude belt.

(*iii*) Major region of LPS : 15°-35° N and 70°-90° E

and intense rainfall occurs over a smaller area while a depression covers relatively larger area giving heavy rainfall to the left of front quadrant in a short duration of time along its track. A low generally produces widespread rainfall to its surrounding area and persists for longer period.

A large number of LPS formed over the Bay of Bengal travel in the north-west direction giving good amount of rainfall to its surrounding area. Some of the LPS formed over land produce rainfall mainly over the central parts of the country. A few LPS formed over the Arabian Sea travel in the north or north-east direction giving rainfall to the western parts the country. A slow movement of LPS gives good amount of rainfall in the neighbouring land. Longer duration and displacement covers larger parts of the country giving widespread rainfall. Due to the movement of LPS, there is a considerable increase in the rainfall activity in the surrounding area.

Many researchers like, Pisharoty and Asnani (1957), Lal (1958), Rao and Jayaraman (1958), Raghavan (1965), Mooley (1973), Sikka (1977), Joseph (1981) and Saha *et al*. (1981) have extensively studied the influence of storms/depressions on the performance of monsoon rainfall. Dhar *et al*. (1981) examined the influence of tropical disturbances (*i.e.* storms/depressions) on monthly rainfall and season's total rainfall for India as a whole. They noted significant relationship only with monthly rainfall and not with seasonal rainfall. Dhar and Nandaragi (1999) have studied contribution of only lows to the summer monsoon rainfall. Mooley and Shukla (1987) have examined some characteristic features of LPS in terms of formation, location, movement and duration of LPS. They found significant relationship (at 1% level) between LPS days during the monsoon season and central India monsoon rainfall.

In this paper performance of monthly monsoon rainfall of the meteorological sub-divisions is studied with respect to the location and duration of LPS. The monsoon rainfall activity is strongly linked with the formation of LPS over the Indian region. With the occurrence of LPS at a particular grid location the rainfall activity increases over certain sub-divisions while decreases in some other sub-divisions. The correlation field maps may give some information about the rainfall performance due to the existence LPS in a particular grid location.

2. Data

Daily locations of LPS formed over the Indian region during the summer monsoon season for period 1891-1983

TABLE 1

Monthly and total number of LPS days during the monsoon season over the Indian region for period 1891-1990

Yr/ Month	Jun	Jul	Aug	Sep	Season	Yr/ Month	Jun	Jul	Aug	Sep	Season	Yr/ Month	Jun	Jul	Aug	Sep	Season
1891	4	15	29	27	75	1926	1	16	15	26	58	1961	18	18	13	31	80
1892	10	20	8	22	60	1927	9	22	23	5	59	1962	7	26	8	20	61
1893	19	6	19	22	66	1928	16	19	11	17	63	1963	11	5	10	15	41
1894	17	23	8	15	63	1929	12	24	26	6	68	1964	10	6	18	15	49
1895	21	13	15	15	64	1930	4	24	8	15	51	1965	4	22	11	15	52
1896	16	18	17	7	58	1931	2	5	18	12	37	1966	10	12	5	14	41
1897	13	15	19	12	59	1932	6	18	8	17	49	1967	5	8	16	22	51
1898	7	21	25	10	63	1933	13	16	19	26	74	1968	12	11	20	10	53
1899	3	12	14	10	39	1934	14	9	20	12	55	1969	8	10	13	20	51
1900	13	10	32	19	74	1935	5	17	7	9	38	1970	12	14	13	24	63
1901	4	14	20	13	51	1936	11	14	12	6	43	1971	23	15	16	10	64
1902	15	20	13	16	64	1937	15	13	9	18	55	1972	8	13	28	16	65
1903	5	18	15	12	50	1938	10	10	8	5	33	1973	12	23	23	19	77
1904	17	17	18	17	69	1939	3	14	24	18	59	1974	13	0	15	16	44
1905	6	25	4	24	59	1940	5	12	22	10	49	1975	19	13	27	13	72
1906	11	11	7	17	46	1941	11	15	19	10	55	1976	13	13	24	23	73
1907	24	2	24	6	56	1942	7	21	15	17	60	1977	27	18	19	18	82
1908	13	11	25	13	62	1943	3	23	12	17	55	1978	12	15	28	25	80
1909	7	18	6	17	48	1944	9	19	32	10	70	1979	14	14	21	20	69
1910	9	10	10	20	49	1945	5	16	3	18	42	1980	26	18	19	18	81
1911	17	3	16	22	58	1946	8	15	16	15	54	1981	11	13	21	24	69
1912	4	7	14	11	36	1947	10	15	19	26	70	1982	9	14	28	18	69
1913	11	20	18	13	62	1948	9	13	19	19	60	1983	12	18	18	19	67
1914	15	17	8	15	55	1949	2	9	11	16	38	1984	22	9	32	13	76
1915	7	6	12	12	37	1950	10	10	15	15	50	1985	10	9	26	22	67
1916	14	3	17	11	45	1951	6	9	12	5	32	1986	10	22	22	10	64
1917	19	4	16	14	53	1952	11	23	18	12	64	1987	11	8	21	20	60
1918	10	4	18	10	42	1953	9	7	17	15	48	1988	23	10	16	26	75
1919	9	13	29	6	57	1954	3	9	11	24	47	1989	20	19	30	13	82
1920	10	15	12	17	54	1955	15	11	15	23	64	1990	17	11	26	20	74
1921	9	11	13	25	58	1956	15	15	17	7	54	–	–	–	–	–	–
1922	8	22	16	25	71	1957	0	8	13	14	35	Total	1070	1380	1699	1597	5746
1923	3	10	23	10	46	1958	0	20	10	19	49	Mean	10.7	13.8	17.0	16.0	57.5
1924	5	4	20	18	47	1959	11	19	16	16	62	S.D.	5.8	5.8	6.7	5.7	12.1
1925	14	18	8	12	52	1960	2	7	24	13	46	C.V.	54.9	42.2	39.7	35.9	21.1

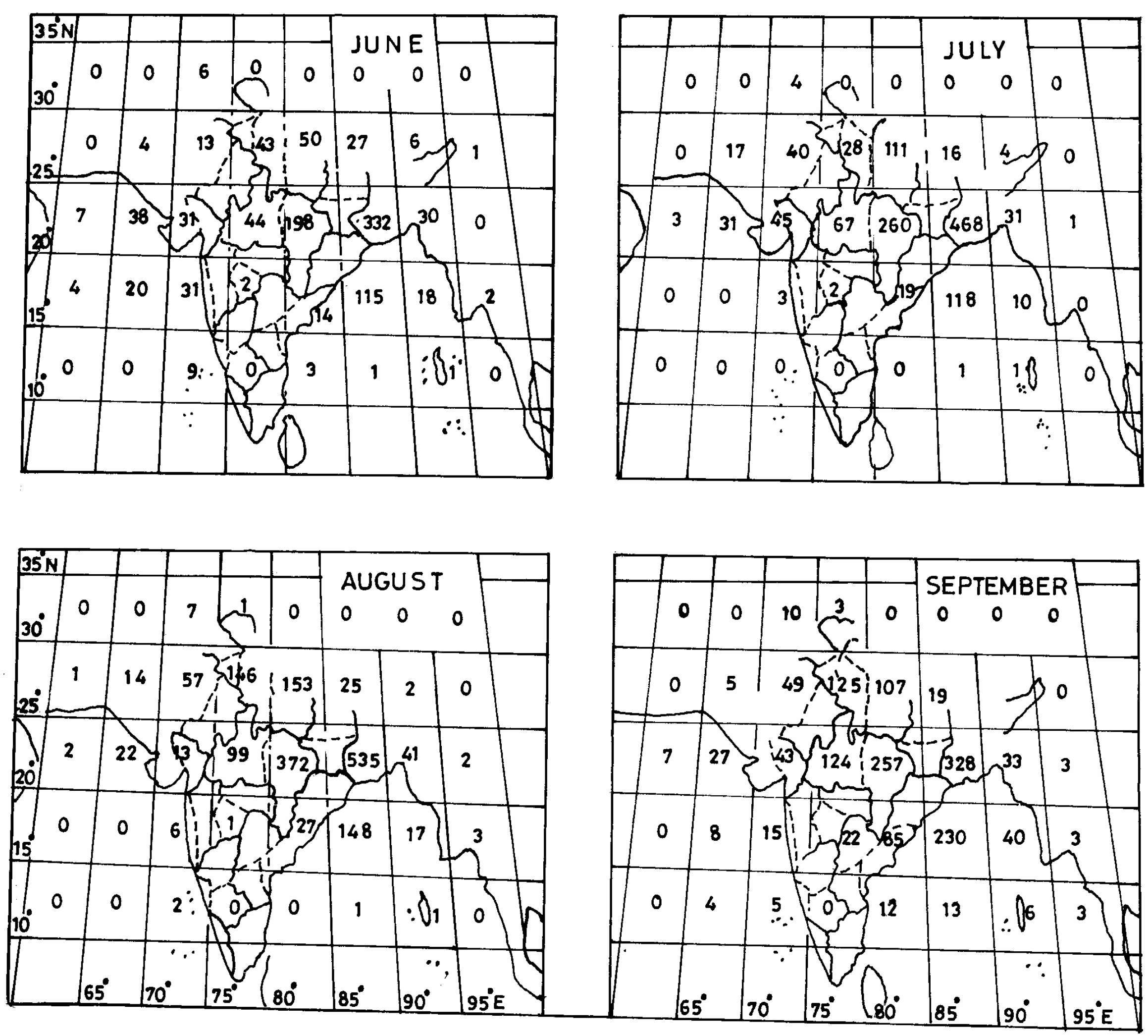

Fig. 2. Gridwise total number of LPS days during the monsoon months June to September for the period 1891-1990

are obtained from Mooley and Shukla (1987) and for the period 1984-90, daily locations of LPS are collected from 0300 UTC daily observation charts of Indian Daily Weather Reports (IDWR), published by the India Meteorological Department, Pune. Sub-divisional rainfall data of the summer monsoon months (June to September) for the period 1891-1990 is obtained from IITM Research Report No. RR-065 by Parthasarathy *et al*. (1995).

3. Method of data analysis

In this paper, sub-divisional summer monsoon rainfall is studied in association with the location and duration of the Low Pressure Systems over the Indian Region. For this purpose, the Indian region (5°-35° N and 60°-100° E) is divided into 5° Lat. × 5° Long. blocks (grids). In all there are 8×6 grids *i.e*. 48 grids (Fig.1). The days for which LPS exists in a particular grid are the LPS days of that grid. If there are more than one LPS occurring simultaneously over the Indian Region then their LPS days are counted separately. The total number of LPS days are computed for the monsoon months June to September for the period 1891-1990 (Table 1). Monthly rainfall for the same period is taken for the sub-divisions from Parthasarathy *et al*. (1995) as shown in the Fig. l. In the sub-divisional monthly rainfall series, the hilly regions of India are excluded.

TABLE 2(a)

LPS days and percentage to the total LPS days for the grids in the major region during the period 1891-1990

Month	June		July		August		September		Season	
Grid	Days	(%)	Days	(%)	Days	(%)	Days	(%)	Days	(%)
19	31	2.9	3	0.2	6	0.4	15	0.9	55	1.0
20	2	0.2	2	0.1	1	0.1	22	1.4	27	0.5
21	14	1.3	19	1.4	27	1.6	85	5.3	145	2.5
22	115	10.7	118	8.6	148	8.7	230	14.4	611	10.6
27	31	2.9	45	3.3	13	0.8	43	2.7	132	2.3
28	44	4.1	67	4.9	99	5.8	124	7.8	334	5.8
29	198	18.5	260	18.4	372	21.9	257	16.1	1087	18.9
30	332	31.0	468	33.9	535	31.5	328	20.5	1663	28.9
35	13	1.2	40	2.9	57	3.4	49	3.1	159	2.8
36	43	4.0	128	9.3	146	8.6	125	7.8	442	7.7
37	50	4.7	111	8.0	153	9.0	107	6.7	421	7.3
38	27	2.5	16	1.2	25	1.5	19	1.2	87	1.5
Total	900	84.1	1277	92.5	1582	93.1	1404	87.9	5163	89.9

TABLE 2(b)

Monthly/Season's total number of LPS and DDS days and their percentage ratio

Month/Season	June	July	August	September	Season
Total LPS days	1070	1380	1699	1597	5746
Total DDS days	445	552	620	675	2292
Percentage ratio	41.6	40.0	36.5	42.3	39.9

TABLE 2(c)

DDS days and percentage to the total DDS days for the grids in the major region during the period 1891-1990

Month	June		July		August		September		Season	
Grid	Days	(%)	Days	(%)	Days	(%)	Days	(%)	Days	(%)
19	16	4.0	0	0.0	1	0.2	8	1.2	25	1.1
20	1	0.2	1	0.2	0	0.0	8	1.2	10	0.4
21	9	0.5	7	1.3	11	1.8	42	6.2	69	3.0
22	43	9.7	51	9.2	55	8.9	90	13.3	239	10.4
27	19	4.3	27	4.9	11	1.8	21	3.1	78	3.4
28	11	2.5	34	6.1	51	8.2	59	8.7	145	6.3
29	53	11.9	117	21.2	131	21.1	112	16.6	413	18.0
30	149	34.5	204	37.0	235	37.9	144	21.3	712	31.1
35	6	1.3	15	2.9	21	3.4	18	2.7	60	2.6
36	11	2.5	29	6.5	34	5.5	45	6.7	119	5.2
37	11	2.5	16	2.9	24	3.9	35	6.2	86	3.8
38	7	1.6	2	0.4	1	0.2	5	0.7	15	0.7
Total	336	75.5	503	92.5	575	92.7	597	87.0	2001	87.3

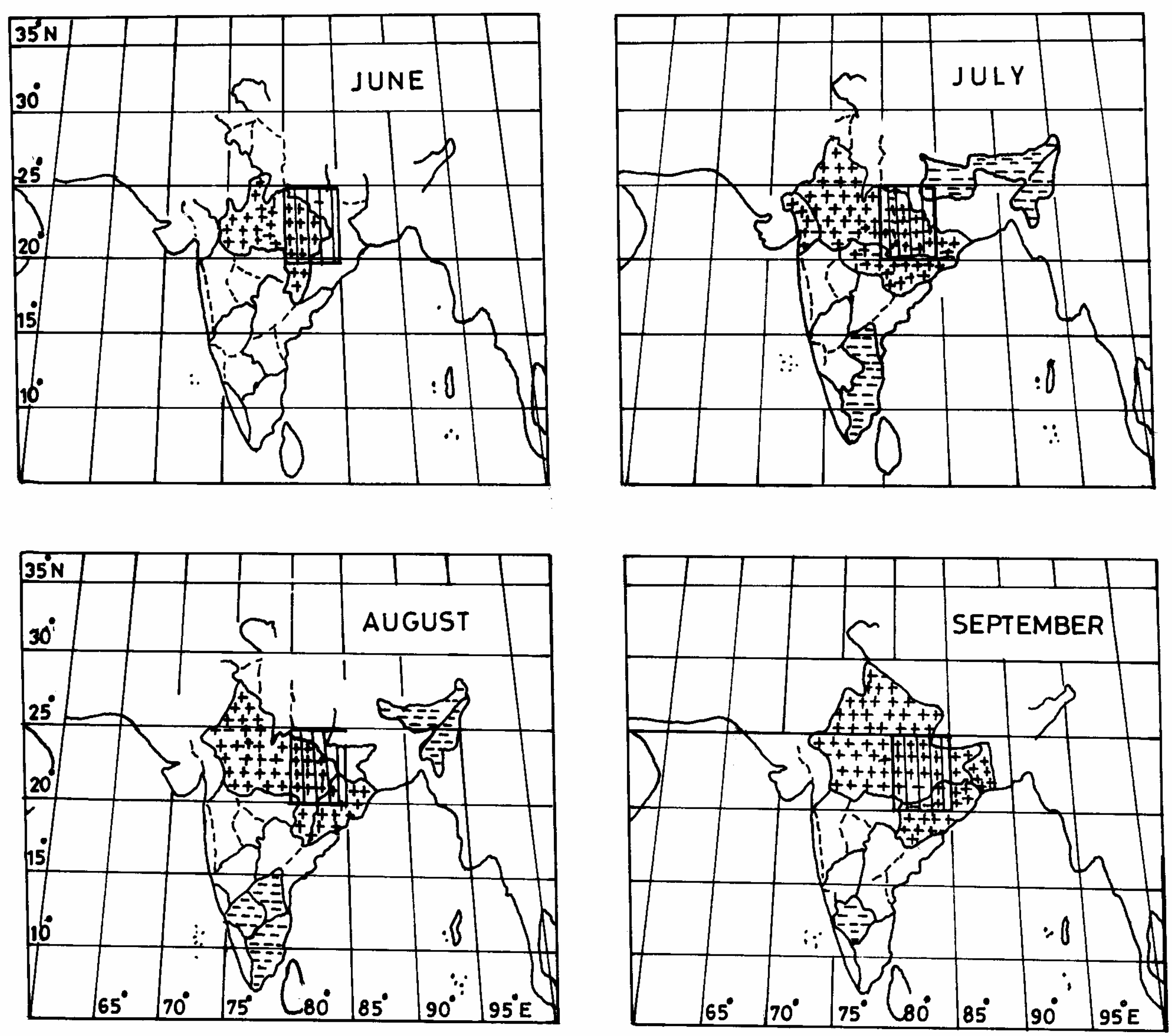

Fig. 3. Significant relationship (at 99% C.L.) between monthly LPS days in the area 20°-25° N and 80°-85° E (Grid 29) and monthly sub-divisional rainfall [++ shaded : positively correlated and – – shaded : negatively correlated]

4. Results

4.1. *LPS days*

From the daily locations of the LPS, the durations of the LPS in a specific grid are counted in terms of LPS Days. Monthly total number of LPS days for each of the 48 grids are computed for the period 1891-1990 (Fig. 2). Highest number of LPS days are found in the latitude belt 20°-25° N. More than 60% of the total LPS days in the months June to August and 50 % of the total LPS days in September are experienced in this latitude belt. The occurrence of LPS in this area largely influences over the performance of summer monsoon rainfall. The LPS days to the south of 20° N are more in September as compared to the other months. The existence of LPS in the grids to the south of 10° N are rare.

Average number of LPS days are maximum in the month of August (17.0) and are minimum in the month of June (10.7). Seasons total number of LPS days ranges from 32 to 82. In the month of June there are two occasions with zero LPS days in 1957, 1958 and in the month of July once in 1974.

The major region of the existence of LPS lies within the area 15°-30° N and 70°-90° E (Fig 2.) The total LPS days and their percentage to the total LPS days over the

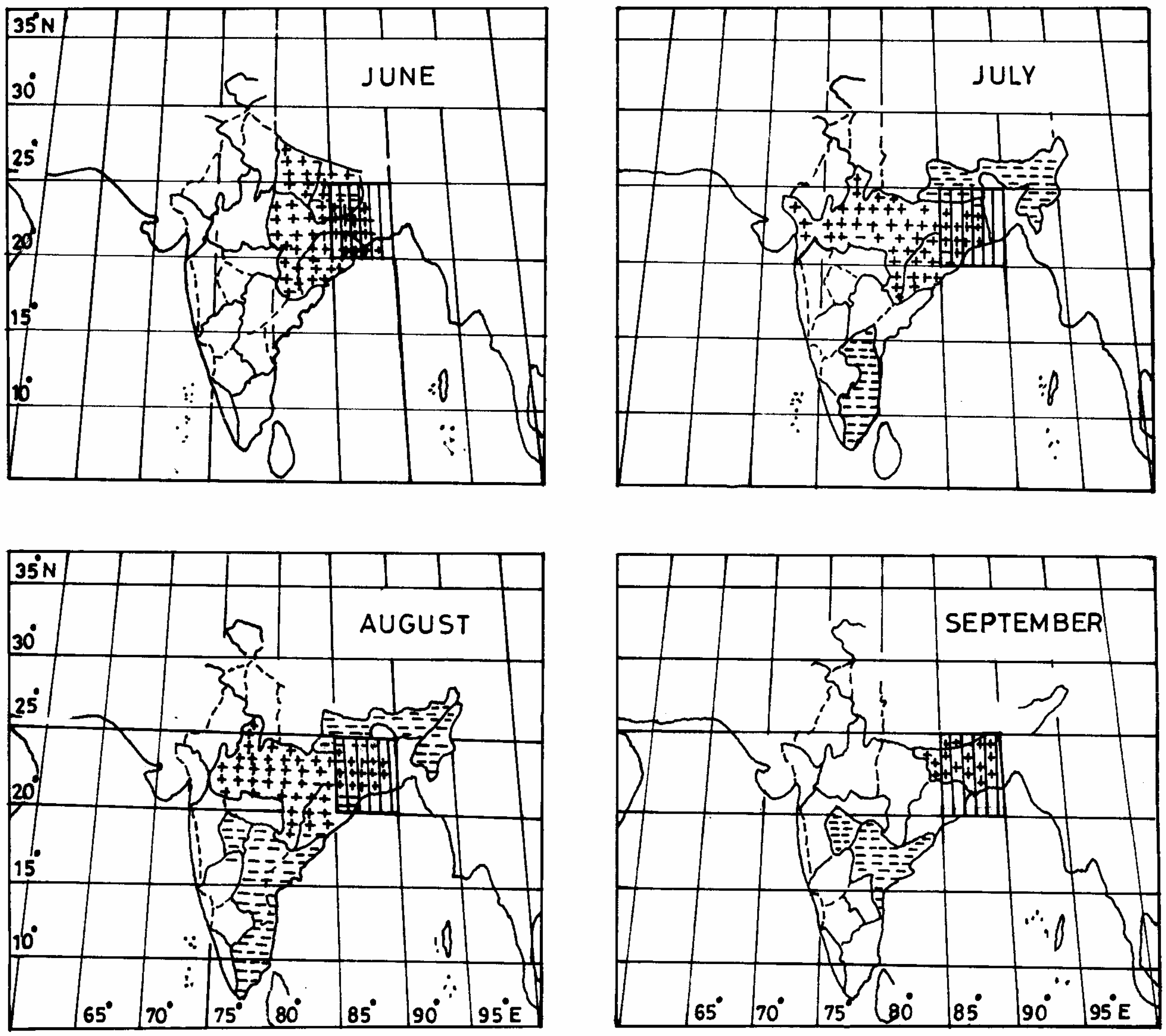

Fig. 4. Significant relationship (at 99% C.L.) between monthly LPS days in the area 20°-25° N and 85°-90° E (Grid 30) and monthly sub-divisional rainfall [++ shaded : positively correlated and – – shaded : negatively correlated]

Indian region for the grids in the above area are shown in Table 2(a). About 90 % of the total LPS days are observed in this area. In July and August the percentage is about 93% while in June and September it is about 84 and 88% respectively. Therefore, monthly LPS days over the grids in this area are considered to study the influence of LPS on the monsoon rainfall.

4.2. *Correlation fields*

Since about 90% of the total duration of LPS is observed in the area 15°-30° N and 70°-90° E, the linear correlation coefficients (CCs) between the monthly total number of LPS days over the grids in this area and monthly sub-divisional rainfall are computed on the basis of data for the period 1891-1990. The CC values are tested for 99% CL and some significant relationships are brought out. The existence of the LPS in a specific grid influences over the performance of monsoon rainfall of certain sub-divisions.

The area, 20°-25° N and 80°-90° E (grids 29 and 30) experiences about half of thc total LPS days. Most of the systems formed in or tavelled across the Bay of Bengal, pass through this area. So it is necessary to find out the relationship between monthly LPS days in this area and

TABLE 3

Significant relationships (at 99% CL) between monthly total number of LPS days over days over a grid and monthly sub-division rainfall

Month	June		July		August		September	
Grids	Subdiv. Nos. CC(+)	Subdiv. Nos. CC(–)	Subdiv. Nos. CC(+)	Subdiv. Nos. CC(–)	Subdiv. Nos. CC(+)	Subdiv. Nos. CC(–)	Subdiv. Nos. CC(+)	Subdiv. Nos. CC(–)
19	22(0.31)	–	–	–	–	–	24(0.28), 34(0.28)	–
20	–	–	25(0.29), 29(0.30)	–	5(0.26), 9(0.31)	–	24(0.37), 25(0.28), 27(0.43), 28(0.36), 32(0.44)	–
21	27(0.42), 33(0.36)	–	25(0.29), 28(0.31)	–	25(0.30), 26(0.31), 27(0.36), 28(0.42)	–	24(0.37), 25(0.38), 27(0.37), 28(0.46), 32(0.37)	8(0.29)
22	17(0.29), 18(0.29), 23(0.28), 25(0.30), 26(0.29), 27(0.33), 28(0.42)	–	27(0.39), 28(0.34), 29(0.26)	6(0.28), 8(0.27)	–	–	7(0.37), 13(0.32), 14(0.26), 21(0.29), 25(0.30), 26(0.27), 28(0.26)	–
27	21(0.28), 20(0.42)	–	22(0.35), 32(0.29)	–	21(0.26)	–	13(0.30), 14(0.33), 21(0.30), 22(0.50), 23(0.33), 24(0.27), 25(0.26)	–
28	13(0.26), 21(0.34), 22(0.29), 24(0.34), 26(0.31)	–	6(0.30), 7(0.31), 19(0.31), 21(0.43), 22(0.44), 24(0.31)	3(0.35), 5(0.26)	6(0.30), 19(0.42), 21(0.32)	3(0.38), 4(0.40), 10(0.32)	7(0.37), 11(0.31), 13(0.35), 17(0.29), 18(0.40), 19(0.58), 20(0.34), 21(0.54), 22(0.30), 23(0.33), 26(0.55)	29(0.34), 30(0.27), 32(0.28), 33(0.35)
29	19(0.28), 20(0.39)	–	7(0.52), 18(0.33), 19(0.54), 20(0.60), 21(0.30), 26(0.38)	3(0.40), 4(0.31), 5(0.42), 9(0.33), 29(0.27), 30(0.37)	6(0.28), 7(0.42), 18(0.35), 19(0.44), 20(0.33)	3(0.37), 4(0.29), 5(0.39), 29(0.36), 30(0.38), 33(0.28)	6(0.27), 7(0.39), 8(0.33), 10(0.27), 11(0.37), 18(0.36), 19(0.45), 20(0.63)	33(0.29)
30	6(0.56), 7(0.57), 8(0.57), 9(0.37), 10(0.31), 20(0.48)	–	6(0.29), 7(0.57), 8(0.52), 19(0.29), 20(0.49), 21(0.35)	3(0.35), 4(0.30), 5(0.52), 9(0.26), 29(0.27), 30(0.47)	6(0.28), 7(0.57), 8(0.37), 19(0.31), 20(0.52)	3(0.26), 4(0.38), 5(0.52), 9(0.30), 25(0.31), 27(0.35), 28(0.28), 29(0.54), 30(0.47)	6(0.40), 8(0.34)	25(0.26), 27(0.32), 28(0.35)
35	14(0.26), 15(0.45), 20(0.30), 22(0.31)	–	8(0.27), 17(0.26), 21(0.27)	–	17(0.45), 19(0.26), 21(0.39), 22(0.32)	–	7(0.35), 13(0.51), 14(0.53), 17(0.66), 19(0.33), 20(0.30), 21(0.57), 22(0.48)	–
36	10(0.29), 11(0.43), 13(0.30), 17(0.34), 18(0.54), 19(0.43), 21(0.28), 24(0.28)	–	18(0.40)	4(0.36)	13(0.33), 18(0.48), 19(0.46), 21(0.27)	4(0.28), 9(0.26)	7(0.38), 11(0.48), 13(0.42), 18(0.42), 19(0.41), 20(0.35), 31(0.31)	–
37	10(0.31), 14(0.41), 18(0.26)	–	9(0.31), 10(0.45)	21(0.29), 24(0.30), 25(0.29), 28(0.27), 32(0.29)	10(0.31), 11(0.27)	–	8(0.26), 10(0.39)	–

monthly sub-divisional monsoon rainfall. The significant relationship for the area 20°-25° N, 80°-85°E (grid 29) and 20°-25° N, 85°-90° E (grid 30) are depicted in the Figs. (3&4). It is seen that the rainfall of the sub-divisions in central India are significantly positively correlated while the rainfall of the sub-divisions in northeast India and southeast peninsular India are significantly negatively correlated for the months July and August.

The significant correlation field maps between monthly LPS days over a specific grid and monthly sub-divisional monsoon rainfall may be useful to meteorologists to get inference on rainfall performance over different meteorological sub-divisions of India due to the occurrence of LPS over a particular location. As it is difficult to present the correlation field maps for all the grids, some relationships with the significant CC values of the respective sub-divisions are summarized in Table 3.

4.3. *Categorizing of LPS days*

LPS term contains the systems like lows, depressions, deep depressions, cyclonic storms and severe cyclonic storms. The depressions/storms are mainly formed over the ocean or coastal area. As they move towards inland area, their intensity decreases and finally turn in to lows. Further to study the relation between sub-divisional rainfall and LPS days, the intensity of LPS is categorized into two parts, one only lows and other depressions/storms. The days experienced by lows are named as Low days and the days observed due to depressions/storms are abbreviated as DDS days. Here for convenience, only DDS days are mentioned. Monthly and season's total number of LPS days, DDS days during the period 1891-1990 and their percentage ratio are shown in the Table 2(b). During the monsoon season, average number of DDS days and Low days are 22.9 and 34.6 respectively. It is seen that out of total LPS days, about 40% are DDS days and remaining 60% are Low days. The percentage ratio of DDS days to the total LPS days is minimum in August (36.5%) and maximum in September (42.3%).

The total number of DDS days for the grids in the major region and their percentage to the total DDS days are given in Table 2(c). About 87% of the total DDS days are observed in this region. From the Table 2(a) and Table 2(c), it is seen that the gridwise percentage of LPS days and percentage of DDS days are approximately equal. Only in June, the percentage of DDS days is little less than the percentage of LPS days. The highest number of DDS days, about 70% of the total, are observed in the latitude belt, 20°-25° N. The DDS days considerably decreases to the north and south of this belt. The area formed by the grids 29 and 30 (20°-25° N and 80°-90° E) experiences about 50% of the total DDS days.

The linear correlation coefficients between monthly sub-divisional rainfall and DDS days/Low days are computed separately. But the relationship obtained shows some diffused picture. The relationship obtained with LPS days is more prominent than the relationships obtained from DDS days or Low days. Moreover the LPS days covers larger duration of the season.

5. Discussion

The low pressure systems over the Indian region dominate the southwest monsoon rainfall activities. The area of low pressure over the Indo-Gangetic plains is termed as monsoon trough. LPS plays a very dominant role in establishing the normal position of the monsoon trough. The area of rainfall mostly shifts in association with change in the location of monsoon trough. Due to the occurrence of LPS in the latitude belt 20°-25°, the position of the monsoon trough is maintained to its normal position. In such active monsoon conditions, the sub-divisions along the mean monsoon trough get good amount of rainfall under the influence of LPS.

The sub-divisions like West Bengal, Orissa, east and west Madhya Pradesh, Vidardha, Gujarat and east Rajasthan receive monsoon rainfall mostly due to the effect of LPS formed over Bay of Bengal. When the LPS travels towards north and over to the foot hills of Himalayas, Bihar and neighbouring area also get good rainfall activity while south-central parts of the country fall under deficient rainfall conditions. Some of the LPS formed in the Arabian Sea travel in north and northeast direction giving rainfall to the western parts of the country. Some of the LPS formed over land produces rainfall mainly over the central India. But the intensity of these LPS is weaker than that formed over Bay of Bengal and Arabian Sea.

It is seen that the sub-divisional monsoon rainfall activity, on large scale, varies with the location and duration of LPS. Due to the existence of LPS, some parts of the country get good rainfall while there is a considerable decrease in monsoon rainfall in some parts. Consequently LPS days over the Indian region do not show significant relationship with all-India monsoon rainfall.

LPS, in general, plays a dominant role in performance of the southwest monsoon rainfall. The depressions/storms give heavy rainfall in shorter duration while lows last longer giving widespread rainfall. The LPS days give better relationship with the sub-division rainfall than individual Low days or DDS days.

6. Conclusions

The following conclusions can be drawn from this study :

(*i*) Average LPS days in the monsoon season is 57.5 and average LPS days for the monsoon months are, June =10.7, July =13.8, August =17.0 and September = 16.0.

(*ii*) With the existence of LPS in a particular grid-location, there is increase in the rainfall activity over neighbouring sub-divisions.

(*iii*) During the monsoon season, maximum number of LPS days (more than 50% of the total LPS days) are observed in the area 20°-25° N and 80°-90° E.

(*iv*) When LPS are in the area 20°-25° N and 80°-90° E, there is significant increase in the rainfall activity in the sub-divisions of Orissa, east and west Madhya Pradesh, east Rajasthan and Gujarat while northeast India and southeast peninsular India experience significant. decrease in rainfall in the months of July and August.

(*v*) Significant correlation fields between sub-divisional rainfall and number of LPS Days in a grid are brought out. These correlation field maps may be useful to meteorologists, for short range forecasts.

(*vi*) LPS days do not show significant relationship with all-India monsoon rainfall.

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