

**INDIA METEOROLOGICAL DEPARTMENT
METEOROLOGICAL CENTRE, JAIPUR**



**RAJASTHAN
MONSOON REPORT-2019**

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MONSOON REPORT-2019
RAJASTHAN
HIGHLIGHTS

- ❖ Southwest monsoon advanced over Kerala on 08th June and over Rajasthan on 28th June (about 13 days behind normal date). Thereafter, monsoon covered the entire state by 19th July against normal date of 15th July (about 4 days behind normal date).
- ❖ The rainfall recorded during monsoon season (June-September, 2019) over the Rajasthan state as a whole was 583.7 mm against its normal of 435.6 mm which is 134% of its long period average (LPA) based on data of 1971-2020. The rainfall received over the state was Excess (Departure +34% of long period average).
- ❖ Meteorological subdivision wise 147% of its LPA over East Rajasthan and 111% of its LPA over West Rajasthan observed during the monsoon season.
- ❖ Monthly rainfall received over the state was 92% of LPA in June, 113% of LPA in July, 168% of LPA in August and 182% of LPA in September.
- ❖ Out of total 33 districts, 08 districts received large excess rainfall (Departure +60% or more), 13 districts received excess rainfall (Departure +20% to +59%), 09 districts received normal rainfall (Departure -19% to +19%) and 03 districts received deficient rainfall (Departure -59% to -20%) during the season.
- ❖ Districtwise highest rainfall 1721.9mm (95% large excess than normal) observed in Jhalawar followed by 1663.0mm (82% large excess than normal) in Pratapgarh district.
- ❖ Southwest monsoon withdrew from parts of West Rajasthan on October 9, 2019 (about 09 days behind normal date). Thereafter, monsoon withdrew from the entire state by 11th October against normal date of 30th September (about 11 days behind normal date).

1. Onset and Advance of Southwest Monsoon 2019

During mid-May, gradual development of southerly to southwesterly flow occurred over southern parts of north Indian Ocean. Within a couple of days, the cross equatorial flow strengthened and deepened over the Andaman Sea. This feature along with enhanced cloudiness and rainfall in association with a cyclonic circulation at mid-tropospheric levels over Andaman Sea, led to the arrival of southwest monsoon (SWM) over south Andaman Sea, some parts of South Bay of Bengal and Nicobar Islands on 18th May. Sustained rainfall activity over Andaman & Nicobar Islands and prevalence of southwesterly winds led to further advance of SWM into some more parts of southeast Bay of Bengal and north Andaman Sea, remaining parts of Nicobar Islands and southern parts of Andaman Islands on 25th May. In association with further deepening of southwesterlies in the near equatorial belt and over south & adjoining eastcentral Bay of Bengal, the SWM further advanced into southernmost parts of Maldives-Comorin area, some more parts of southwest and southeast Bay of Bengal, some parts of eastcentral Bay of Bengal, remaining parts of Andaman Sea and Andaman Islands on 30th May.

In view of the enhanced cloudiness, strengthening of westerlies and persistent cyclonic circulation in lower & mid-tropospheric levels over Lakshadweep area and neighbourhood, the SWM advanced into some more parts of south Arabian Sea, most parts of Lakshadweep area, some parts of Kerala & south Tamil Nadu, remaining parts of Maldives-Comorin area, some more parts of south & eastcentral Bay of Bengal and some parts of northeast Bay of Bengal on 8th June. Thus the southwest monsoon set in over Kerala on 08th June 2019 with a delay of about 7 days as against the normal date of 1st June.

Subsequent to the onset over the mainland, the onset vortex which was in the form of a cyclonic circulation off the west coast of India, descended down and developed into Very Severe Cyclonic Storm (VSCS) 'VAYU' over east central Arabian Sea during 10th – 17th June. During this period, the further advance of SWM remained sluggish. It further advanced into: remaining parts of south Arabian Sea & Lakshadweep area, most parts of Kerala, some more parts of Tamil Nadu, some more parts of Bay of Bengal, most parts of Mizoram and some parts of Manipur on 10th June; some parts of central Arabian Sea, remaining parts of Kerala, some parts of Karnataka, Tamil Nadu, some more parts of Bay of Bengal and of northeast India on 14th June and into most parts of Bay of Bengal, remaining parts of northeast India and some parts of east India on 16th June.

Further advance took place after the dissipation of VSCS 'VAYU'. SWM further advanced into: some more parts of central Arabian Sea, peninsular India and of Bay of Bengal, remaining parts of northeastern states and some more parts of West Bengal on 20th June; some more parts of peninsular India, some parts of south Chhattisgarh & Odisha, remaining parts of Bay of Bengal, most parts of West Bengal and some parts of Jharkhand and Bihar on 21st June; some more parts of Maharashtra, remaining parts of

Karnataka, Telangana, Odisha, Jharkhand, Gangetic West Bengal & Bihar, most parts of Chhattisgarh and some parts of East Uttar Pradesh on 22nd June; some more parts of Maharashtra and East Uttar Pradesh on 23rd June; some more parts of central Arabian Sea, Konkan, most parts of interior Maharashtra, some parts of Madhya Pradesh, some more parts of Chhattisgarh & Uttar Pradesh and some parts of Uttarakhand on 24th June; remaining parts of central Arabian Sea, Maharashtra, some parts of north Arabian Sea and south Gujarat and some more parts of Madhya Pradesh on 25th June and into some more parts of north Arabian Sea, Gujarat & Madhya Pradesh on 28th June.

In association with a well marked low pressure area developed over southeast Jharkhand & neighbourhood, SWM further advanced into some parts of East Rajasthan, most parts of Madhya Pradesh, remaining parts of Chhattisgarh, some more parts of Uttar Pradesh, most parts of Uttarakhand and some parts of Himachal Pradesh and Jammu & Kashmir on 02nd July. Subsequently, it advanced into: some more parts of Gujarat, Rajasthan, Madhya Pradesh and Uttar Pradesh on 03rd July; remaining parts of north Arabian Sea, Gujarat, Madhya Pradesh and some more parts of Rajasthan on 04th July; some more parts of Rajasthan, remaining parts of Uttar Pradesh, Himachal Pradesh, Uttarakhand and Jammu & Kashmir and some parts of Punjab, Haryana, Chandigarh and entire Delhi on 05th July; remaining parts of East Rajasthan & Haryana and some more parts of West Rajasthan & Punjab on 09th July; most parts of Haryana and Punjab on 15th July and into remaining parts of Punjab & Haryana and some more parts of West Rajasthan on 17th July. The SWM further advanced into remaining parts of West Rajasthan and thus covered the entire country on 19th July, with a delay of 4 days, against normal date of 15th July. The onset dates of Monsoon 2019 are shown in Fig.1.

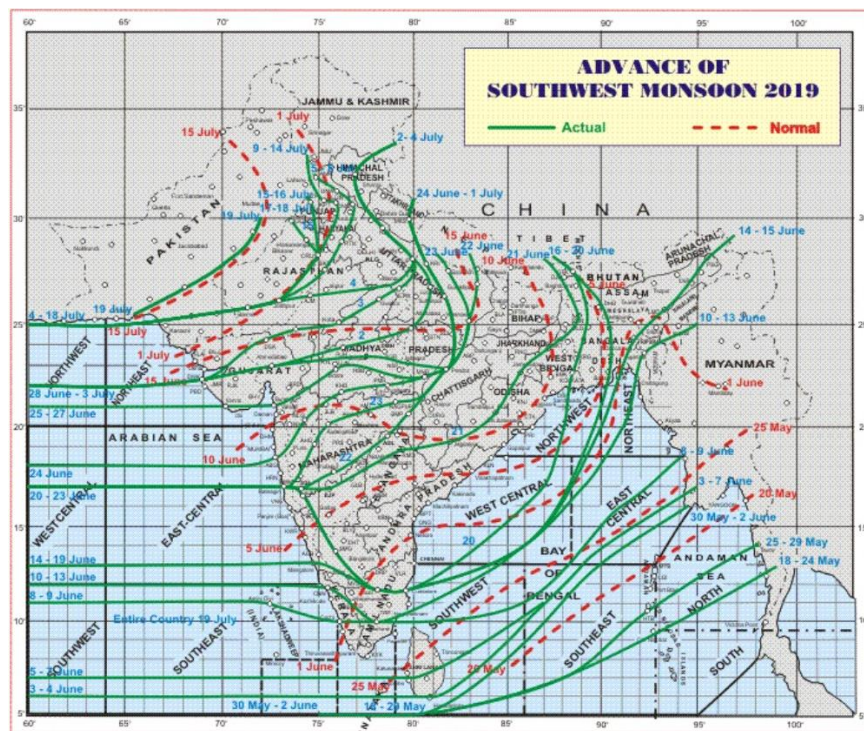


Fig. 1: Isochrones of advance of the Southwest monsoon during 2019

2. Rainfall Distribution

The districtwise, subdivisionwise and seasonal rainfall over the state during Southwest Monsoon 2019 are given in **Table 1** along with respective long period average (LPA) values and % departure from normal.

The seasonal rainfall over Rajasthan was 134% of its LPA during SW monsoon season 2019. East Rajasthan 147% of its LPA and West Rajasthan 111% of its LPA. Out of 33 districts, 08 districts received large excess rainfall, 13 districts received excess rainfall, 09 districts received normal rainfall, 03 districts received deficient rainfall and none of the districts received scanty rainfall during the season.

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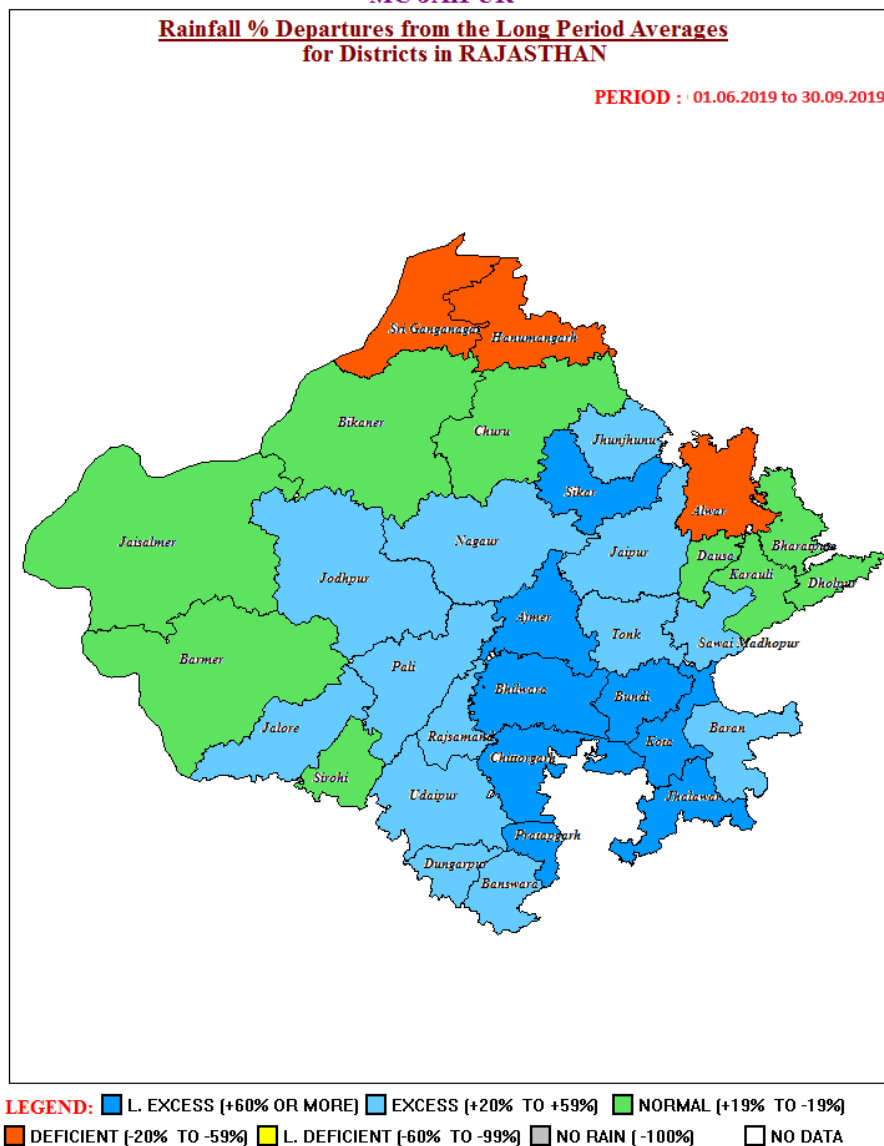


Fig. 2: Districtwise June-September 2019 Rainfall % Departures from the Long Period Averages

Table 1: CUMULATIVE RAINFALL STATISTICS (01/06/2019 to 30/09/2019)

SR NO.	NAME	ACTUAL RAINFALL (MM)	NORMAL RAINFALL (MM)	DEPARTURE FROM NORMAL (%)	CATEGORY
1	RAJASTHAN AS WHOLE	583.7	435.6	34	EXCESS
2	EAST RAJASTHAN	920.7	626.6	47	EXCESS
3	WEST RAJASTHAN	316.1	283.6	11	NORMAL
EAST RAJASTHAN					
1	AJMER	764.3	458.3	67	LARGE EXCESS
2	ALWAR	376.4	545.9	-31	DEFICIENT
3	BANSWARA	1223.7	886	38	EXCESS
4	BARAN	1237.4	832	49	EXCESS
5	BHARATPUR	486.4	543.3	-10	NORMAL
6	BHILWARA	1064.7	604.5	76	LARGE EXCESS
7	BUNDI	1175	644.4	82	LARGE EXCESS
8	CHITTORGARH	1177.2	727.2	62	LARGE EXCESS
9	DAUSA	647.1	594.5	9	NORMAL
10	DHOLPUR	692.2	584.1	19	NORMAL
11	DUNGARPUR	1007.2	706.5	43	EXCESS
12	JAIPUR	695.5	524.3	33	EXCESS
13	JHALAWAR	1721.9	884.3	95	LARGE EXCESS
14	JHUNJHUNU	601	408.8	47	EXCESS
15	KARALI	528	595.8	-11	NORMAL
16	KOTA	1291.9	732.2	76	LARGE EXCESS
17	PRATAPGARH	1663	914.2	82	LARGE EXCESS
18	RAJSAMAND	841.7	538.1	56	EXCESS
19	SAWAI MADHOPUR	929.4	661.5	40	EXCESS
20	SIKAR	680.7	407.1	67	LARGE EXCESS
21	SIROHI	953.9	873	9	NORMAL
22	TONK	836.8	566.8	48	EXCESS
23	UDAIPUR	976.1	617.7	58	EXCESS
WEST RAJASTHAN					
24	BARMER	448.6	272.7	5	NORMAL
25	BIKANER	423.3	247	-19	NORMAL
26	CHURU	536.3	334	10	NORMAL
27	HANUMANGARH	328.4	253.6	-41	DEFICIENT
28	JAISALMER	438.2	176.9	-9	NORMAL
29	JALORE	471.6	417.8	23	EXCESS
30	JODHPUR	507.6	292.6	35	EXCESS
31	NAGPUR	656.5	369.5	44	EXCESS
32	PALI	779.9	491.6	41	EXCESS
33	SRI GANGANAGAR	314.1	204.7	-27	DEFICIENT

Stationwise Total Seasonal Rainfall

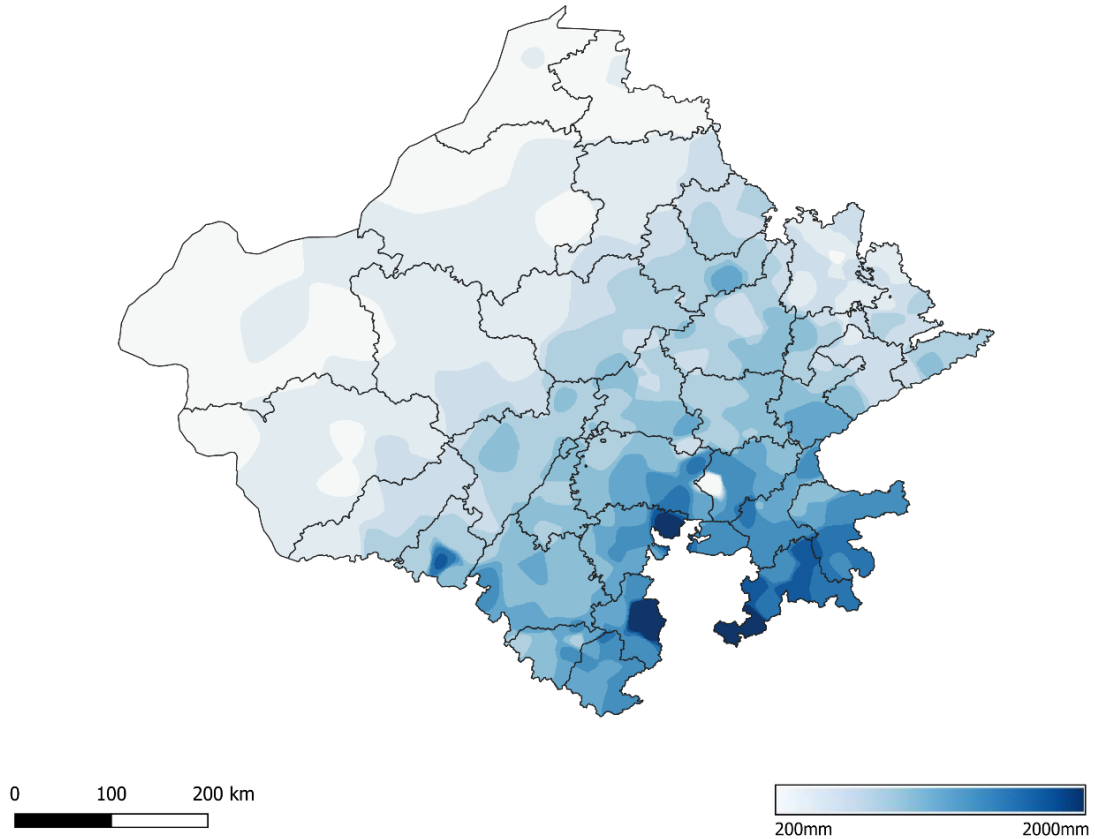


Fig 3.: Station wise Total Seasonal Rainfall

The rainfall recorded during monsoon season (June-September, 2019) over the Rajasthan state as a whole was 583.7 mm against its normal of 435.6 mm which is 134% of its long period average (LPA) based on data of 1971-2020. The top ten highest monsoon rainfall from 1901-2019 is shown in **Table 2**.

Table 2: Top Ten monsoon (1901-2019) for Rajasthan

Sr. No.	Year	Actual rainfall	Normal (1971-2020)	% Departure
1	1917	844.2	435.6	94
2	1908	682.2	435.6	57
3	1975	665.4	435.6	53
4	1973	641.8	435.6	47
5	1944	627.4	435.6	44
6	2011	593.7	435.6	36
7	2019	583.8	435.6	34
8	1916	570.1	435.6	31
9	1977	569.6	435.6	31
10	1994	567.3	435.6	30

South and southeastern parts of the state received large excess rainfall. Whereas, Northern Rajasthan received deficient rainfall. In terms of percentage departure from normal, Hanumangarh district received least rainfall (59% of LPA) and Jhalawar district received highest rainfall (195% of LPA).

The monthly rainfall during monsoon season (June to September) for the State as a whole and its two meteorological sub divisions with respective LPA values and departure from normal is given in **Table 3-5**.

Table 3: Rainfall during southwest monsoon 2019 over Rajasthan

Month	Actual Rainfall (in mm)	Long Period Average (in mm)	Departure from Normal (in %)
June	46.3	55	-16
July	173.4	161.4	7
August	248.2	155.8	59
September	115.8	63.5	82

Table 4: Rainfall during southwest monsoon 2019 over East Rajasthan

Month	Actual Rainfall (in mm)	Long Period Average (in mm)	Departure from Normal (in %)
June	72.8	74.7	-21
July	269.9	228.6	18
August	384.3	231.5	66
September	193.6	91.8	111

Table 5: Rainfall during southwest monsoon 2019 over West Rajasthan

Month	Actual Rainfall (in mm)	Long Period Average (in mm)	Departure from Normal (in %)
June	25.2	39.4	-36
July	96.8	107.8	-10
August	140.1	95.5	47
September	54	40.9	32

Both East Rajasthan and West Rajasthan received their highest rainfall during month of August which was 166% of LPA (large excess) and 147 % of LPA (excess) respectively.

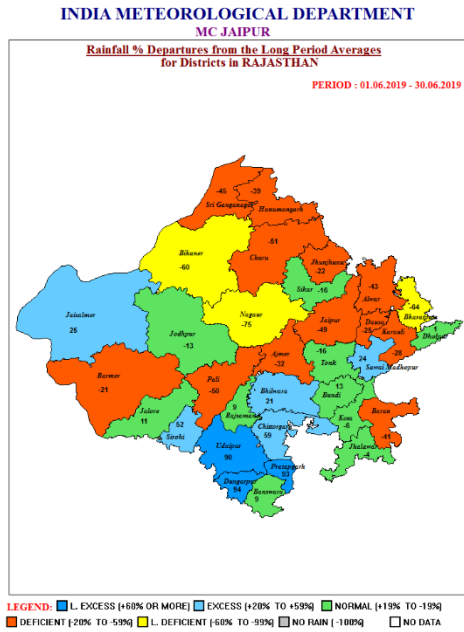


Fig. 4: Districtwise Monthly Distribution over Rajasthan – June

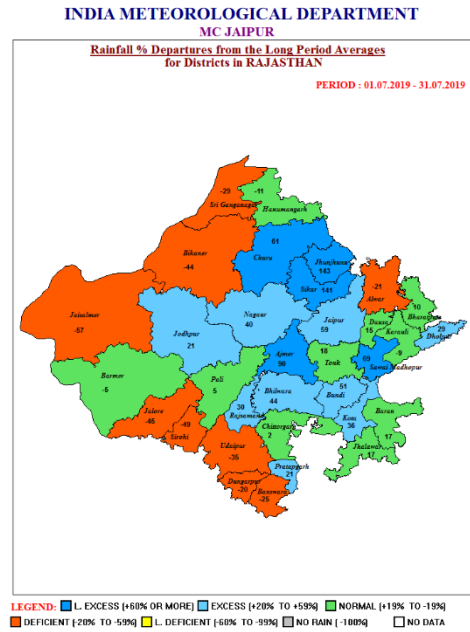


Fig. 5: Districtwise Monthly Distribution over Rajasthan – July

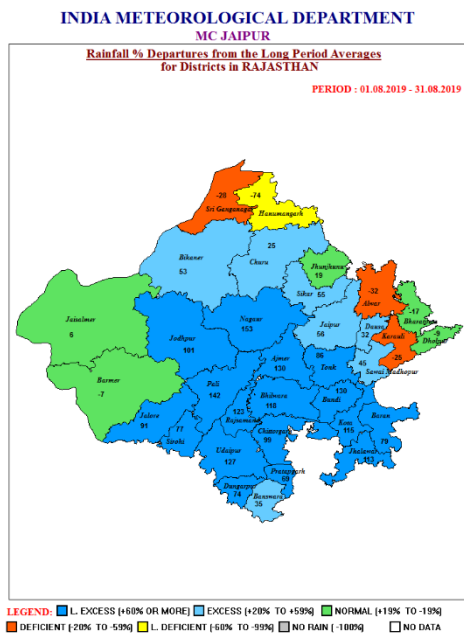


Fig. 6: Districtwise Monthly Distribution over Rajasthan – August

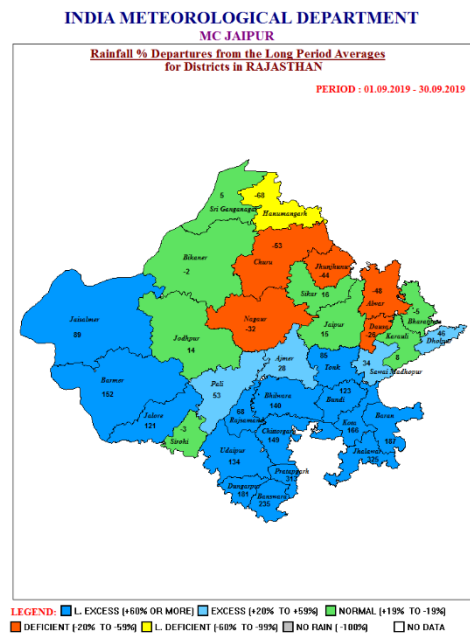


Fig. 7: Districtwise Monthly Distribution over Rajasthan – September

Fig. 8 depicts the monthly variation for Rajasthan and two subdivisions during 2019 southwest monsoon season and **Fig. 9** depicts the weekly and cumulative weekly rainfall anomaly expressed as percentage departure from the LPA.

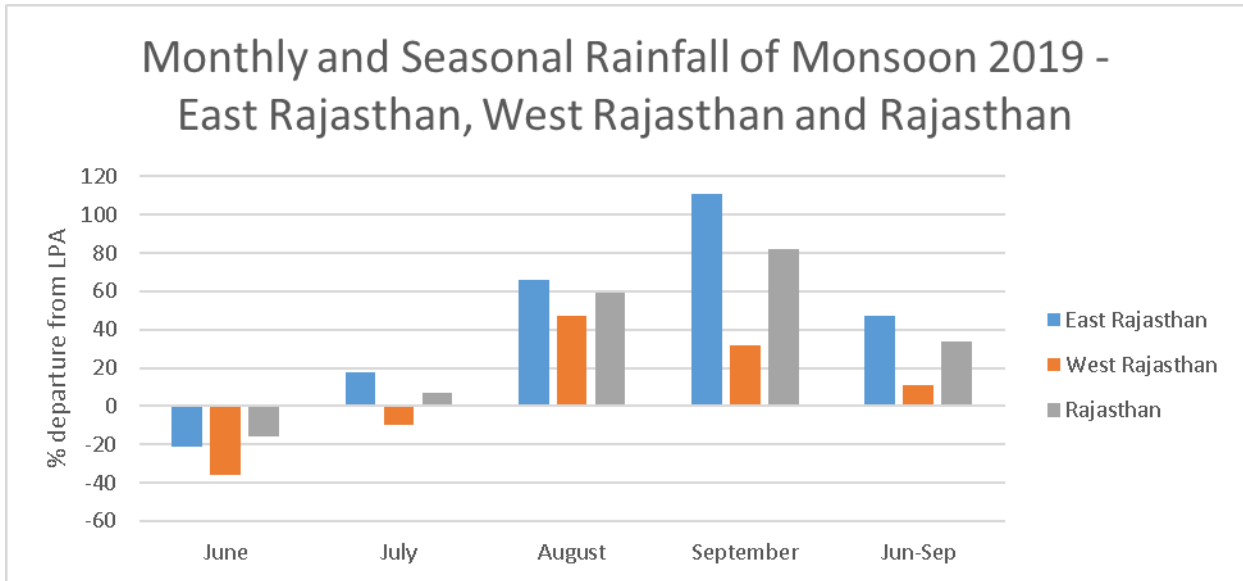


Fig. 8: Monthly and seasonal monsoon rainfall of 2019 over East Rajasthan, West Rajasthan and Rajasthan as whole in % departure.

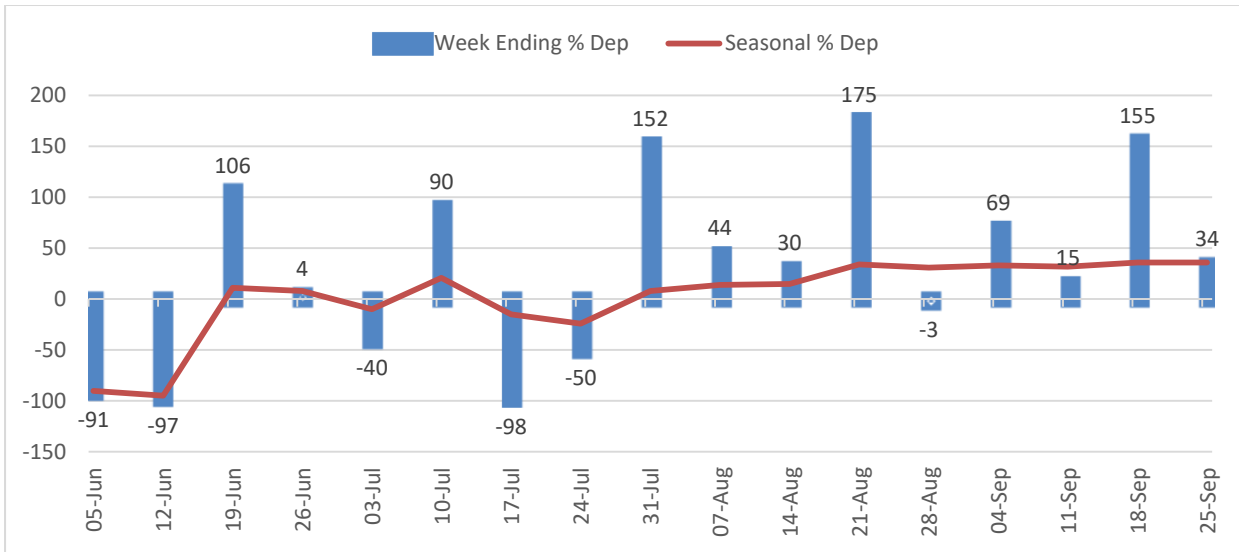


Fig. 9: Week by week progress and cumulative rainfall (% departure from normal) over Rajasthan as whole.

Out of the 11 positive rainfall anomaly weeks, 2 weeks were in June, 2 weeks were in July, 3 weeks were in August and 4 weeks were in September. The highest negative weekly rainfall anomaly was recorded during the week ending 17th July (-98% of LPA). The highest positive rainfall anomalies were recorded during the week ending on 21st August (175% of LPA), 18th September (155% of LPA), followed by the week ending on 31st July (152% of LPA).

Table 6: Weekly Rainfall (in mm)

	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	11-Sep	18-Sep	25-Sep
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RAJASTHAN	0.4	0.2	23.7	16.4	14.2	51.8	0.8	20.1	90.8	55.7	45.1	98.8	27.8	42.3	27.3	30.8	12.7
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EAST RAJASTHAN	0.5	0.2	44.3	17.3	23.8	98.9	0.1	23.1	133.9	82.4	80.8	148.1	53.1	42.9	46.4	69.3	22.3
AJMER	0	0.1	10.7	13.6	17	118.9	0	22.8	158.7	95.9	37.4	138.5	54.9	37.5	27	21.6	2.3
ALWAR	0	0.2	23.5	8.2	1.6	29.2	1	30.5	90.9	18.9	43.2	66.2	6.1	18.3	10	6.8	9.5
BANSWARA	0	0	54.3	44.9	32.4	159.1	0	5.8	29.1	80.1	158.5	89.9	91.5	32.5	82	249.3	43.4
BARAN	0	0	24.4	17.3	16.8	118.4	0	17.9	190.9	117.5	58.5	216.5	80.9	55.1	85	100.5	97.9
BHARATPUR	0	0	10.8	6.9	7	102.8	0.6	33.9	54.2	60.3	53.8	49.5	7.1	16.8	9.7	19.5	32.9
BHILWARA	0	0	45.5	10.6	37.7	85	0	23.4	176.8	84.6	103.3	194.2	67.6	60.6	33.7	94.6	9.1
BUNDI	1.2	0	44.8	15	40.3	103.8	0	5.2	227.3	96	64.7	262.3	55.2	56.5	35.5	108.2	17.2
CHITTORGARH	0.4	0.9	81.5	12.2	28.3	137.6	0	10.7	97.8	117.9	92.3	194.1	82	76.1	73	124.4	14.1
DAUSA	0	0	36.8	8.4	7.8	119.4	0	25.6	106.2	52.4	73.2	108.2	31.3	25.4	18.6	20.4	2.4
DHOLPUR	0	0	24	13	27.8	184.3	0	8.8	61.8	79	36.8	69.3	27	10	62.2	38.8	25.8
DUNGARPUR	0	0	94.3	56.9	17.3	132.7	0.5	10.4	16.1	76.7	141.8	94.8	75	26.5	59.9	66.8	31.2
JAIPUR	0	0.1	23	6.4	7.8	58.2	0	29	215.6	87.1	45.5	104	22.9	33.3	20.7	20	10.5
JHALAWAR	1.1	0	30.2	29.6	71.3	125.1	0	14.9	133.8	135.8	148.2	259.8	138.7	31.6	170.3	294.3	70.8
JHUNJHUNU	0	0.3	28.3	8.5	18.4	79.2	0	65.3	197.6	52.1	19.9	93.1	0.5	8.4	4.5	0	13.9
KARAULI	0	0	21.2	16.7	11.3	107.7	0	16.2	58.5	49.7	49.2	52.8	22	25.2	40.5	29	11.2
KOTA	0.2	0	33.1	11.6	53.6	135.9	0	8.8	193.8	126	52.9	263.8	82.7	51.1	42.6	146.3	46.2
PRATAPGARH	0	0	135.6	22.2	58.8	210.8	0.6	24.8	88.4	78.4	208.8	177.6	115	41.2	65.8	305.4	42.6
RAJSAMAND	0	0	53.9	5.7	32.4	102.3	0	13.4	99.6	43.7	64.3	193.6	52.1	74.6	68.7	7.9	10.7
SAWAI MADHOPUR	0.3	0	32.1	25.3	31.6	134.5	0	11.5	225.6	36.9	78.3	126.8	75.1	50.7	22.6	57.3	14.1
SIKAR	0	0	28.5	14.8	10.8	87.9	0	57.4	228.3	77.7	23.8	82.1	9.9	33.7	4.4	1	1.8
SIROHI	0	0	69.7	37	5.7	30.2	0	47.3	81.4	140.9	151	190.4	29.6	73.3	25	1.4	15.3
TONK	0	0.3	34.4	5.1	22.1	56	0	9.2	169.3	87.6	49.8	185.2	40.3	41.6	28.3	85.1	5.2
UDAIPUR	3.6	0.8	92.5	32.7	22.8	82.9	0	17.4	23.7	73.8	150.2	150.9	76.5	57.8	86.5	19.1	24.7

WEST RAJASTHAN	0.3	0.3	7.3	15.8	6.7	14.5	1.3	17.7	56.6	34.4	16.7	59.7	7.7	41.9	12.1	0.1	5.1
BARMER	1.1	0	1.3	21.8	8	7.8	0	9.3	59.6	11.2	19.5	19.4	12.4	58.4	20.7	0	7.3
BIKANER	0.6	0	7.4	4	2.8	3.3	0	22.3	25	51.3	4.6	35.7	4.7	26.1	0.1	0	1.9
CHURU	0	0	14.7	1	10	45.6	0	41.3	92.4	48.9	15.7	41.6	4.6	13.8	0.6	0.1	7
HANUMANGARH	0	0	26.1	0.7	0.4	9.9	22	28.4	30	18.7	0.3	1.6	0.4	1	0	0	0
JAISALMER	0	0	0.1	31.8	0	0	0	5.9	18.7	12.3	6.5	9.3	7.3	49.3	11.6	0	0.7
JALORE	0	0	21	20.7	21.4	17	0	22.3	25.1	33	37	91.6	31.7	89.3	26.6	0	33.7
JODHPUR	0.1	2.4	0.2	28.3	9.4	13.5	0	13.5	93.3	23.9	27.3	101.6	2.1	49.9	18.6	0.6	3.9
NAGOUR	0	0	9.5	1.9	10.4	47.1	0	28.7	113	93.5	19.4	154.6	4.8	33.7	1.1	0.3	3.3
PALI	0	0	13.5	9.7	15.3	32.1	0	17.5	119.6	52.6	48.7	230.1	12.3	56	45.4	0	7.2
SRI GANGANAGAR	0	0	14.3	3.2	1.2	1.2	4.7	15.1	33.2	26.5	9.7	1.8	0.9	16	0	0	0.1

Fairly wide spread to wide spread rainfall occurred on 6 days (minimum) to 62 days (maximum) over different districts in Rajasthan during the whole monsoon season. Jhalawar district got wide spread rainfall on 49 days (highest) during the whole season. The districtwise daily rainfall distribution of Monsoon 2019 is shown in **Fig.10**.

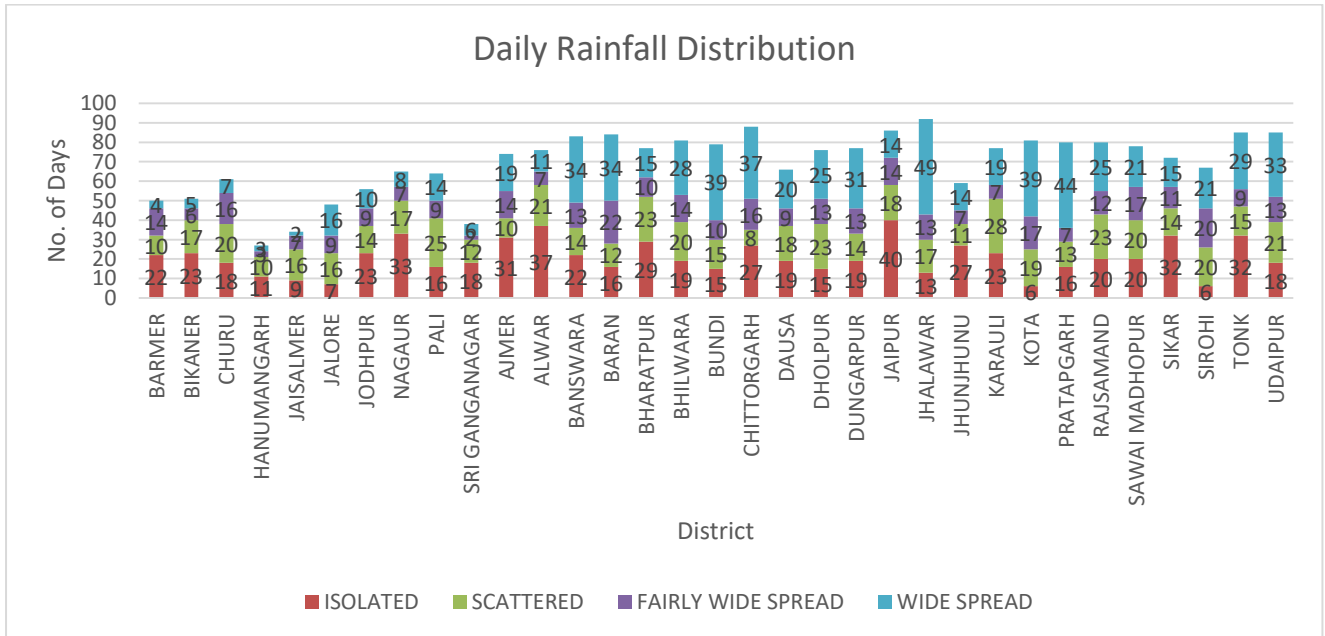


Fig. 10: Districtwise Daily Spatial Rainfall Distribution

Heavy to extremely heavy rainfall occurred at isolated to most places in all districts of the state on a few days. The districts namely Pratapgarh, Jhalawar and Pali received heavy rainfall on a greater number of days at most places during the whole season. Pratapgarh, Udaipur and Sirohi districts experienced heavy rainfall at many places on 2 to 4 days during the season. The districtwise daily heavy to extremely heavy rainfall distribution of Monsoon 2019 is shown in **Fig.11**. Extremely Heavy rainfall of the season is shown in **Table 7**.

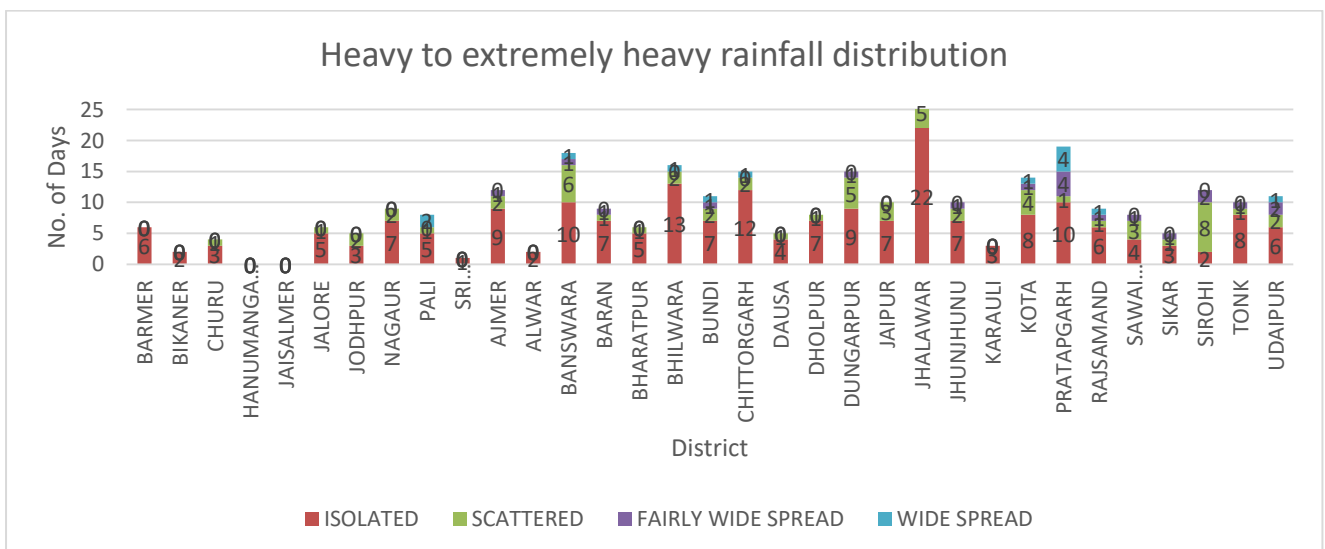


Fig. 11: Districtwise Daily Heavy to Extremely Heavy Rainfall Distribution

Table 7: Extremely Heavy Rainfall during Southwest Monsoon 2019

S.No.	Station	Date	Amount (in mm)	District
1	Begu	16 th August	302.0	Chittorgarh
2	Pratapgarh	19 th June	280.0	Pratapgarh
3	Pali	16 th August	276.0	Pali
4	Pratapgarh	14 th September	270.0	Pratapgarh
5	Bundi	28 th July	264.0	Bundi
6	Chabra	16 th August	256.0	Baran
7	Atru	16 th August	241.0	Baran
8	Mandalgarh	16 th August	237.0	Bhilwara
9	Dug	14 th September	224.0	Jhalawar
10	Gangdhar	15 th September	224.0	Jhalawar
11	Pali	29 th July	221.0	Pali
12	Pratapgarh	16 th August	220.0	Pratapgarh

Month wise very heavy and extremely heavy rainfall events are shown in **Fig.12** and **Fig. 13** respectively. Most number of very heavy to extremely heavy rainfall events occurred in the month of August. Highest rainfall of 302mm occurred in Begu on 16th August.

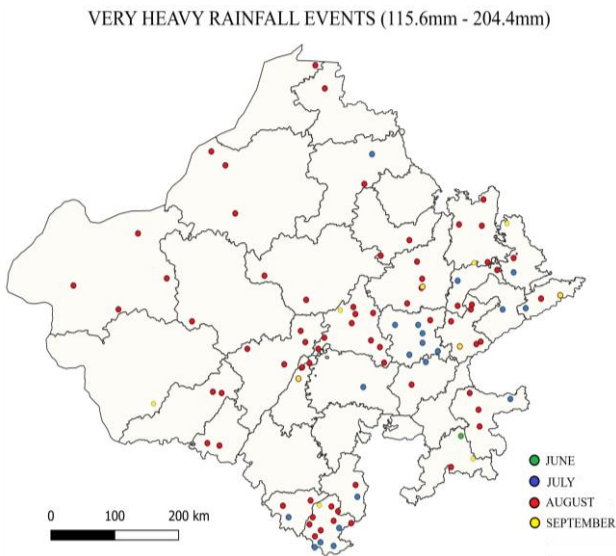


Fig. 12: The location of Very Heavy Rainfall (115.6 to 204.4 mm)

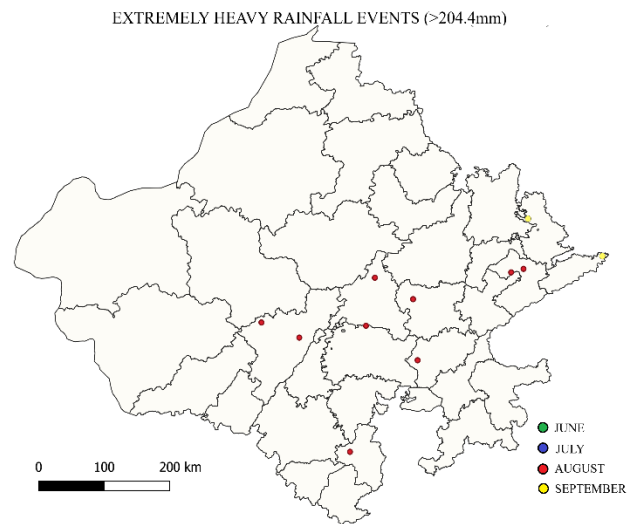


Fig. 13: The location of Extremely Heavy Rainfall (more than 204.4 mm)

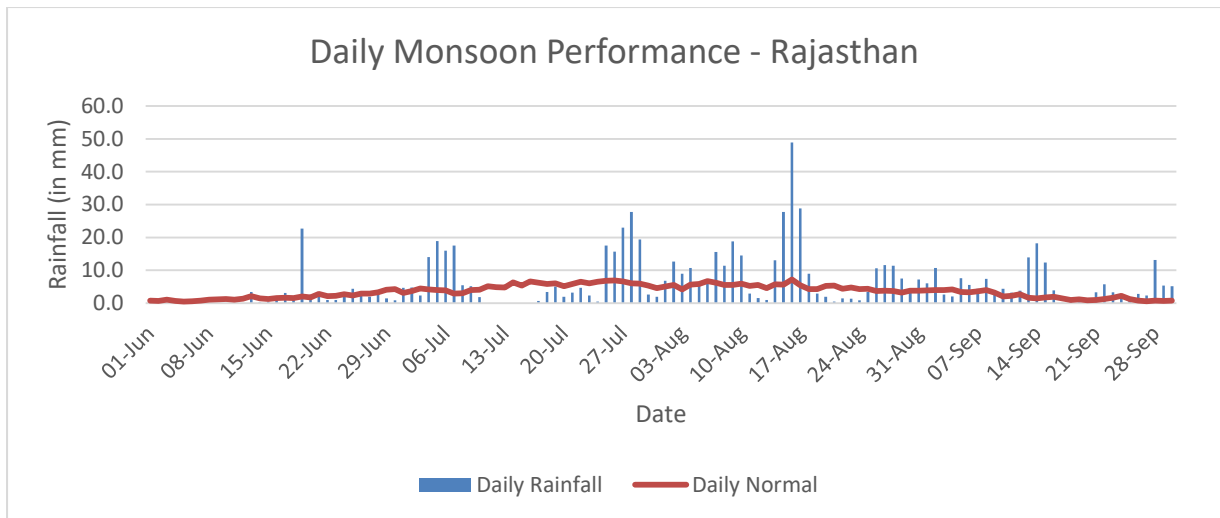


Fig. 14: Daily Rainfall - Rajasthan

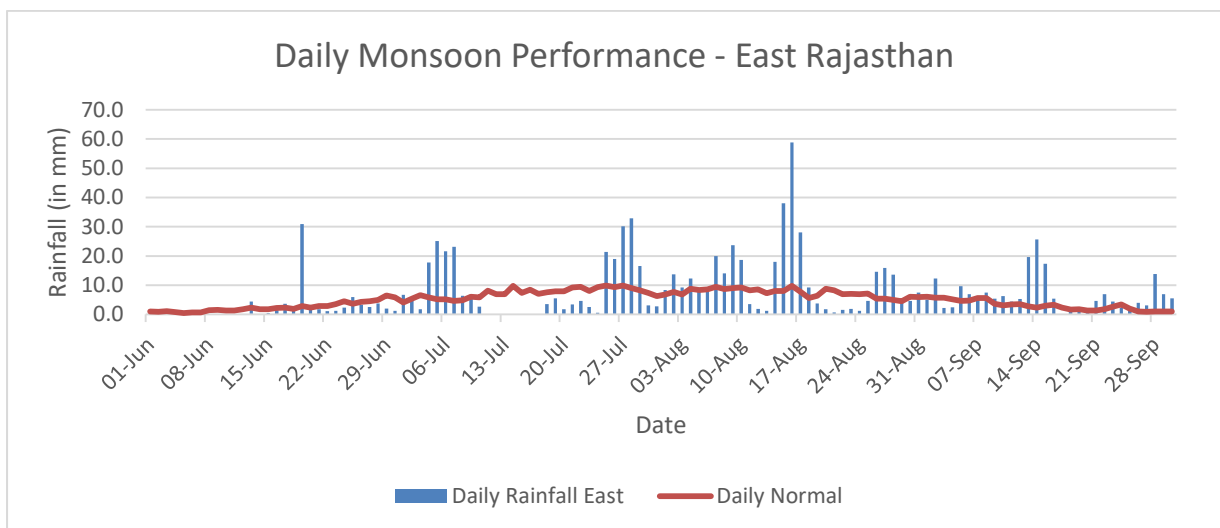


Fig. 15: Daily Rainfall – East Rajasthan

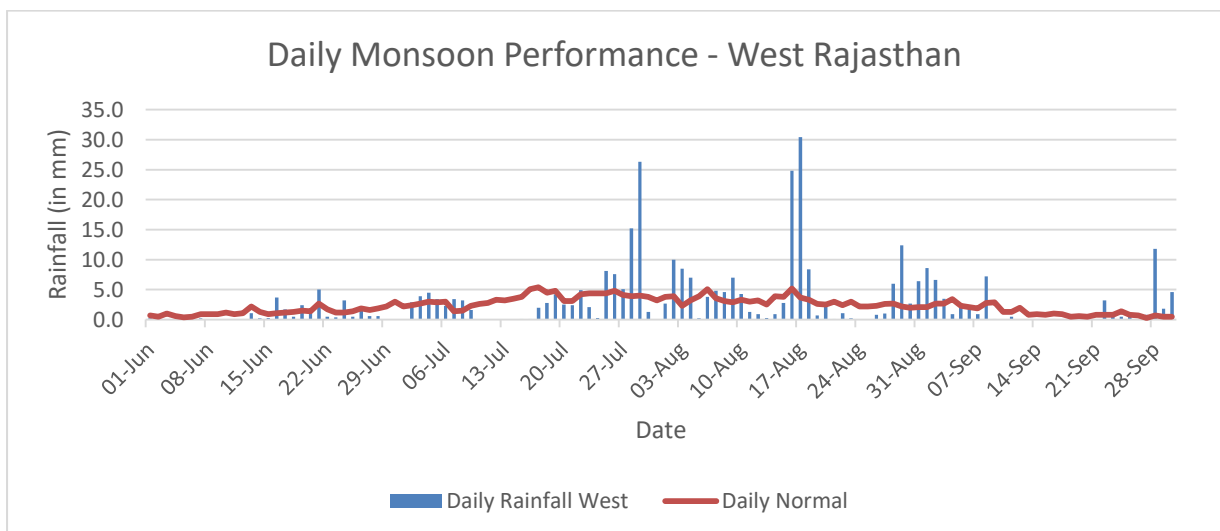


Fig. 16: Daily Rainfall – West Rajasthan

3. Chief Synoptic Features of Southwest Monsoon Season

During the season, 14 monsoon low pressure systems formed in the North Indian Ocean. Their month-wise frequency and intensity is given in the table below. The tracks of the Very Severe Cyclonic Storm and Deep Depression are shown in **Fig. 14**. The information of number of low-pressure systems formed during the season is shown in **Table 8**. This year, June & September witnessed the formation of one Very Severe Cyclonic Storm (VSCS) each, while 1 DD formed during August and 1 D during September. Though the frequency of cyclonic storms is less during the southwest monsoon period, there had been 3 more such years in the recent 30 years, viz., 1996 (2 CS in June, one each over the Bay of Bengal & the Arabian Sea), 2007 (2 in June, both over the Arabian Sea) and 2015 (1 in June over the Arabian Sea and the other in July, over the Bay of Bengal).

3.1 Very Severe Cyclonic Storm 'VAYU' over Eastcentral Arabian Sea (10-17 June 2019)

In the leading edge of the monsoon flow, a cyclonic vortex gradually concentrated into a D over Southeast Arabian Sea (AS) and adjoining Lakshadweep & Eastcentral AS in the early morning of 10th June. It gradually intensified into Cyclonic Storm 'VAYU' by late night of 10th June over eastcentral & adjoining southeast Arabian Sea. It further intensified into a VSCS by late night of 11th June over Eastcentral Arabian Sea. Skirting Saurashtra coast during 13-14 June, it started moving away from the coast, weakened into a Severe Cyclonic Storm on 16th early morning and then into a Cyclonic Storm in the night of 16th June, over north AS. Then it started recurving eastwards and gradually weakened into a D by the afternoon of 17th. It weakened further and lay as a Well Marked Low Pressure Area over Northeast Arabian Sea and adjoining Saurashtra & Kutch in the night of 17th. It further weakened into a Low Pressure Area and lay over Kutch and adjoining areas in the morning of 18th June.

This system, during its course of movement, caused adverse weather in the coastal districts of Maharashtra & Goa and Gujarat state in the form of heavy rainfall /thunderstorm activity and strong winds. The remnant of the system also caused rainfall activity over East Rajasthan, West Madhya Pradesh and Gujarat State.

3.2 Deep Depression over northwest Bay of Bengal off north Odisha-West Bengal coasts (6-9 August, 2019)

A low pressure area concentrated into a D over northwest Bay of Bengal (BoB) off north Odisha - West Bengal coasts in the morning of 6th August. It intensified into a Deep Depression over the same region in the early morning of 7th and crossed north Odisha-West Bengal coasts close to north of Balasore in the afternoon of 7th. It weakened into a D over northeast Chhattisgarh & neighbourhood in the early morning of 8th August, further into a well marked low pressure area over southeast Rajasthan & neighbourhood in the evening of 9th August and into a low pressure area over northwest Arabian Sea and neighbourhood in the evening of 12th.

This system caused fairly widespread to widespread rainfall along with very heavy rainfall over Chattisgarh, West Madhya Pradesh, Gujarat State and Madhya Maharashtra. Strengthening of the monsoon current due to this system caused fairly widespread to widespread and very heavy rainfall over Kerala, Coastal & Interior Karnataka, Konkan & Goa and over Ghat sections of Tamil Nadu.

3.3 Very Severe Cyclonic Storm 'HIKAA' over the Arabian Sea (22-25 September 2019)

A Depression formed over Eastcentral and adjoining Northeast Arabian Sea off Gujarat coast on 22nd September. Moving nearly westwards, it gradually intensified into Cyclonic Storm 'HIKAA' over Northeast and adjoining Eastcentral Arabian Sea on 23rd early morning and into a Severe Cyclonic Storm over Northeast and adjoining Northwest and Central Arabian Sea by the afternoon of the same day. Moving nearly westwards further, it rapidly intensified into a VSCS in the early morning hours of 24th over Northwest and adjoining Westcentral Arabian Sea. Moving west-southwestwards, it crossed Oman coast close to north of Duqm between 1930 and 2030 hours IST of 24th September as a VSCS. After crossing the coast, it moved westwards further and weakened rapidly.

3.4 Depression over Gulf of Kutch and adjoining areas (29 September-01 October, 2019)

A low pressure area formed over northeast Arabian Sea & adjoining coastal areas of Saurashtra & Kutch on 28th September. It concentrated into a Depression over Gulf of Kutch and neighbourhood in the evening of 29th, close to Kandla (Gujarat). It moved east-northeastwards and weakened into a well marked low pressure area over southeast Rajasthan & neighbourhood in the morning of 01st October.

3.5 Low Pressure Areas/ Well Marked Low Pressure Areas

Apart from VSCS VAYU, one more low pressure area formed in the month of June over northeast BoB during 20th -22nd June. Moving inland, it became less marked over interior Odisha and adjoining areas of Jharkhand & Chhattisgarh. The next one formed on 30th June over northwest Bay of Bengal & adjoining areas of north Odisha, West Bengal and Bangladesh. It became well marked on 1st July over the northwest Bay of Bengal and adjoining areas of West Bengal and Odisha coast. It lay as a low pressure area over central parts of Uttar Pradesh and adjoining Madhya Pradesh on 5th July and became less marked on 6th July.

The third low pressure area formed in the evening of 6th July, over western parts of Bihar and adjoining Jharkhand. It became well marked on 9th and became less marked on 11th July. The fourth low pressure area formed over northwest Bay of Bengal and adjoining coastal areas of west Bengal on 26th July. It became less marked on 27th July. Fifth low pressure area also formed over land, ie, over east Madhya Pradesh and

adjoining Chhattisgarh on 30th July. This low pressure area became less marked on 31st July.

Besides the DD in August, four more low pressure areas formed during the month. Three low pressure areas formed over Bay of Bengal during the period (12-18 Aug), (24-25 Aug) and (29-30 Aug). Out of these three low pressure areas, one became a well marked low pressure area. Fourth low pressure area formed over land (central parts of Gangetic West Bengal and Jharkhand) during (18 - 22Aug).

Apart from VSCS HIKAA and another short lived D, one more low pressure area formed in the month of September. It formed over northwest Bay of Bengal & neighbourhood on 2nd September, moved west-northwestwards upto north Madhya Pradesh before becoming in-significant on 16th September.

The number of Low Pressure System (LPS) days [low pressure areas and Depressions combined] had been 4 in June, 15 in July, 21 in August and 17 in September against a normal of 11, 14, 17 & 16 for the respective months. The total number of LPS days had been 57 as against the normal of 57 (Mohapatra, 2008). The VSCS days are not counted as their direct contribution to the rainfall had been nominal.

3.6 Upper Air Cyclonic Circulations

There were 137 upper air cyclonic circulations (in lower, mid and upper tropospheric levels) which formed during the season. The month wise distribution of these is: 36, 32, 34 & 35 during June, July, August and September respectively.

3.7 Eastward Moving Cyclonic Circulations/Western Disturbances

During the month of June, about 6 (six) western disturbances (WDs) affected northwest India during 1st & 2nd June, 3rd – 8th June, 11th – 14th June, 13th – 17th June, 23rd – 27th June and the sixth one from 29th June – 2nd July 2019. Out of these, three WDs caused fairly widespread to widespread rainfall/thunderstorms over Western Himalayan Region and isolated to scattered rainfall/thunderstorm activity over adjoining plains.

During the month of July, 4 WDs affected northwest India during 4th – 5th July, 7th – 9th July, 12th – 18th July, 25th – 30th July. Out of these, three of them caused fairly widespread to widespread rainfall/thunderstorms over Western Himalayan Region upon their interaction with the monsoon flow.

In total, there were 22 eastward moving systems as upper air cyclonic circulations and troughs. The month wise distribution is 6 in June, 5 in July, 7 in August and 4 in September.

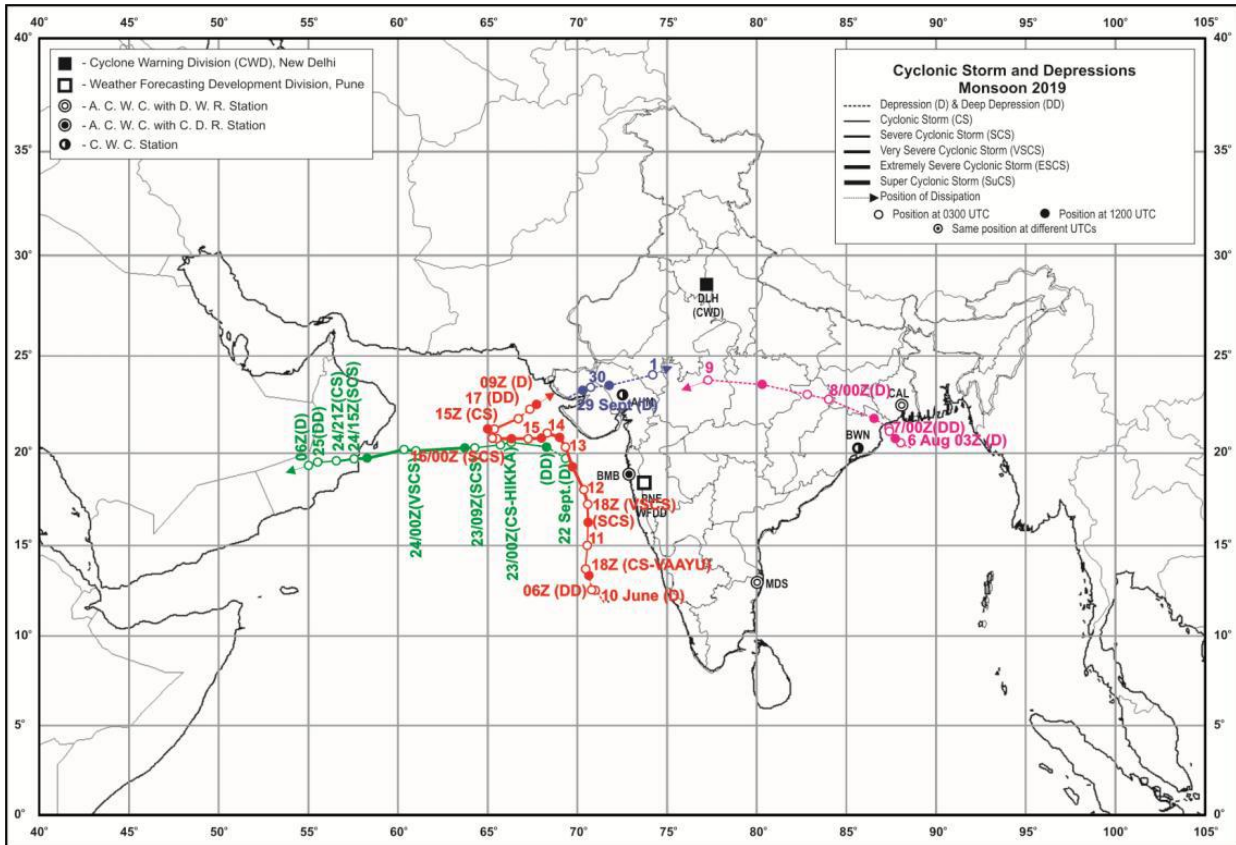


Fig. 14: Tracks of the Cyclonic Storms and Depressions formed during Monsoon 2019

Table 8: Number of Low-pressure Area (LOPAR), Well Marked Low (WML), Depression (D), Deep Depression (DD) and Very Severe Cyclonic Storm (VSCS) in monsoon 2019.

Systems/ Month	VSCS	DD	D	WML	LOPAR	Total Systems
June	1	0	0	0	1	2
July	0	0	0	1	3	4
August	0	1	0	1	3	5
September	1	0	1	0	1	3

4. Withdrawal of Southwest Monsoon 2019

Due to the prevalence of an active Inter Tropical Convergence Zone, across central India, north Indian Ocean, extending upto western north Pacific Ocean, the withdrawal of southwest monsoon was delayed upto the 1st week of October. Anti-cyclonic circulation in lower levels over Rajasthan could only be established after 05th October. This led to the most delayed commencement of withdrawal since 1961.

Against normal date of withdrawal of SWM 01st September, the Monsoon Withdrawal commenced only on 09th October. In 1961, it was 01st October followed by 30th September in 2007.

It withdrew from some parts of Haryana, Punjab and north Rajasthan on 09th October. With the increase in dominance of mid-latitude circulation regime over the northern half of India and consequent reduction in moisture led to further withdrawal of southwest monsoon from entire Northwest India, some parts of West Bengal, Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Gujarat and north Arabian Sea during 10th - 12th October; from entire north Bay of Bengal, some parts of central Bay of Bengal, entire Odisha, Chhattisgarh, some parts of Coastal Andhra Pradesh, some parts of Telangana, most parts of Maharashtra, some parts of North Interior Karnataka, entire north Arabian Sea and some parts of central Arabian Sea during 13th-15th October. Thus in a rapid phase, the Southwest Monsoon withdrew from the entire country, giving way to simultaneous commencement of northeast monsoon rains on 16th October, 2019. The withdrawal dates of the 2019 Southwest Monsoon are illustrated in **Fig.15**.

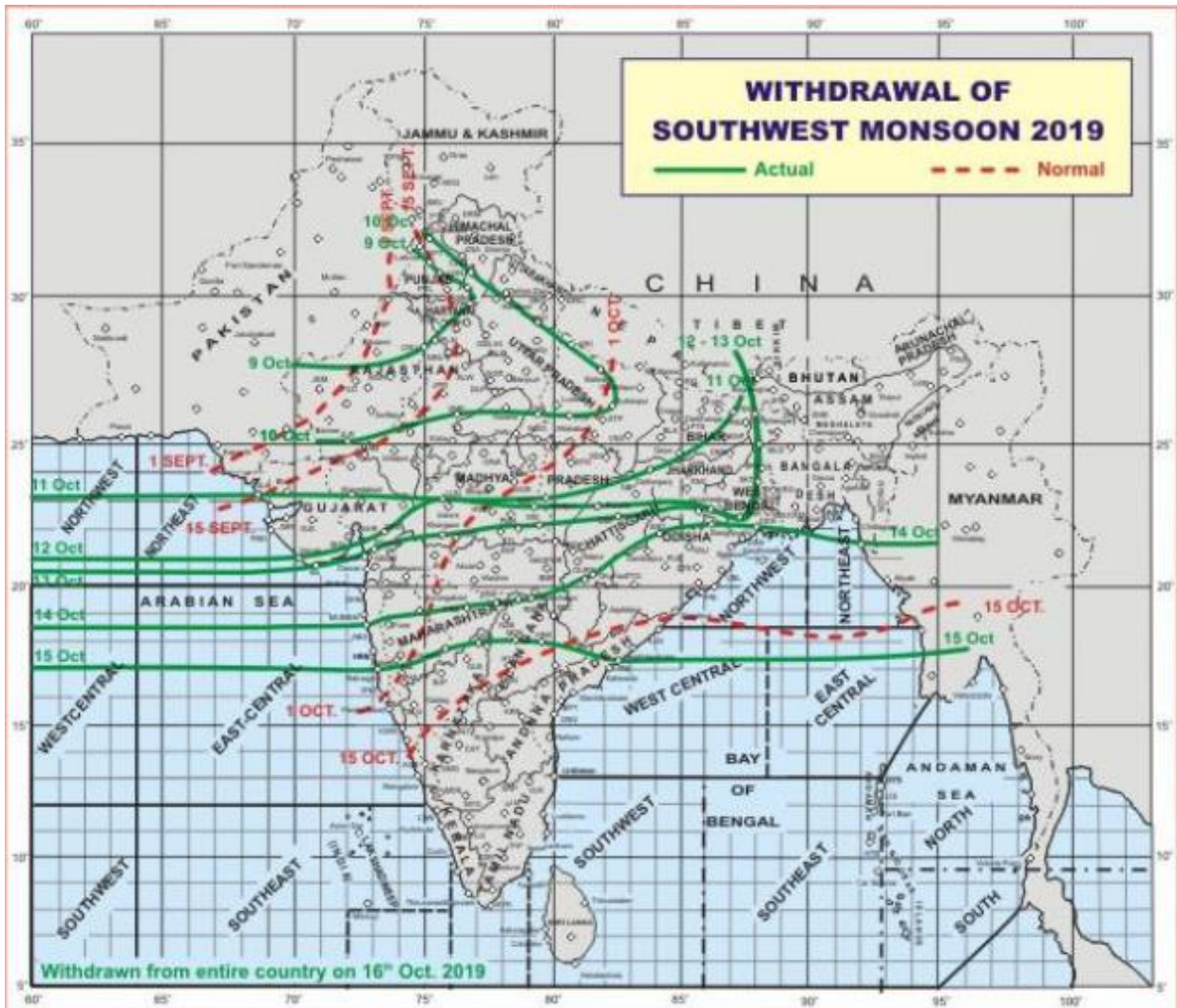


Fig. 15: Isochrones of advance of the Southwest monsoon during 2019

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