



**INDIA METEOROLOGICAL DEPARTMENT  
(MINISTRY OF EARTH SCIENCES)  
SOUTHWEST MONSOON-2016  
END OF SEASON REPORT  
FOR  
UTTARAKHAND STATE  
HIGHLIGHTS**

- For the state as a whole, the rainfall for the season (June-September) was 90% of its long period average (LPA) and thus categorized as a normal monsoon.
- Monthly rainfall over Uttarakhand as a whole was 104% of LPA in June, 119% of LPA in July, 72% of LPA in August and 54% of LPA in September respectively.
- Out of the total 13 districts of Uttarakhand 02 districts received excess seasonal rainfall, 06 districts received normal seasonal rainfall and 05 districts received deficient seasonal rainfall.
- Monsoon current advanced over Uttarakhand on 21<sup>st</sup> June 2016 about 1 day earlier than its normal date of 22<sup>nd</sup> June and covered the entire State on the same day.
- The monsoon activity over Uttarakhand was mostly weak/subdued during the later half of August and the September.
- Withdrawal of monsoon from Uttarakhand commenced on 8<sup>th</sup> October and it withdrew from the entire State on 12<sup>th</sup> October.

### 1. ONSET OF SOUTHWEST MONSOON – 2016

The southwest (SW) monsoon 2016 set in over Kerala on 8<sup>th</sup> June, 7 days later than its normal date of 1<sup>st</sup> June. The SW monsoon also advanced into entire south Arabian Sea, entire Lakshadweep area, most parts of Kerala and Tamil Nadu, entire south Bay of Bengal, some parts of west central and east central Bay of Bengal on the same day. The SW monsoon advanced further northwards and covered the most parts of the country by 20<sup>th</sup> June. On 21<sup>st</sup> June it further advanced over Uttarakhand and the Northern Limit of Monsoon (NLM) passed through Dahanu, Ratlam, Jhansi, Lucknow, Pantnagar, Dehradun, Una and Jammu. After a brief hiatus during the last week of June, monsoon advanced further very rapidly to cover most parts of the country, outside some areas of Kutch and west Rajasthan by 5<sup>th</sup> July. The monsoon covered the entire country on 13<sup>th</sup> July in association with the formation of an east west shear zone at mid-tropospheric levels and its northward shifting to the north of Lat. 20° N.

The isochrones of advance of SW monsoon over the country are shown in Fig.1.

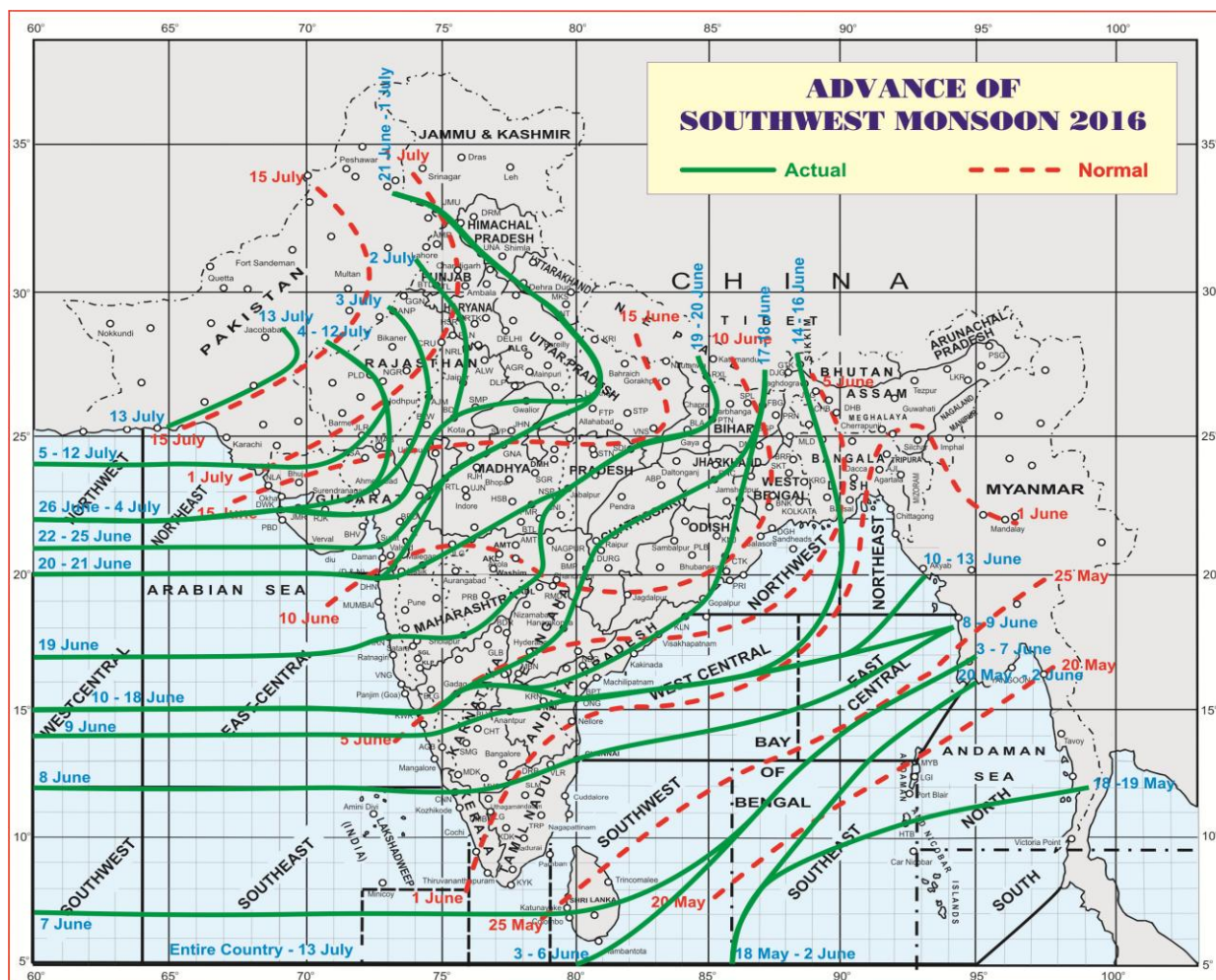


Fig.1 Isochrones of advance of SW Monsoon 2016



## 2. CHIEF SYNOPTIC FEATURES OF SW MONSOON - 2016:

The monsoon current advanced over Uttarakhand on 21<sup>st</sup> June with fairly widespread rainfall activity over the state. The advance of South West monsoon over Uttarakhand was associated with the movement of an upper air cyclonic circulation over west Uttar Pradesh & neighbourhood between 1.5 & 5.8 km above mean sea level and the trough at mean sea level from north Rajasthan to Manipur across Uttar Pradesh on 21<sup>st</sup> June. The western end of the trough at mean sea level gradually shifted northwards and eastern end shifted southwards over Bay of Bengal. The trough ran from Punjab to east central Bay of Bengal on 26<sup>th</sup> June across Haryana, north Madhya Pradesh and center of low pressure area over west central and adjoining northwest Bay of Bengal off north Andhra Pradesh and south Odisha coasts and the trough remained practically stationary till 2<sup>nd</sup> July. The trough shifted southwards on 3<sup>rd</sup> July and remained near normal position till 15<sup>th</sup> July. The western end of the axis of monsoon trough shifted northwards on 16<sup>th</sup> and it passed through Amritsar, Meerut, Sultanpur, Patna, Malda and thence southeastwards to northeast Bay of Bengal. The western end of the monsoon trough continued to remain closed to foothills or north of its normal position till 23<sup>rd</sup> July causing above normal rainfall during the week ending on 23<sup>rd</sup> July. The western end of the axis of monsoon trough shifted southwards to normal position on 24<sup>th</sup> July. The axis of the monsoon trough remained near normal position or the south of the normal position on most of the days till 13<sup>th</sup> August. The western end of the axis of monsoon trough shifted northwards and remained close to foothills until 19<sup>th</sup> August and the eastern end continued to remain near normal position. The western end of monsoon trough shifted southwards to its normal position on 20<sup>th</sup> and further southwards from 21<sup>st</sup> August till 1<sup>st</sup> September and the eastern end remained near normal position till 29<sup>th</sup> August and subsequently shifted northwards over north eastern states. From 2<sup>nd</sup> September till the commencement of the withdrawal of the monsoon (13<sup>th</sup> September) from the country, the monsoon trough remained close to the foothills of Himalayas causing subdued rainfall activities over Uttarakhand.

During SW monsoon season 2016 a total of 20 Western Disturbances (WD) passed over Western Himalayan region. These passing WDs when interacted with monsoon trough caused enhancement in rainfall activities over Uttarakhand. After the onset of monsoon over Uttarakhand, first WD passed through the northern parts of the country during 26<sup>th</sup> to 30<sup>th</sup> June. Afterwards, a fresh western disturbance moved as a trough in mid-tropospheric westerlies along longitude 60.0°E and north of latitude 30.0°N on 30<sup>th</sup> June and it crossed the country by 6<sup>th</sup> July causing active monsoon with widespread rainfall on most of the days over the state. Around 3 to 4 WD passed through the northern parts of the country during 6<sup>th</sup> to 15<sup>th</sup> July however the monsoon remained weak on most of the days over the state. A fresh WD moved as a trough in mid-tropospheric westerlies along Longitude 64°E and north of Latitude 32°N on 14<sup>th</sup> July and passed through the northern parts of the country from 16<sup>th</sup> to 18<sup>th</sup> July followed by the movement of another fresh western disturbance as a trough in mid-tropospheric westerlies along Longitude 64° E and north of Latitude 30° N on 18<sup>th</sup> July. Also, an upper air cyclonic circulation laid over central parts of Uttar Pradesh & neighbourhood extending up to mid-tropospheric levels on 16<sup>th</sup> and 17<sup>th</sup> July and it laid over Sub-Himalayan West Bengal & Sikkim and neighbourhood extending upto 3.1 km above mean sea level on 18<sup>th</sup> July. During 16<sup>th</sup> to 18<sup>th</sup> July, the WDs interacted with the monsoon trough with its western end north of its mean position and the upper air cyclonic circulation extending up to mid-tropospheric levels over central parts of Uttar Pradesh & neighbourhood and caused active to vigorous monsoon activities over Uttarakhand. From 20<sup>th</sup> July to 24<sup>th</sup> August monsoon activities remained normal over the state. Towards the end of August(after 24<sup>th</sup>) and during September monsoon activity remained subdued over Uttarakhand due to the shifting of MT very close to foothills or almost over the western Himalayan region on most of the occasions and thus cutting normal southeasterly wind flow over Uttarakhand from the Bay of Bengal. Moreover, the movement of most of the Lows and Depressions and their remnant remained south of normal position of the monsoon trough.

## 3. WITHDRAWAL OF SOUTHWEST MONSOON:

The rainfall activity was very weak/ subdued in Uttarakhand during the later half of August and the September. The withdrawal of SW monsoon commenced on 15<sup>th</sup> September from west Rajasthan with a change in the lower tropospheric circulation pattern. The change in the wind flow pattern over Uttarakhand from southeasterly to northwesterly and the development of anti-cyclonic circulation over west Rajasthan in lower levels made conditions favorable for the withdrawal of southwest monsoon from Uttarakhand. Consequently, SW monsoon withdrew from most parts of Uttarakhand on 8<sup>th</sup> October and it withdrew from the entire State on 12<sup>th</sup> October. Fig.3 shows the isochrones of withdrawal of SW Monsoon 2016.

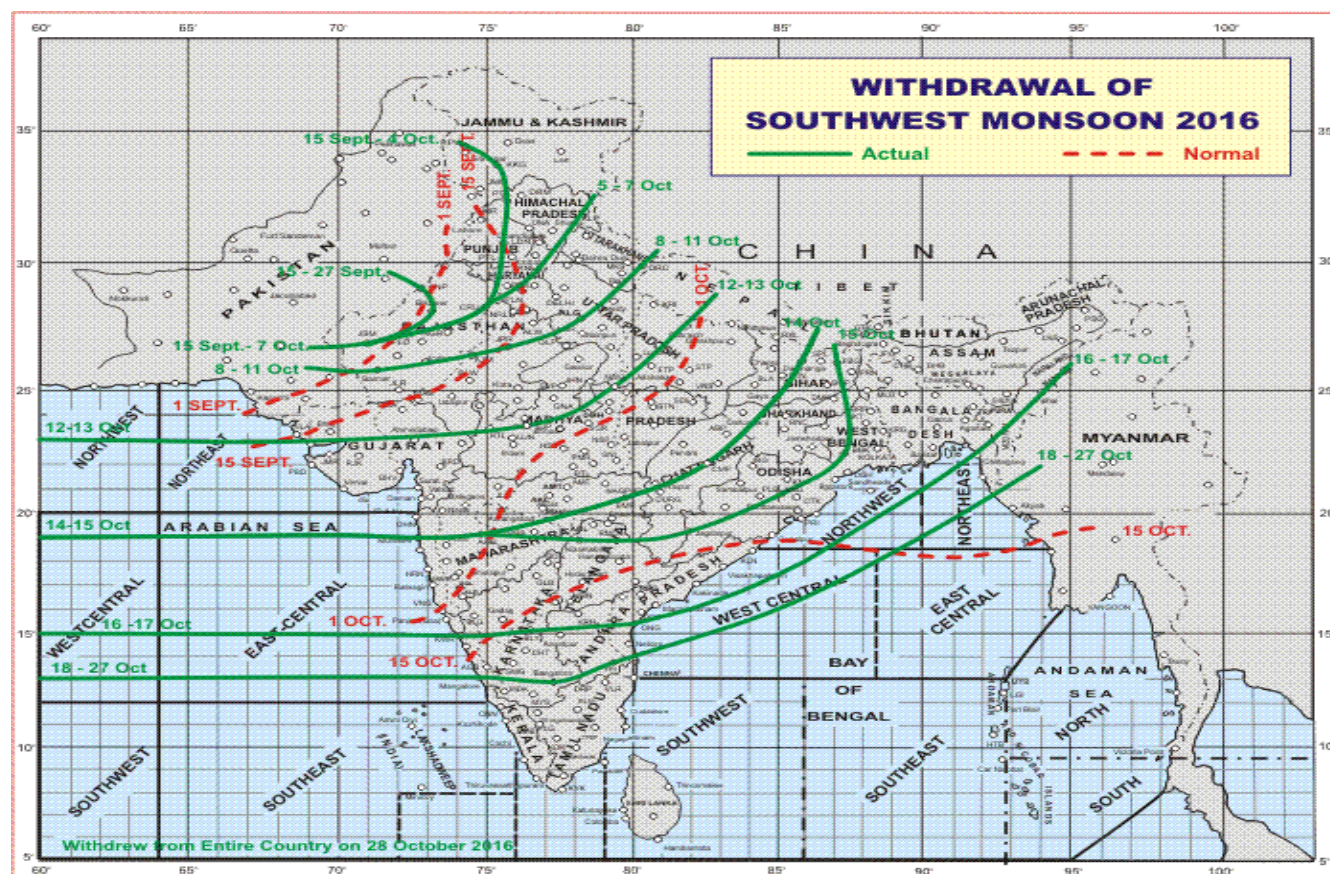


Fig.3: Isochrones of withdrawal of Monsoon 2016

#### 4. RAINFALL DISTRIBUTION OVER UTTARAKHAND DURING MONSOON – 2016:

The rainfall during SW monsoon season (June to September) for the State as a whole is as follows:

Met. Sub-division/ State	Actual Rainfall June-September (in mm)	Normal/Long Period Average Rainfall June-September (in mm)	Departure from normal (in %)
Uttarakhand	1102.7	1229.2	-10

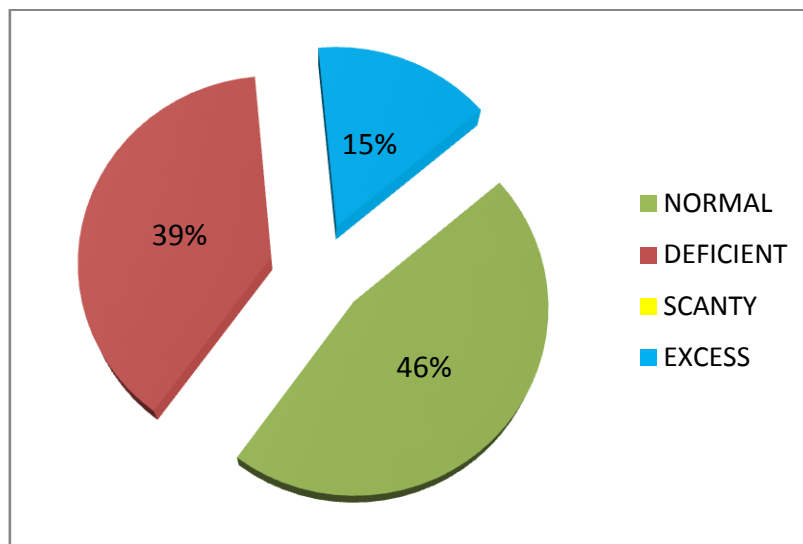


Fig. 4 Rainfall Distribution over the area of Uttarakhand

As seen in the table above, the seasonal rainfall over Uttarakhand State/ sub-division as a whole was 90% of its LPA. The seasonal rainfall intensity distribution over the State was in the categories of excess, normal and deficient. Out of 13 districts of Uttarakhand 02 districts received excess, 06 districts received normal and 05 districts received deficient seasonal rainfall. In terms of area 15% area received excess, 46% area received normal and 39% area received deficient rainfall. In totality, the monsoon rainfall was normal (-10%) over the state.

#### 5. INTENSITY DISTRIBUTION OF RAINFALL DURING MONSOON-2016 OVER UTTARAKHAND:

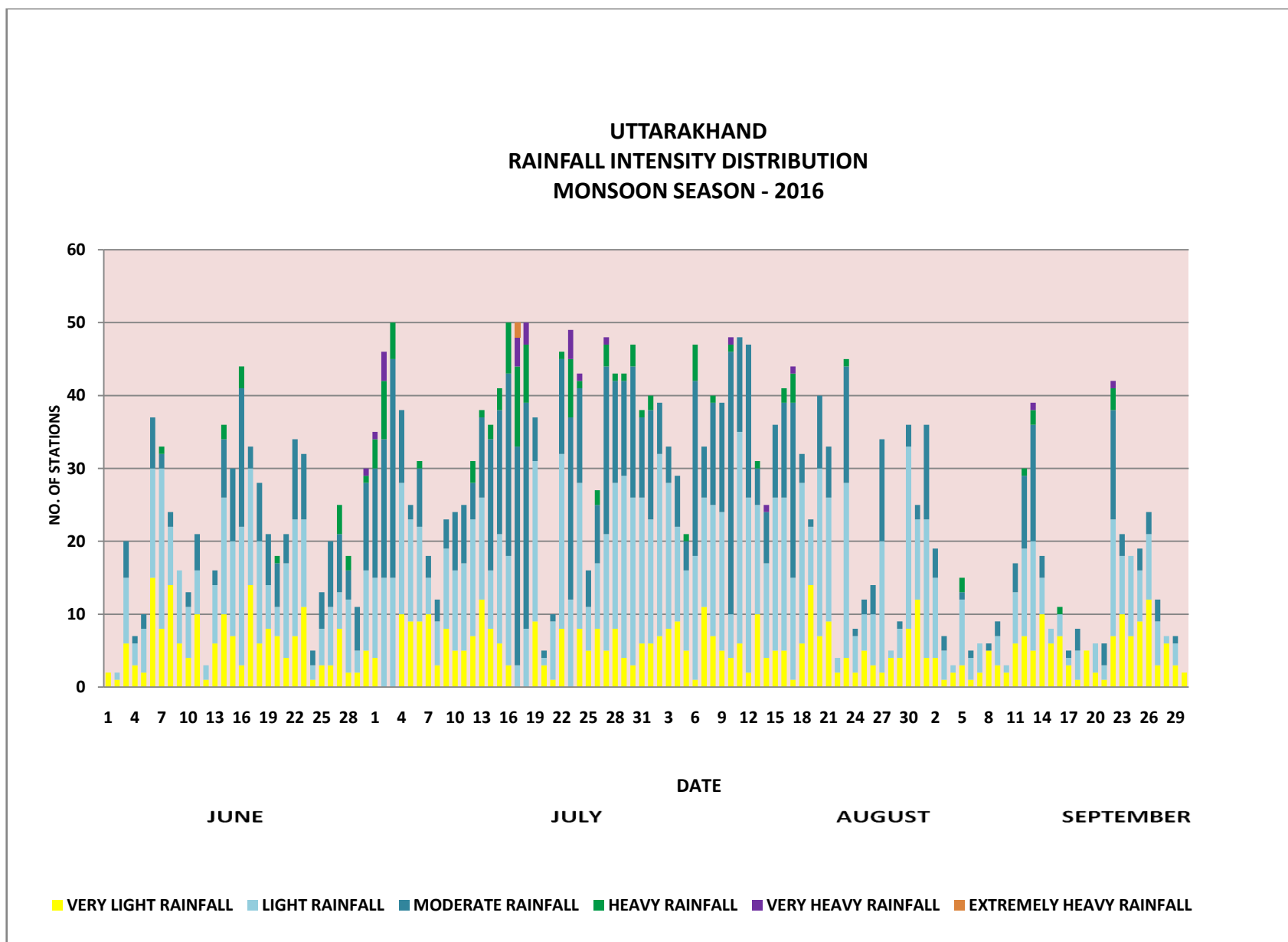


Fig. 5 Rainfall Intensity Distribution

## 6. MONTHLY DISTRIBUTION OF RAINFALL OVER THE STATE:

The monthly rainfall distribution of the state is given in a table below:

Met. Sub-division/ State	Month	Actual Rainfall (in mm)	Normal or Long period average (LPA) ( in mm)	Departure from normal (in %)
Uttarakhand	June-2016	174.4	167.8	04
	July- 2016	508.4	428.1	19
	August- 2016	308.5	426.2	-28
	September-2016	111.4	207.1	-46

From the above table, the monthly rainfall was normal over the state during June & July and deficient in August & September. The June rainfall was 104%, July 119%, August 72% and September 54% of their respective monthly LPAs. The amount of rainfall (in terms of % of LPA) was maximum in July and minimum in September. This year 15% area of Uttarakhand received excess, 46% area received normal and 39% area received deficient rainfall. In this way, the performance of monsoon 2016 was normal over the State.

## 7. WEEKLY RAINFALL DISTRIBUTION:

Weekly rainfall distribution and departure over Uttarakhand Meteorological sub-divisions is shown in Fig. 6 and Fig. 7 below respectively:

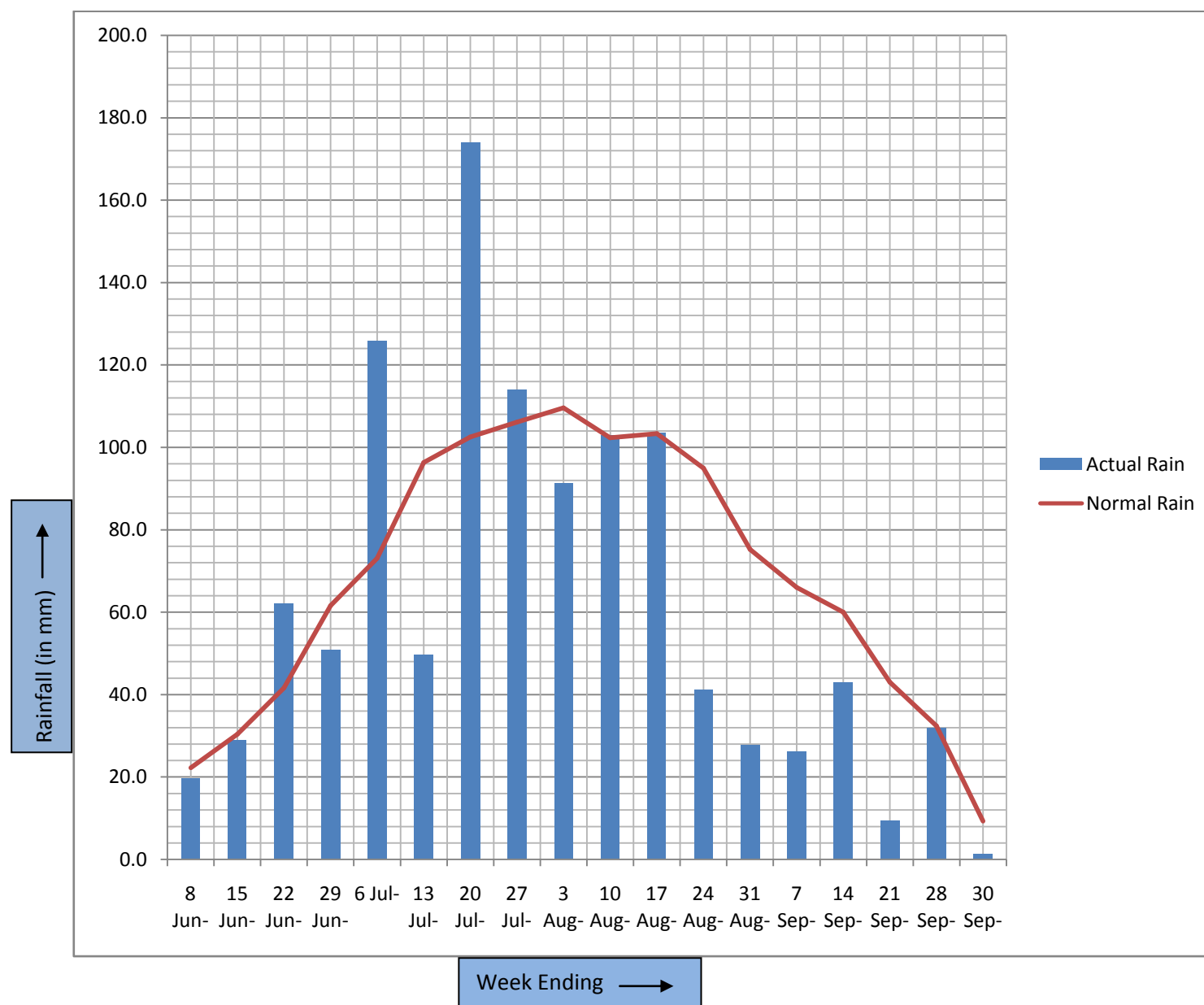


Fig.6: Weekly Monsoon Rainfall-2016 over Uttarakhand

The weekly monsoon rainfall was more than normal over the State on 5 occasions, 1 in June, 3 in July and 1 in August, normal on 1 occasion in August and it was less than normal on other weeks. In terms of percentage departure from normal, the weekly rainfall was excess ( $\geq 20\%$ ) during 3 weeks, normal (-19% to +19%) during 8 weeks, deficient (-20% to -59%) during 3 weeks and scanty (-60% to -99%) during 4 weeks. Thus, week by week monsoon rainfall performance was average.

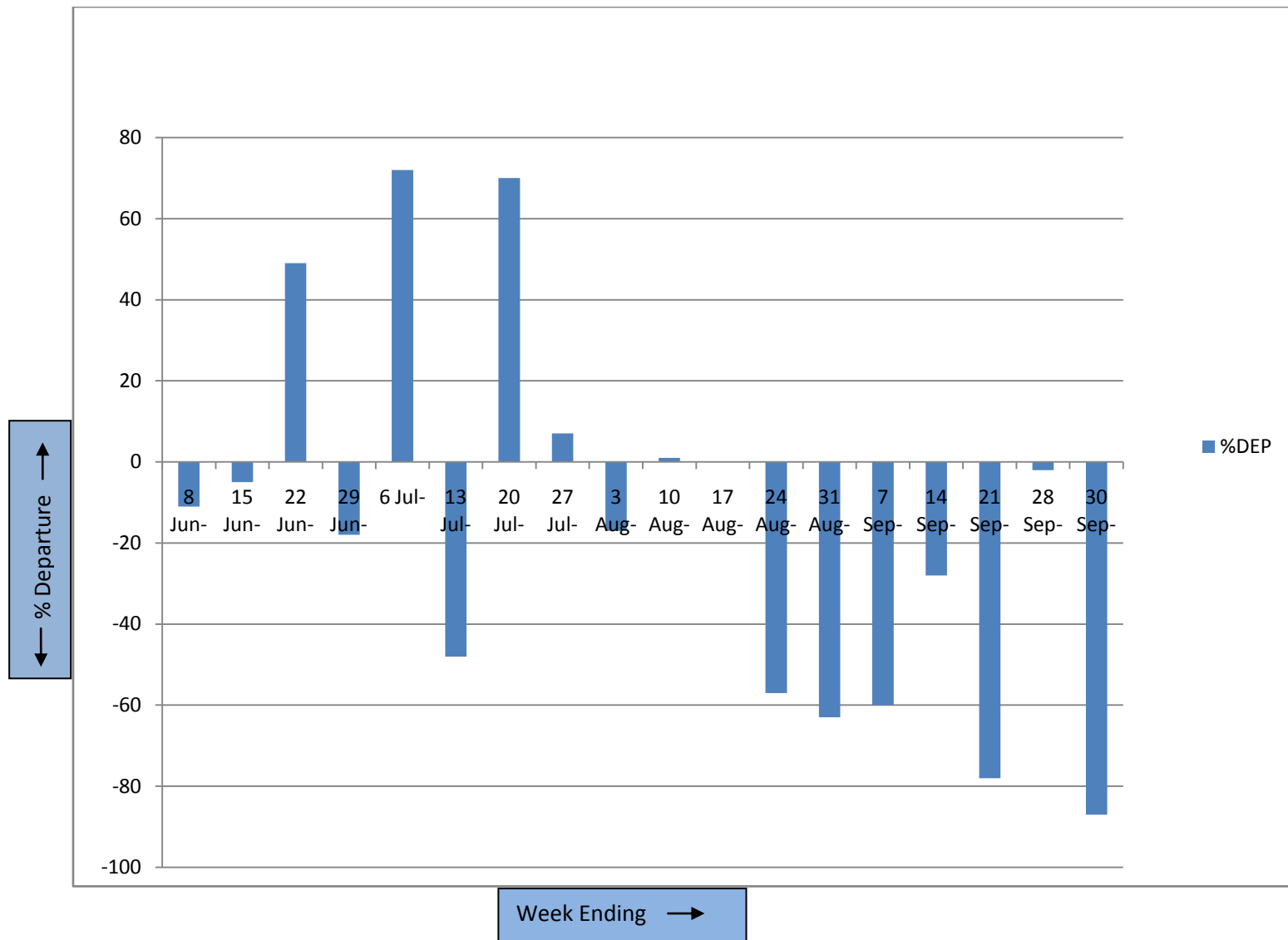


Fig.7 Weekly departure of the Monsoon Rainfall 2016 over Uttarakhand

### 8. DISTRICT-WISE SPATIAL DISTRIBUTION OF RAINFALL MONSOON 2016

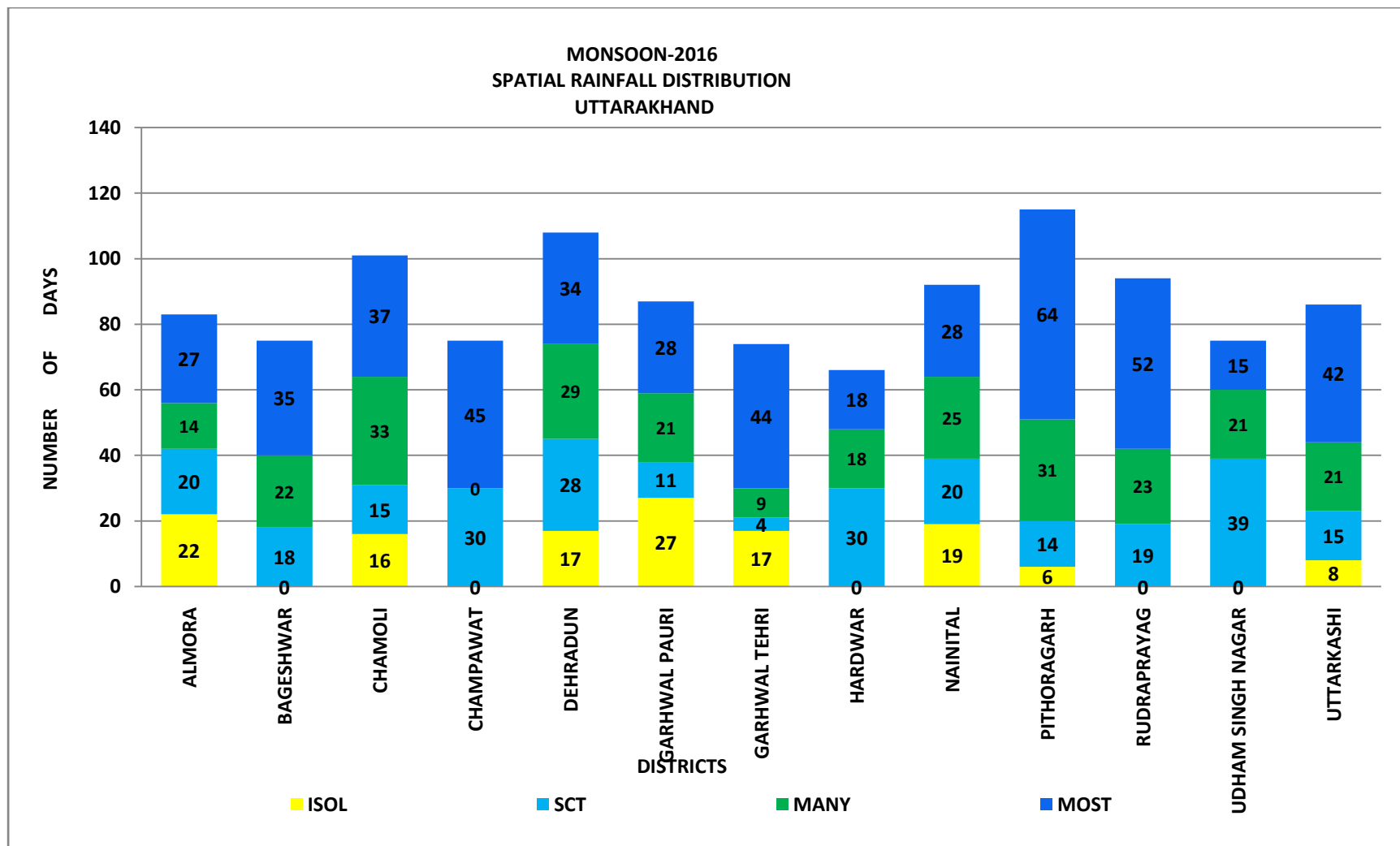


Fig.8 District wise Spatial Distribution of Rainfall during monsoon 2016 over Uttarakhand

The maximum number of rainfall days was over Pithoragarh district (115 days) and minimum rainfall days were over Hardwar district (66 days). Widespread to fairly widespread rainfall occurred on 50 days or more (maximum) in Bageshwar, Chamoli, Dehradun, Nainital, Pithoragarh, Rudraprayag, Tehri and Uttarkashi districts and 36 days (minimum) over Hardwar and Udham Singh Nagar districts.



## 9. DISTRICT-WISE HEAVY RAINFALL DISTRIBUTION MONSOON 2016

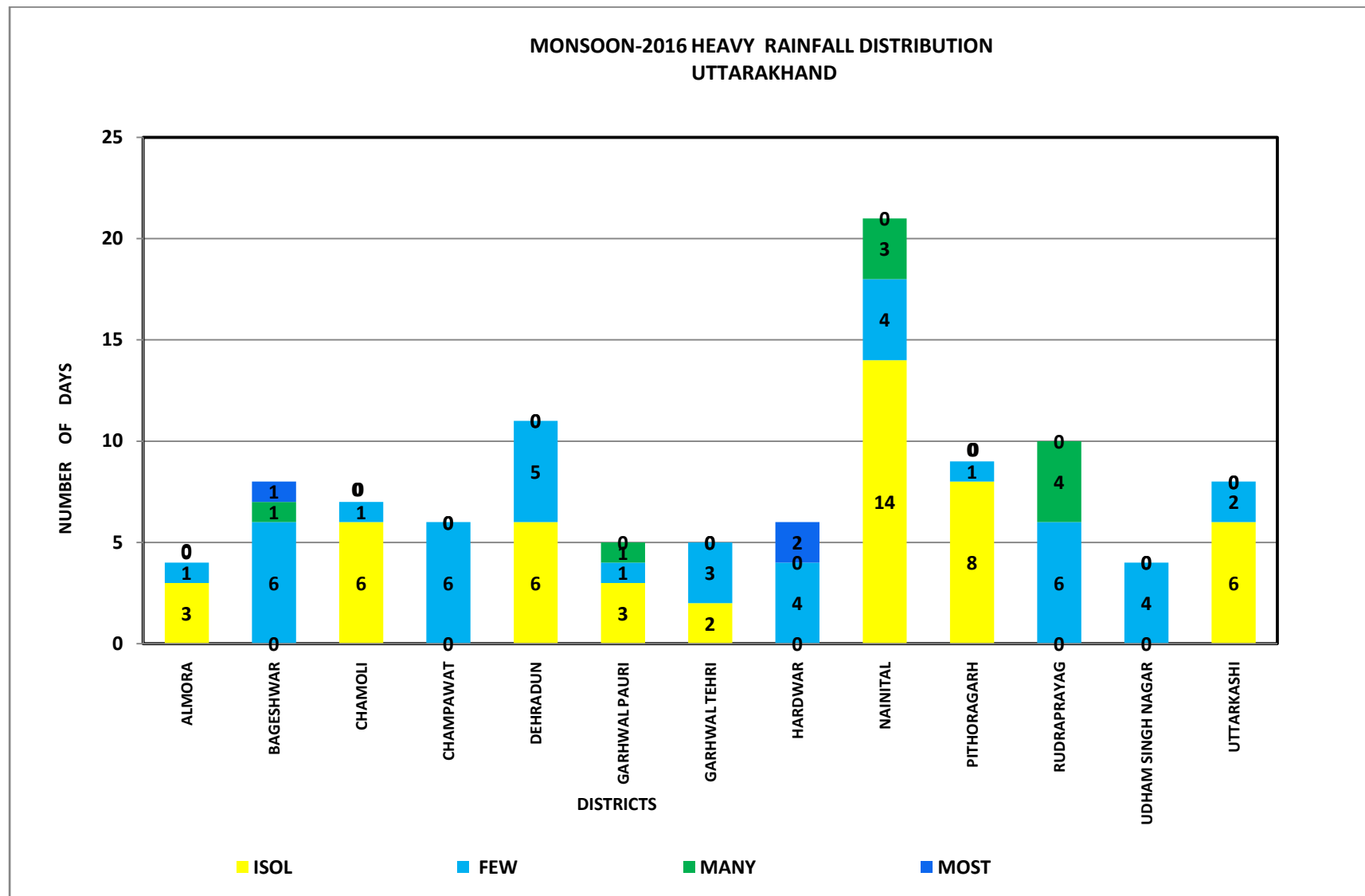


Fig.9 District wise Heavy Rainfall distribution during monsoon 2016 over Uttarakhand

The maximum number of heavy rainfall days was over Nainital district (21 days) and minimum over Almora and Udham Singh Nagar districts (4 days each).

## 10. DISTRICTS WISE RAINFALL DISTRIBUTION (JUNE-SEPTEMBER) 2016:

The following table shows the district wise rainfall distribution for Uttarakhand:

Serial No	State/ Districts	Actual Rainfall June-September (in mm)	Normal/ Long period average (LPA) June-September (in mm)	Departure from normal (in %)
1.	Almora	861.3	858.4	0
2.	Bageshwar	1096.5	858.4	28
3.	Chamoli	1197.5	859.3	39
4.	Champawat	1158.5	1319.7	-12
5.	Dehradun	1194.9	1802.1	-34
6.	Garhwal Pauri	901.9	1213.5	-26
7.	Garhwal Tehri	752.4	1047.1	-28
8.	Hardwar	1000.1	961.9	4
9.	Nainital	1544.5	1439.1	7
10.	Pithoragarh	1262.7	1687.9	-25
11.	Rudraprayag	1660.5	1671.1	-1
12.	Udham Singh Nagar	643.3	1119.9	-43
13.	Uttarkashi	1006	1148.6	-12

From the above table, it is clear that the rainfall distribution was uneven over the State. Out of 13 districts, 5 districts viz. Dehradun, Garhwal Pauri, Garhwal Tehri, Pithoragarh and Udham Singh Nagar received the deficient, 6 districts viz. Almora, Champawat, Hardwar, Nainital and Uttarkashi received the normal and 2 districts viz. Bageshwar and Chamoli received excess rainfall in varying intensity. The actual rainfall of the season was maximum over Rudraprayag (1660.5 mm) and minimum over Udham Singh Nagar (643.3 mm) districts. However, in terms of % of the normal rainfall/ LPA, Chamoli district received the

maximum 139% and Udham Singh Nagar minimum 57%. Thus, monsoon 2016 has been a normal (-10%) monsoon year for Uttarakhand.

### 11. Monthly district-wise rainfall (in mm) over Uttarakhand during Monsoon Season-2016

S.N.	State/ Districts	June (in mm)	Departure June	July (in mm)	Departure July	Aug (in mm)	Departure Aug	Sept (in mm)	Departure Sept
1	Almora	126.4	-4	425.5	42	231.6	-16	77.9	-48
2	Bageshwar	196.5	49	573.1	91	261.6	-6	65.3	-56
3	Chamoli	229.9	111	442.3	53	369.4	12	156	18
4	Champawat	160.6	-25	606.4	30	225	-45	166.5	-29
5	Dehradun	182.8	-1	542.9	-21	303.3	-55	166	-36
6	Garhwal Pauri	86.4	-30	489.2	8	242.9	-45	83.5	-57
7	Garhwal Tehri	80.6	-41	415	12	225.5	-39	31.4	-82
8	Hardwar	134.7	27	573.7	73	216.5	-41	75.3	-52
9	Nainital	224.7	10	714.8	39	407.1	-11	197.9	-24
10	Pithoragarh	235.8	-21	556.2	0	325.8	-40	144.9	-51
11	Rudraprayag	275.8	27	696.7	21	551.9	-14	136.1	-42
12	Udham Singh Nagar	97.7	-34	346.3	-14	116.8	-68	82.5	-60
13	Uttarkashi	166.5	13	430.9	13	354.6	-12	54	-75

### 12. Weekly district-wise rainfall (in mm) over Uttarakhand during Monsoon Season-2016

Week Ending	8 Jun-	15 Jun-	22 Jun-	29 Jun-	6 Jul-	13 Jul-	20 Jul-	27 Jul-	3 Aug-	10 Aug-	17 Aug-	24 Aug-	31 Aug-	7 Sep-	14 Sep-	21 Sep-	28 Sep-	30 Sep-
ALMORA	10.3	11.0	72.3	32.9	120.6	16.0	205.7	35.9	59.7	84.0	83.6	37.5	14.2	5.2	23.8	1.2	47.3	0.8
BAGESHWAR	25.8	37.3	81.7	45.8	149.8	76.3	166.7	137.0	71.2	98.2	85.5	32.4	23.5	13.5	20.3	0.0	31.5	0.0
CHAMOLI	18.2	22.0	88.6	95.2	109.2	61.7	172.9	56.6	67.0	146.7	133.1	29.7	40.9	34.9	72.9	9.9	34.7	3.7
CHAMPAWAT	10.7	19.7	67.8	43.9	189.5	56.9	97.2	192.5	123.3	103.8	75.7	9.5	1.5	0.0	77.5	0.0	89.0	0.0
DEHRADUN	24.3	28.2	50.9	27.4	171.9	29.7	199.9	114.7	111.1	96.0	118.6	38.3	17.9	103.7	20.3	11.7	30.3	0.8
GARHWAL PAURI	7.3	19.9	43.9	15.1	99.6	22.8	110.3	166.3	119.6	72.6	68.2	49.8	23.2	30.6	32.6	3.8	16.6	0.0
GARHWAL TEHRI	4.0	22.5	38.3	3.9	85.3	6.1	130.5	164.1	62.0	100.6	51.6	35.6	16.5	9.0	21.1	0.2	1.1	0.0
HARIDWAR	44.0	15.1	75.3	0.3	74.4	23.4	332.3	125.6	30.5	62.8	72.9	61.1	7.2	19.3	12.3	0.1	37.9	5.7
NAINITAL	19.5	73.7	89.4	36.9	217.4	75.7	290.2	70.2	122.2	69.6	212.7	56.0	13.5	19.0	118.2	23.9	36.7	1.2
PITHORAGARH	21.0	42.3	62.9	82.6	155.0	77.0	178.5	109.6	101.6	127.7	90.7	36.5	32.1	21.8	53.9	28.1	39.7	1.4
RUDRAPRAYAG	75.7	28.1	52.8	93.7	159.4	36.1	247	194.8	146.3	181.8	175.7	72.4	60.6	32.8	66.2	0.7	36.4	0.1
U.S NAGAR	32.1	16.3	29.5	18.9	88.8	32.4	66.4	123.7	54.2	18.9	59.9	13.1	6.4	15.6	31.2	2.3	33.1	0.7
UTTARKASHI	11.1	21.7	47.9	69.5	82.0	67.3	136	113.3	101.7	111.4	89.6	51.8	48.9	22.8	0.1	6.9	24.2	0.3

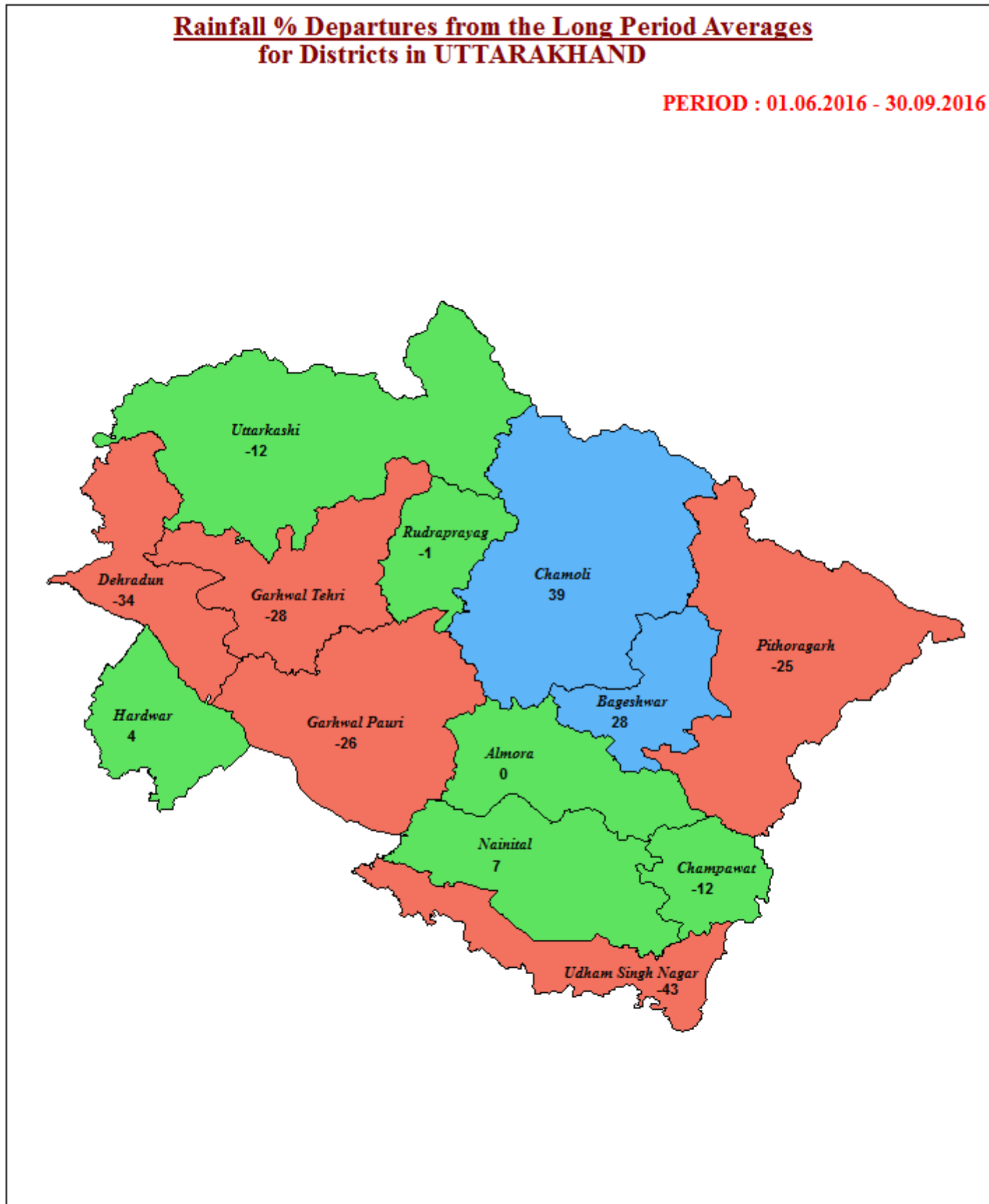


13. Rainfall Map of Monsoon-2016 of different Districts of Uttarakhand Met Sub-division:

**INDIA METEOROLOGICAL DEPARTMENT**  
**MC DEHRADUN**

**Rainfall % Departures from the Long Period Averages**  
**for Districts in UTTARAKHAND**

**PERIOD : 01.06.2016 - 30.09.2016**



**LEGEND:** ■ EXCESS (+20% OR MORE) ■ NORMAL (+19% TO -19%) ■ DEFICIENT (-20% TO -59%)  
■ SCANTY (-60% TO -99%) ■ NO RAIN (-100%)  NO DATA

**NOTE:** Percentage Departures of Rainfall are based on operational data.