Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)

India Meteorological Department

2017 Southwest Monsoon End of Season Report

HIGHLIGHTS

- The rainfall over the country as a whole during the monsoon season (June – September) was 95% of its long period average (LPA).
- Seasonal rainfall over Northwest India, Central India, south Peninsula and Northeast (NE) India were recorded at 90%, 94%, 100% and 96% of respective LPAs.
- Out of the total 36 meteorological subdivisions, 25 subdivisions constituting 65% of the total area of the country received normal seasonal rainfall, 5 subdivisions received excess rainfall (18% of the total area), and 6 subdivisions (17% of the total area) received deficient seasonal rainfall.
- Monthly rainfall over the country realized as a whole was 104% of LPA in June, 102% of LPA in July, 87% of LPA in August, and 88% of LPA in September.
- Southwest monsoon reached parts of southeast Bay of Bengal, south Andaman Sea and Nicobar Islands on 14th May (6 days ahead of its normal date). It advanced over Kerala on 30th May (2 days ahead of the normal schedule) and covered the entire country by 19th July (4 days later than the normal date).
- Monsoon withdrawal was delayed and commenced from parts of northwest India on 27th September (with a delay of nearly 3 weeks). It withdrew from some more parts of northwest India on 30th September. As on 11th October, the monsoon has withdrawn from most parts of northwest India except east Uttar Pradesh.
- During the season, 14 low pressure systems (1 Deep Depression, 2 Depressions, 6 well marked low pressure areas & 5 low pressure areas) formed against an average of 6 Depressions & 8 low pressure areas.
- The forecast for monsoon onset over Kerala for this year was very accurate, as both the forecasted and realized date of onset of monsoon over Kerala was 30th May.
- The forecasts for the seasonal rainfall over country as whole and the four broad geographical regions and the forecast for July rainfall over the country as whole were within the forecast range. However, the forecasts for the rainfall during the second half of the monsoon season and the August rainfall were found to be overestimated to the observed rainfall.

1. Onset and Advance of southwest Monsoon

The heating of land mass and moisture availability in the lower troposphere led to convection over major parts of India during the first week of May. Later the Madden Julian Oscillation (MJO) also strengthened and propagated eastwards across the Indian Ocean since 13th May and thus enhanced the convection over the Andaman region. With the formation of a cyclonic circulation over Andaman Sea, southwesterlies crossing the equator strengthened and deepened leading to persistent cloudiness and rainfall over the region. This resulted into advance of Southwest monsoon (SWM) into some parts of southeast Bay of Bengal, Nicobar Islands, entire south Andaman Sea and parts of north Andaman Sea on 14th May. It further advanced into some parts of southwest Bay of Bengal, some more parts of southeast Bay of Bengal and north Andaman Sea and remaining parts of Andaman & Nicobar Islands on 16th May and further into parts of southeast and east central Bay of Bengal and remaining parts of north Andaman Sea on 18th May.

However, the predominance of mid-latitude westerlies and sub-tropical ridge during the third week of May caused a hiatus in the further advance of monsoon for 6 days. Towards the end of the month, propagation and strengthening of MJO made conducive conditions for the genesis of Severe Cyclonic Storm (SCS) **'Mora'** over the Bay of Bengal during 28th -31st May. In association with its genesis phase, further advance of SWM took place into southern parts of Comorin area and some more parts of southwest, southeast and east central Bay of Bengal on 26th and into some parts of south Arabian Sea, Maldives, Comorin area and some more parts of southwest, southeast and east central Bay of Bengal on 29th May. The SWM advanced over Kerala on 30th May. It further advanced into some more parts of northeast Bay of Bengal, remaining parts of Arunachal Pradesh, Nagaland, Manipur, Mizoram and most parts of Tripura and Assam & Meghalaya on 2nd June. Subsequently there was a hiatus in the advancement due to the weakening of the monsoon flow over the Arabian Sea upto 5th June. Later on, the formation of a cyclonic circulation over Madhya Maharashtra and neighbourhood and the formation of a low pressure area over west central Arabian Sea on 6th June revitalized the monsoon current. It led to advance of monsoon over remaining parts of south Arabian Sea, Lakshadweep area, most parts of Kerala and some more parts of Tamil Nadu and southwest Bay of Bengal on 6th and into some parts of central Arabian Sea, remaining parts of Kerala and Tamil Nadu, most parts of coastal Karnataka and south interior Karnataka, some parts of Rayalaseema, coastal Andhra Pradesh and some more parts of central Bay of Bengal on 7th.

The formation of first intense low pressure system as a Deep Depression over North Bay of Bengal and its northward movement during 11th – 12th June accelerated the monsoon westerlies. This led to advancement of monsoon which almost covered most

parts of Peninsular India and entire northeast India by 14th June. It slowed thereafter owing to the presence of anti-cyclones over the Arabian Sea & Bay of Bengal. The presence of a short-lived low pressure area over northwest Bay of Bengal and its associated cyclonic circulation along with the north-south trough over the eastern parts of India and the east-west shear zone along Lat. 17° N & Lat.18°N led to the advance of monsoon into some more parts of Madhya Maharashtra, remaining parts of Marathwada, some parts of Vidarbha, some more parts of Chhattisgarh, most parts of Odisha, remaining parts of West Bengal and some parts of Jharkhand and Bihar on 16th June and into some more parts of Vidarbha, Chhattisgarh, Jharkhand & Bihar and remaining parts of Odisha on 21st June. During the third week of June, the stronger than normal cross equatorial flow over the Bay of Bengal, increase in north-south pressure gradient and establishment of Tibetan High in its normal position, led to the increased rainfall over the core monsoon zone. This led to further advance of SWM over most parts of central and western India by 27th June. It covered remaining parts of north Arabian Sea, Saurashtra & Kutch, Gujarat region, some more parts of Madhya Pradesh and some parts of south Rajasthan by 27thJune. Thereafter, a hiatus of 3 days occurred towards the end of June.

Subsequent westward movement of cyclonic circulations along the seasonal trough zone triggered the rainfall activity over the central and north India. It caused further advancement of southwest monsoon over remaining parts of central India and most parts of north India during 1st - 3rd July. It covered remaining parts of Bihar, Madhya Pradesh, Uttar Pradesh and Uttarakhand by 3rd July. Thereafter, the seasonal trough along the northern plains gradually shifted northwards, due to a Western Disturbance which caused widespread precipitation over parts of northwest India. This led to a weak monsoon pattern, with an anomalous anticyclone prevailing over western India causing a prolonged hiatus of 8 days. As the trough became active and a well-marked low pressure area formed over Indo- Gangetic plains, SWM advanced into remaining parts of Himachal Pradesh and Jammu & Kashmir and some more parts of east Rajasthan, Haryana and some parts of Punjab on 12th July. Further, with the subsequent advance on 14th, 17th and 18th, it advanced into remaining parts of west Rajasthan, Haryana and Punjab on 19th and thus covering the entire country on 19th July 2017.

Fig.1 shows the isochrones of advance of monsoon 2017.

2. Chief Synoptic Features

During the season, 14 low pressure systems formed over the Indian subcontinent. Their month-wise frequency and intensity are given in the table below.

Systems / Month	Deep Depression	Depression	Well marked low pressure area	Low pressure area	Total
June	1	0	2	2	**5**
July	0	2	1	3	**6**
August	0	0	2	0	**2**
Sept.	0	0	1	0	**1**
Total	**1**	**2**	**6**	**5**	**14**

The first intense system formed as a Deep Depression (11^{th} – 12^{th} June) over northwest and adjoining northeast Bay of Bengal and dissipated over Bangladesh. The second system in June, a well marked low pressure area, formed over west central Arabian Sea and neighbourhood and dissipated off Oman coast (6^{th} – 8^{th} June). Two subsequent low pressure systems; a low pressure area (15^{th} – 16^{th} June) and a well marked low pressure area (25^{th} – 26^{th} June) formed over northwest Bay of Bengal. The first one weakened over Bangladesh and northwest Bay of Bengal and adjoining areas of coastal Odisha and the second weakened over Gangetic west Bengal. The last system during June formed as a low pressure area (28^{th} – 30^{th} June) over Saurashtra and adjoining northeast Arabian Sea and dissipated over Kutch and neighbourhood.

The first low pressure area in July (7^{th} – 8^{th} July) formed over northern parts of Uttar Pradesh and neighbourhood and dissipated over northeastern parts of Uttar Pradesh and adjoining Bihar. The second system, a well marked low pressure area (11^{th} – 16^{th} July) also formed over east Uttar Pradesh and neighbourhood but moved westwards and became less marked over south Pakistan and neighbourhood. The third system concentrated into a Depression (18^{th} – 19^{th} July) which formed over northwest and adjoining westcentral Bay of Bengal and coastal areas of Odisha and dissipated over coastal Odisha and neighbourhood. This was followed by two very short lived low pressure areas on 20^{th} & 21^{st} July respectively over Kutch and neighbourhood and south Gujarat region and neighbourhood. The last system of July formed as a Land Depression (26^{th} – 27^{th} July) over northwest Jharkhand and neighbourhood and dissipated over southeast Uttar Pradesh and neighbourhood.

Cyclogenesis during August and September remained very much subdued as a result of the overall weakening of the monsoon flow pattern over the Indian region. This is also reflected in the number of Low Pressure System (LPS) [low pressure areas and depressions combined] days, which shows 11 in June, 12 in July, 10 in August and 6 in

September against a normal of 11, 14, 17 & 16 during the respective months. **The total number of LPS days during the season had been only 39 as against the normal of 58.** The two well marked low pressure areas in August occurred during 18th – 21st August & 27th August – 1st September. However, both of them traversed across central India, the first one formed over northwest Bay of Bengal and neighbourhood and dissipated over Kutch & neighbourhood and the second one formed over southeast Odisha and neighbourhood and became less marked over south Pakistan. The only one system formed in September, a well marked low pressure area (19th–24th September) formed over northwest Bay of Bengal and neighbourhood and dissipated over west Uttar Pradesh and adjoining Uttarakhand.

Tracks of Depressions & Deep Depressions are given in Fig.2.

Apart from the above depicted low pressure systems got manifested from the mean sea level, there had been numerous cyclonic circulations formed at various levels in the lower & mid-troposphere, troughs and east-west shear zones which affected the rainfall distribution, all through the season. Most of the low level cyclonic circulations formed during August and especially in September which could not develop into low pressure areas as they formed in general in the rising pressure field.

The off-shore trough along the west coast was noticed to be present only during 50% of the days in June & July and very rarely in August & September. The seasonal heat trough made its appearance along the Indo-Gangetic plains from last week of May and got established as the monsoon trough from 19th July. Though it remained shallow and oscillated north-south quite often, was active on more number of days in June & July in association with the formation and movement of low pressure systems. However the trough remained to the north of its normal position and often close to the foothills of the Himalayas during August and September. It may be noted that the Typhoon activity over west Pacific Ocean had a slow start initially upto mid-July and increased drastically thereafter. This had a direct linkage with the pressure field over the Indian region which reflected in terms of the suppressed genesis of monsoon lows over the Bay of Bengal as the Bay branch of southwest monsoon got deflected towards Southeast Asia owing to the strengthening of west Pacific systems. Thus, the location of the monsoon trough during the latter half of the season was largely to the north of its mean position.

Break like conditions prevailed during the first week of July and on several days during the first fortnight of August. Only two Typhoons' remnants propagated westwards

and induced genesis of monsoon lows over the India region during August & September, viz., Typhoons 'Hato' and 'Doksuri' which contributed to the re-invigoration of the monsoon trough during 27th – 30th August and 18th – 20th September respectively.

The low pressure area formed over northwest Bay of Bengal and neighborhood traversed across central India and became well marked during 19th – 24th September. Prior to its dissipation over west Uttar Pradesh and adjoining Uttarakhand, it had a brief interaction with a trough in the westerlies. Soon after the weakening of this low, the westerly regime started dominating the atmospheric flow, paving the way for the commencement of withdrawal.

3. Withdrawal of southwest Monsoon

Dry weather prevailed over western parts of Rajasthan since 18th September. However, the changeover of atmospheric circulation was delayed. Establishment of an anti-cyclone in the lower tropospheric levels, substantial reduction in moisture content and prevalence of dry weather indicated the withdrawal of southwest monsoon from some parts of Punjab, Haryana, most parts of west Rajasthan, some parts of Kutch and north Arabian Sea on 27th September. It further withdrew from remaining parts of Punjab, Haryana, Chandigarh & Delhi, west Rajasthan, Kutch, entire Jammu & Kashmir, Himachal Pradesh, some parts of Uttarakhand, west Uttar Pradesh, most parts of east Rajasthan, some parts of west Madhya Pradesh, north Gujarat region, Saurashtra and some more parts of north Arabian Sea on 30th September. A cyclonic circulation which subsequently developed into a Deep Depression in the monsoon flow regime over Gangetic west Bengal caused moisture incursion over the mainland and thereby delayed further withdrawal of southwest monsoon. However, it further withdrew from remaining pats of Uttarakhand, West Uttar Pradesh and East Rajasthan, some parts of East Uttar Padesh and some more parts of north Madhya Pradesh and Gujarat on 11th October. As on 11th October, the monsoon withdrawal line passes through Lat. 28.5˚N / Long. 81.0˚E, Kheri, Nowgong, Shajapur, Ahmedabad, Dwarka, Lat. 22.0˚N / Long. 65.0˚E and Lat. 22.0˚N / Long. 60.0˚E.

Fig.3 shows the isochrones of withdrawal of monsoon 2017.

4. High Impact Weather Events

Fig. 4 depicts the met. Sub-divisions or parts thereof, which experienced high impact weather events like, floods, landslides, lightning associated with thunderstorms and Heat waves during the southwest monsoon season (June- September) along with the dates. **Fig.4** also indicates areas that experienced isolated extremely heavy rainfall (Rainfall amount ≥ 21 cm reported during the 24 hours ending at 0830 hrs IST) events during the season without any reference to the dates of these occurrences.

Apart from the flood situations experienced in association with the advance phase of SWM over northeast India and southern most peninsular India, there had been flood situations over various other parts including Odisha, Bihar, Gujarat, Konkan (Mumbai city also experienced extremely heavy rainfall twice during the season viz., 29th August & 19th September), Karnataka, Madhya Pradesh, East Rajasthan (Mount Abu received exceptionally heavy rainfall of 77 cm on 24th July), parts of Haryana etc. High temporal and spatial variability of rainfall caused such floods and flash floods and at the same time, intense convection during the weak phases of monsoon led to events of severe thunderstorms and lightning over major parts of the country.

5. Rainfall Distribution

The realized 2017 southwest monsoon season (June to September) rainfall over the country as a whole and four broad geographical regions are given in the table below along with respective long period average (LPA) values. The rainfall during the 4 monsoon months and the second half of the monsoon season (August + September) over the country as whole are also given below.

Season (June to September) rainfall			
Region	**Long Period Average (LPA) (mm)**	**Actual Rainfall for 2017**	
		Rainfall (mm)	**Rainfall (% of LPA)**
All India	887.5	841.3	95
Northwest India	615.0	552.9	90
Central India	975.5	918.8	94
East & Northeast India	1438.3	1386.4	96
South Peninsula	716.1	717.6	100
Monthly & second half of the monsoon season rainfall over the country as a whole (All India)			
Month	**LPA (mm)**	**Actual Rainfall for 2017**	
		Rainfall (mm)	**Rainfall (% of LPA)**
June	163.6	170.2	104
July	289.2	294.0	102

August	261.3	228.1	87
September	173.4	152.1	88
August + September	434.7	380.2	87

As seen in the table above, the 2017 season rainfall over the country as a whole (95% of LPA) was less than the long period average (LPA). The 2017 season rainfalls over three of the four geographical regions of the country (except south Peninsula) were also less than the respective LPAs. The highest rainfall (100% of LPA) was received by South Peninsula and lowest rainfall (90% of LPA) was received by Northwest India. Central India and East & Northeast India received season rainfalls of 94% of LPA and 96% of LPA respectively. The monthly rainfall over the country as a whole were more than LPA during first two months of the season (104% of LPA in June and 102 % of LPA in July) and were less than LPA during the last two months of the season (87% of LPA in August and 88% of LPA in September).

Fig.5 shows the subdivision-wise seasonal (June to September) rainfall.

Out of the total 36 meteorological subdivisions (Fig.5), the seasonal rainfall was normal in 25 subdivisions (65% of the total area of the country) and excess in 5 subdivisions (18% of the total area of the country). However, the season rainfall was deficient in 6 subdivisions constituting 17% of the total area of the country. Out of the 6 deficient subdivisions, 4 subdivisions were from Northwest India (West and East Uttar Pradesh, Punjab and Haryana, Chandigarh & Delhi) and 2 subdivisions were from the Central India (East Madhya Pradesh and Vidarbha). Similarly, out of the 5 excess subdivisions, 2 subdivisions were from South Peninsula (Rayalaseema and Tamil Nadu & Pondicherry) and one each from Northwest India (west Rajasthan), Central India (Saurashtra & Kutch) and Northeast India (Nagaland, Manipur, Mizoram, & Tripura (NMMT)).

Fig.6 shows the subdivision-wise monthly rainfall.

In June, 15 subdivisions received excess rainfall, 14 subdivisions received normal rainfall, and 7 subdivisions received deficient rainfall. Out of the 15 excess subdivisions, 6 were from north and northwestern part of the country, 5 were from South Peninsula, 3 were from Central India and 1 (NMMT) from East & Northeast India. Out of 7 deficient subdivisions, 4 were from Northeast (Bihar, Jharkhand, Gangetic West Bengal and Arunachal Pradesh), 2 from South Peninsula (South Interior Karnataka and Andaman & Nicobar Islands), and one from Northwest (West Uttar Pradesh). Region-wise, Northwest India received excess rainfall (52% of LPA).

In July, 07 subdivisions received excess rainfall, 14 subdivisions received normal rainfall, and 15 subdivisions received deficient rainfall. Out of the 7 excess subdivisions, 4 were from Northwest India (2 each from Gujarat and Rajasthan states), and 3 were from East and Northeast (Jharkhand, Gangetic West Bengal and NMMT). Out of 15 deficient subdivisions majority of the subdivisions (8) were from South Peninsula resulting overall large rainfall deficiency (-36% of LPA) over the region. Out of the remaining 7 deficient subdivisions, 4 subdivisions were from northern part of the country (Himachal Pradesh, West Uttar Pradesh, Punjab and Haryana, Chandigarh & Delhi), 2 subdivisions (sub Himalayan West Bengal & Sikkim and Assam & Meghalaya) were from East and Northeast, and one subdivision was from Central India (Marathawada).

In August, 8 subdivisions were excess, 12 were deficient, and 16 were normal. Most noticeable feature of rainfall distribution during August was that, 6 of the 9 subdivisions from Northwest India and 5 of the 10 subdivisions from Central India were deficient resulting in large rainfall deficiencies in both the geographical regions (-33% of LPA in Northwest India and -24% of LPA in Central India). On the other hand, other two geographical regions received above normal rainfalls (15% and 16 % of LPA respectively for East & Northeast and South Peninsula); Out of the 8 excess subdivisions, 3 each were from East & Northeast India (Jharkhand, Gangetic West Bengal and NMMT), and South Peninsula (Tamil Nadu & Pondicherry, Rayalaseema, and coastal Andhra Pradesh), and 2 subdivisions from central India (Saurashtra & Kutch and Marathawada).

In September, 9 subdivisions were excess, 14 subdivisions were deficient, and 13 subdivisions were normal. The region that mainly benefited during September was South Peninsula with 9 out of 10 subdivisions from the region (except Telangana (-30% of LPA)) receiving excess (6 subdivisions) or normal rainfall resulting in excess rainfall (26% of LPA) over the region. In addition, 2 subdivisions from Central India (Konkan & Goa and Madhya Maharashtra), and one subdivision from northeast (NMMT) also received excess rainfall. However, the other 3 geographical regions experienced noticeable rainfall deficiency (-38% of LPA for Northwest India with deficient subdivisions, -17% of LPA for East and Northeast India with 3 deficient subdivisions and -14% of LPA for Central India with 5 deficient subdivisions).

It can be seen from the monthly rainfall distribution that there was also not a single subdivision that received deficient during all the four months. On the other hand, NMMT was the only subdivision which received excess rainfall during all the four months. However,

there were three subdivisions (Punjab, East Uttar Pradesh, Jharkhand) that received deficient rainfall during 3 out of the 4 months with East Uttar Pradesh (-28% of LPA) and Punjab (-22% of LPA) ending with deficient season rainfall.

Fig.7 depicts the all India weekly and cumulative weekly rainfall anomaly expressed as percentage departure from the LPA.

The all India weekly rainfall anomalies during 10 out of the 17 calendar weeks of the monsoon season (till 27th September) were negative. Out of the 7 positive rainfall anomaly weeks, 3 weeks were from July (weeks ending 5th, 19th & 26th), 2 weeks from June (first two weeks) and 1 week each from August (week ending 30th) and September (week ending 20th). It is noteworthy to mention that the weekly rainfall anomalies were negative for 5 of the 6 weeks from first week of August to second week of September with the exception of last week of August. The highest negative weekly rainfall anomaly was recorded during the week ending 13th September (-31% of LPA) followed by the week ending 9th August. Highest positive rainfall anomaly was recorded by week ending 30th August (24% of LPA) followed by the week ending 26th July (22% of LPA).

The all India cumulative weekly rainfall anomalies were positive during the first 9 weeks (till week ending 2nd August) except in two weeks (weeks ending 28th June and 12th July) when the cumulative weekly rainfalls were slightly negative. However, after that the weekly cumulative rainfall remained negative (<-3% of LPA) till the end of the season. The highest positive cumulative weekly rainfall anomaly was in the first week (17.6% of LPA). Thereafter it went down regularly to its highest negative value of -6.1% of LPA in the week ending 13th September with occasional increase.

6. Verification of the Long Range Forecasts

Based on indigenously developed models, it was predicted on 16th May 2017 that monsoon will set in over Kerala on 30th May with a model error of ±4 days. The actual monsoon onset over Kerala was also 30th May and therefore the forecast was accurate.

The long range forecast for the 2017 southwest monsoon rainfall was issued in 3 stages. The first stage long range forecast issued on 18th April consisted of only forecast for seasonal (June-September) rainfall over the country as a whole. In the second stage (6th June), along with the update for the April forecast, forecast for seasonal rainfall over the four broad geographical regions (northwest India, central India, south Peninsula and northeast India) and that for monthly rainfall over the country as a whole for the months of

July and August were issued. In the 3rd stage (8th August), the forecast for the rainfall during the second half of the monsoon season over the country as a whole was issued.

The first stage forecast for the seasonal (June-September) rainfall over the country as a whole issued in April was 96% of LPA with a model error of ± 5% of LPA. The update issued in June for this forecast was (98% of LPA) with a model error of ± 4% of LPA. The actual season rainfall for the country as a whole was 95% of LPA, which is 1% & 3% of LPA less than the April and June forecasts respectively. Thus the actual seasonal rainfall over the country as a whole is within the lower forecast range.

Considering the four broad geographical regions of India, the forecasts issued in June for the seasonal rainfall over northwest India, central India, northeast India and south Peninsula were 96%, 100%, 96% & 99% of the LPA respectively all with model errors of ± 8%. The actual rainfalls over northwest India, central India, northeast India and south Peninsula were 90%, 94%, 96% and 100% of the LPA respectively. Thus the forecasts for the seasonal rainfall over all the four broad geographical regions are realized to be within the stipulated forecast error ranges.

The forecast for the second half of the monsoon season (August –September) for the country as a whole was 100% with a model error of ±8% of LPA against the actual rainfall of 87% of LPA. Thus the forecast for the rainfall during the second half of the monsoon season over the country as a whole was found to be an overestimate to the actual rainfall.

The forecasts for the monthly rainfall over the country as a whole for the months of July & August issued in June were 96% & 99% respectively with a model error of ± 9%. The actual monthly rainfalls during July and August were 102% & 87% of LPA respectively. Thus the actual July rainfall was well within the forecast limit. However, the forecast of the August rainfall was an over estimate to the actual value. The Table below gives the summary of the verification of the long range forecasts issued for the 2017 Southwest monsoon.

Table: Details of long range forecasts and actual rainfall.

Region	Period	Forecast (% of LPA)		Actual Rainfall (% of LPA)
		18th April	6th June	
All India	June to September	96 ± 5	98 ± 4	95
Northwest India	June to September		96 ± 8	90
Central India	June to September		100 ± 8	94

Northeast India	June to September		96 ± 8	96
South Peninsula	June to September		99 ± 8	100
All India	July		96 ± 9	102
All India	August		99 ± 9	87
All India	August to September (issued on 8th August)		100 ± 8	87

The rainfall deficiency of 5% of LPA in the all India seasonal rainfall was basically caused by the below normal rainfalls during the last two months of the season. During the second half of the season, the highest rainfall deficiency was observed over northwest India (-35% of LPA) and Central India (-21% of LPA).

During the season, warm ENSO neutral conditions were observed in the first half and cool ENSO neutral conditions were observed in the second half. The IOD conditions were also neutral during the season. Madden Julian Oscillation (MJO), which has significant influence on the monsoon intra-seasonal variability, was in the weak phase during most part of the season except in mid-June when it was in the favorable phase for stronger than normal monsoon activity over monsoon trough region. Therefore, the large scale SST forcings from both Pacific and Indian Oceans as well as from MJO was nearly absent during the season. Thus the rainfall activity over Indian main land during this season was mainly decided by the intra-seasonal activity of the synoptic systems over Indian monsoon region. Earlier studies have shown a robust inverse concurrent relationship between the anomalous convective activity over Indian monsoon trough region and that over the northwest Pacific and neighboring areas. In the intra-seasonal scale, the rainfall activity over monsoon trough zone including central India and neighboring northwest India has a positive (negative) relationship with the number of low pressure systems (LPS) (lows, depressions, cyclones etc.) and LPS days over the Indian monsoon region (northwest Pacific). During the season, 4-6 depressions form over the Indian monsoon region. This year, 11 low pressure areas formed in the first half of the season with 3 of them intensifying into depressions. On the other hand, during the second half of the season, only 3 low pressure systems formed in the Indian monsoon region with none of them intensified into depression. The number of LPS days, had been 11 in June, 12 in July, 10 in August and 6 in September against a normal of 11, 14, 17 & 16 during the respective months. The total number of LPS days during the season had been only 39 as against the normal of 58. The activity of low pressure systems (with intensity of depression and above) over the northwest Pacific was normal during the first

half and above normal during the second half of the season. This resulted in above normal convective activity over the northwest Pacific and below normal convective activity across the entire Intertropical convergence zone including the monsoon trough zone over India during the second half of the season. The below normal rainfall over the central and northwest India during the second half of the season was also caused by the above normal convective activity over southern hemispheric equatorial trough (SHET) during the period and due to the fact that the Bay of Bengal branch of southwest monsoon got deflected towards southeast Asia owing to the strengthening of west Pacific systems.

New Delhi
the 11th October, 2017 **(K J Ramesh)**
18th Asvina 1939 (SE) **Director General of Meteorology**

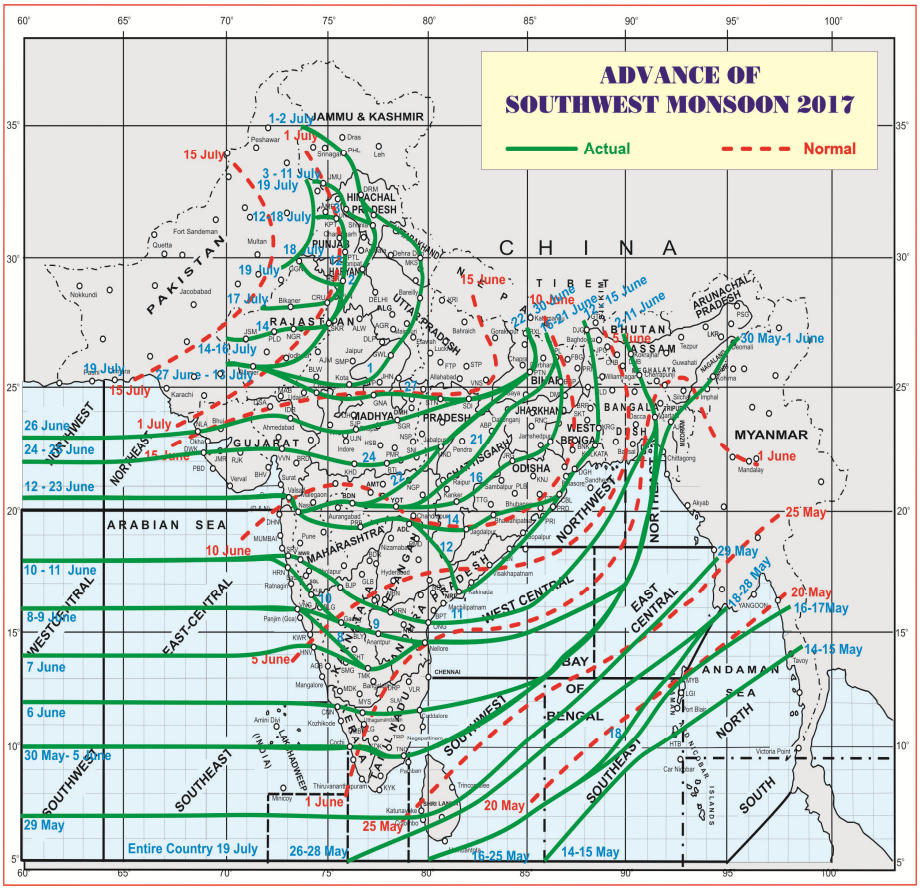


Fig.1: Progress of Southwest Monsoon – 2017.

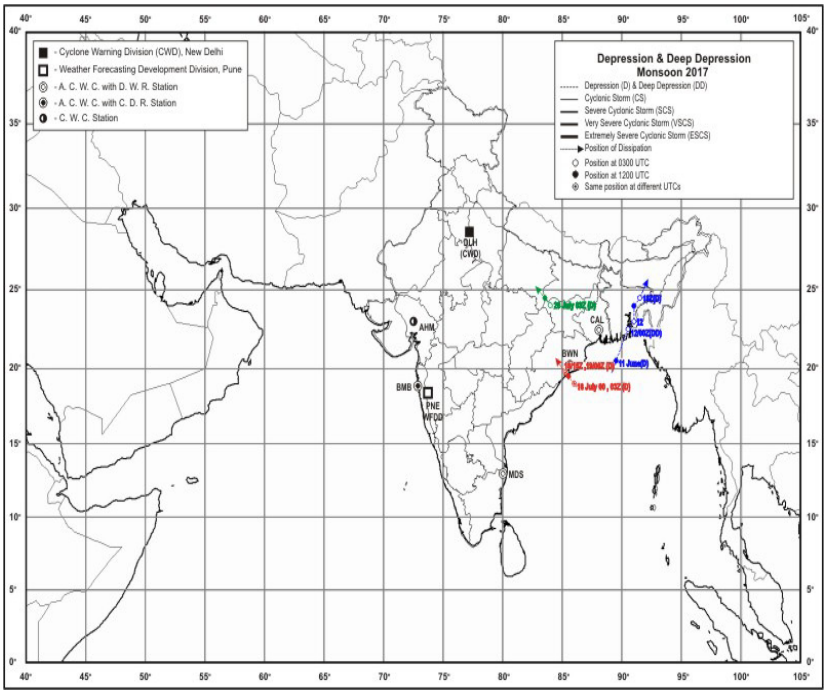


Fig.2: Tracks of the monsoon Depressions

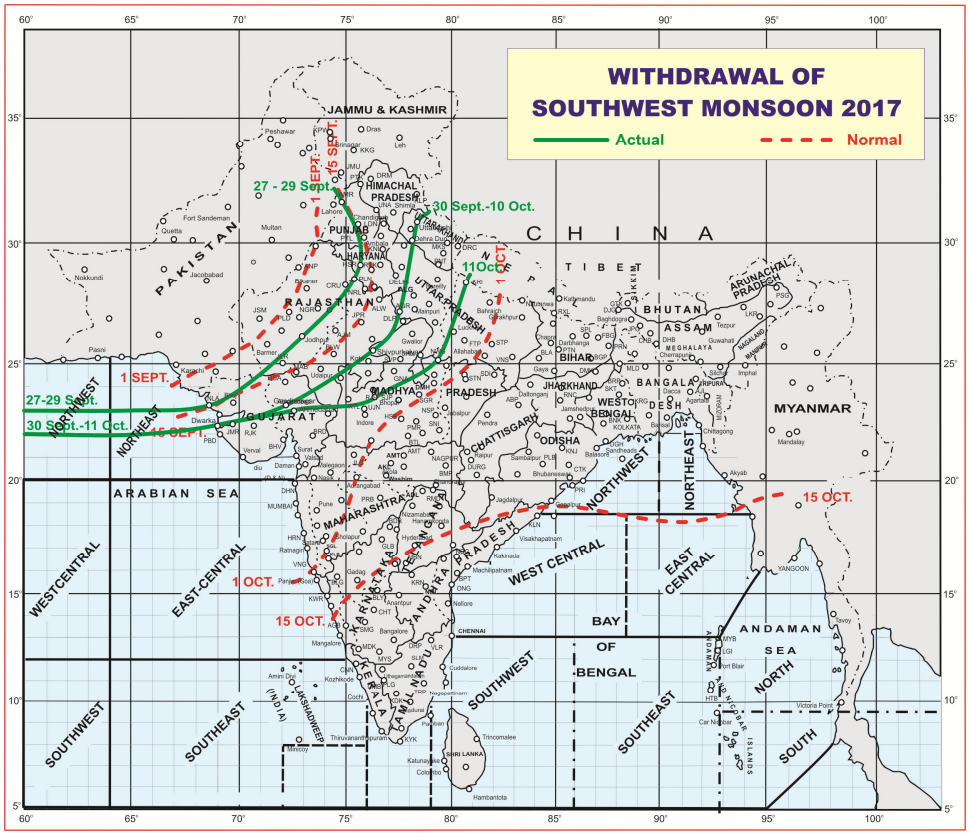
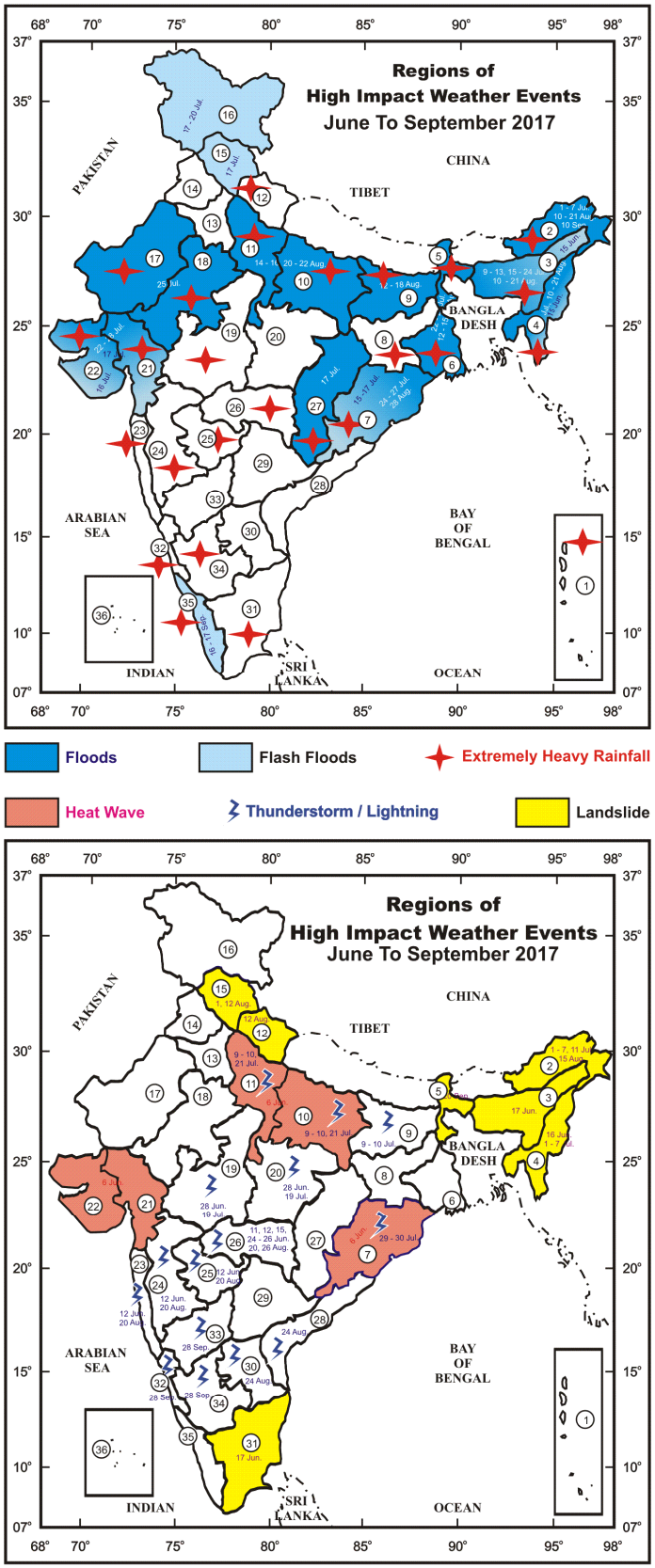


Fig.3: Isochrones of withdrawal of southwest monsoon - 2017.



Extremely Heavy Rainfall (>=21 cm)

(1) 6 Jun.: - 21 - Port Blair.

(2) 1 Jul.: - 21 - Itanagar; 10 Aug.: - 26 - Roing; 11 Aug.: - 26 - Roing; 23 - Passighat.

(3) 3 Jun.: - 41 - Sohra (Cherrapunji); 37 - Mawsynram; 24 - Sohra [Cherrapunji (Rkm)]; 13 Jun.: - 33 - Sohra [Cherrapunji (Rkm)]; 32 - Sohra (Cherrapunji); 17 Jun.: - 64 - Sohra (Cherrapunji); 61 - Mawsynram; 48 - Sohra [Cherrapunji (Rkm)]; 22 Jun.: - 27 - Mawsynram; 25 - Sohra (Cherrapunji); 1 Jul.: - 29 - Mawsynram; 21 - Sohra [Cherrapunji (Rkm)]; 2 Jul.: - 36 - Mawsynram; 3 Jul.: - 22 - Mawsynram; 4 Jul.: - 33 - Mawsynram; 25 Jul.: - 24 - Mawsynram; 9 Aug.: - 23 - Mawsynram and Sohra (Cherrapunji) each; 10 Aug.: - 33 - Mawsynram; 24 - Sohra [Cherrapunji (Rkm)]; 11 Aug.: - 50 - Mawsynram; 38 - Sohra [Cherrapunji (Rkm)]; 30 - Sohra (Cherrapunji); 28 - Kokrajhar; 23 - Gossaigaon; 12 Aug.: - 41 - Mawsynram; 37 - Gossaigaon; 28 - Sohra (Cherrapunji); 26 - Panbari; 24 - Aie Nh Xing; 22 - Sohra [Cherrapunji (Rkm)], Williamnagar and Kokrajhar each; 21 - Beki Mathungari; 13 Aug.: - 21 - Sohra (Cherrapunji); 14 Aug.: - 39 - Mawsynram; 25 - Sohra (Cherrapunji) and Sohra [Cherrapunji (Rkm)] each; 9 Sep.: - 35 - Mawsynram; 21 - Sohra [Cherrapunji (Rkm)]; 10 Sep.: - 22 - Sohra (Cherrapunji); 30 Sep.: - 35 - Goalpara Cwc; 29 - Goalpara; 23 - Mawsynram.

(4) 4 Jun.: - 23 - Kailashahar; 13 Jun.: - 24 - Serchip (Hydro).

(5) 22 Jun.: - 25 - Kumargram; 9 Jul.: - 23 - Kumargram and Buxaduar each; 22 - Hasimara; 8 Aug.: - 23 - Buxaduar; 9 Aug.: - 25 - Haldibari; 10 Aug.: - 27 - Haldibari; 23 - Alipurduar and Alipurduar CWC each; 22 - Kumargram; 11 Aug.: - 25 - Cooch Behar; 12 Aug.: - 48 - Hasimara; 45 - Buxaduar; 44 - Barobhisha; 39 - Alipurduar CWC and Haldibari each; 35 - Kumargram; 32 - Chepan; 29 - Jalpaiguri and Nh31 Bridge each; 27 - Mohitnagar; 25 - Domohani; 23 - Garubathan, Cooch Behar and Chengmari / Diana each; 21 - Tapan and Murti each; 13 Aug.: - 25 - Gangarampur; 22 - Chanchal; 21 - Tapan; 16 Aug.: - 25 - Buxaduar; 27 Aug.: - 21 - Chanchal; 10 Sep.: - 21 - Garubathan; 11 Sep.: - 27 - Garubathan.

(6) 22 Jul.: - 24 - Durgachak; 22 - Nandigram; 23 Jul.: - 27 - Bankura; 25 Jul.: - 23 - Bankura.

(7) 10 Jul.: - 26 - Balisankara ARG; 16 Jul.: - 24 - Kashipur; 17 Jul.: - 39 - Narla ARG; 25 - Ambadola and Lanjigarh each; 28 Aug.: - 23 - Tentulikhunti ARG.

(8) 24 Jul.: - 23 - Jamshedpur AP; 26 Jul.: - 21 - Ranchi AP.

(9) 10 Jul.: - 27 - Parsa; 23 - Taibpur; 11 Jul.: - 25 - Hayaghat; 4 Aug.: - 30 - Tribeni / Balmiki; 12 Aug.: - 32 - Bahadurganj; 31 - Taibpur; 27 - Kishanganj; 25 - Galgalia, Forbesganj and Thakurganj each; 13 Aug.: - 45 - Birpur; 37 - Gaunaha and Bagaha each; 36 - Bahadurganj; 35 - Ramnagar; 29 - Kishanganj; 26 - Taibpur; 25 - Forbesganj and Darbhanga each; 24 - Dhengraghat; 23 - Thakurganj; 22 - Bhimnagar; 21 - Galgalia; 14 Aug.: - 40 - Tribeni / Balmiki.

(10) 14 Aug.: - 30 - Kakrahi; 21 - Maharajganj and Bhinga Hmo each.

(11) 23 Sep.: - 28 - Bah.

(12) 4 Aug.: - 25 - Kotdwar.

(13) 23 Sep.: - 23 - Chhansa.

(17) 24 Jul.: - 39 - Raniwada; 26 - Bhinmal; 23 - Erinpura Rd. and Sumerpur each; 25 Jul.: - 39 - Sanchore; 23 - Gudamalani.

(18) 14 Jul.: - 24 - Ghatol and Pipalkhunt each; 23 - Dug; 24 Jul.: - 77 - Mounnt Abu Tehsil; 73 - Mount Abu; 40 - Reodar; 38 - Sirohi; 30 - Pindwara; 27 - Abu Road; 25 Jul.: - 73 - Mount Abu and Mounnt Abu Tehsil each; 45 - Reodar; 30 - Sirohi; 27 - Abu Road; 26 Jul.: - 32 - Mount Abu and Mounnt Abu Tehsil each; 29 Jul.: - 24 - Pratapgarh; 20 Aug.: - 22 - Pipalkhunt.

(19) 28 Jul.: - 23 - Narsingarh; 21 - Raisen and Raisen - AWS each; 22 Sep.: - 26 - Isagarh.

(21) 24 Jun.: - 29 - Umerpada; 25 Jun.: - 48 - Vapi; 38 - Silvassa; 37 - Daman; 33 - Madhbun; 2 Jul.: - 33 - Siddhpur; 22 - Dantiwada; 15 Jul.: - 26 - Kaprada; 18 Jul.: - 28 - Valsad; 27 - Pardi; 25 - Chikhli; 23 Jul.: - 22 - Kalol (G); 24 Jul.: - 34 - Dantiwada; 25 - Palanpur, Deesa and Amirgadh each; 23 - Dhanera; 22 - Lakhani; 25 Jul.: - 46 - Dantiwada; 38 - Palanpur; 36 - Vadgam; 34 - Amirgadh; 31 - Lakhani; 29 - Patan; 28 - Deodar; 27 - Dhanera and Deesa each; 22 - Saraswati; 26 Jul.: - 22 - Himatanagar; 27 Jul.: - 26 - Gandhinagar; 28 Jul.: - 30 - Dharampur; 27 - Waghai; 25 - Kalol (G); 24 - Mahuva; 22 - Kaprada; 29 Jul.: - 22 - Kaprada; 29 Aug.: - 41 - Vapi; 29 - Silvassa.

(22) 2 Jul.: - 35 - Kodinar; 28 - Tankara; 15 Jul.: - 45 - Chotila; 35 - Rajkot; 34 - Tankara; 16 Jul.: - 32 - Abdasa; 29 - Naliya; 26 - Jodia; 24 - Dasada; 18 Jul.: - 24 - New Kandla; 22 Jul.: - 33 - Chotila; 25 - Vadia; 23 - Visavadar.

(23) 1 Jun.: - 22 - Valpoi; 10 Jun.: - 32 - Harnai; 21 - Palghar Agri and Dapoli Agri each; 25 Jun.: - 47 - Talasari; 37 - Wada; 32 - Vikramgad; 21 - Bhiwandi; 26 Jun.: - 21 - Murud; 27 Jun.: - 21 - Pen; 29 Jun.: - 40 - Pen; 24 - Karjat Agri; 23 - Roha and Matheran each; 30 Jun.: - 24 - Bhira; 2 Jul.: - 41 - Jawhar; 14 Jul.: - 24 - Pen and KarjatAgri each; 26 Aug.: - 22 - Bhira; 29 Aug.: - 26 - Pen; 21 - Mokheda - FMO and Mhasla each; 30 Aug.: - 33 - Mumbai (SCZ); 28 - Palghar Agri; 25 - Thane; 19 Sep.: - 37 - Harnai; 29 - Wakwali Agri; 26 - Dapoli Agri; 22 - Chiplun; 20 Sep.: - 37 - Vasai; 36 - Matheran; 31 - Dahanu; 30 - Mumbai (SCZ); 25 - Panvel Agri; 24 - Uran; 22 - Harnai and Pen each; 21 - Mumbai (Colaba) and Wada each; 22 Sep.: - 32 - Harnai.

(24) 25 Jun.: - 22 - Igatpuri; 20 Jul.: - 22 - Radhanagari; 30 Aug.: - 21 - Lonavala Agri; 20 Sep.: - 25 - Mahabaleshwar*.

(25) 20 Aug.: - 21 - Nanded.

(26) 19 Jul.: - 34 - Bhamragad; 26 - Chamorshi; 21 - Bramhapuri.

(27) 18 Jul.: - 27 - Dondilohara; 21 Sep.: - 21 - Dondilohara.

(31) 5 Sep.: - 24 - Uttamapalayam.

(32) 11 Jun.: - 27 - Shirali and Shirali PTO each; 2 Jul.: - 25 - Kollur.

(34) 11 Jun.: - 23 - Agumbe; 20 Jul.: - 29 - Bhagamandala; 27 - Ponnampet PWD; 21 - Kottigehara; 21 Jul.: - 21 - Hosanagar.

(35) 17 Sep.: - 23 - Mannarkad.

Fig.4: Areas and dates of high impact weather events during the 2017 southwest Monsoon.

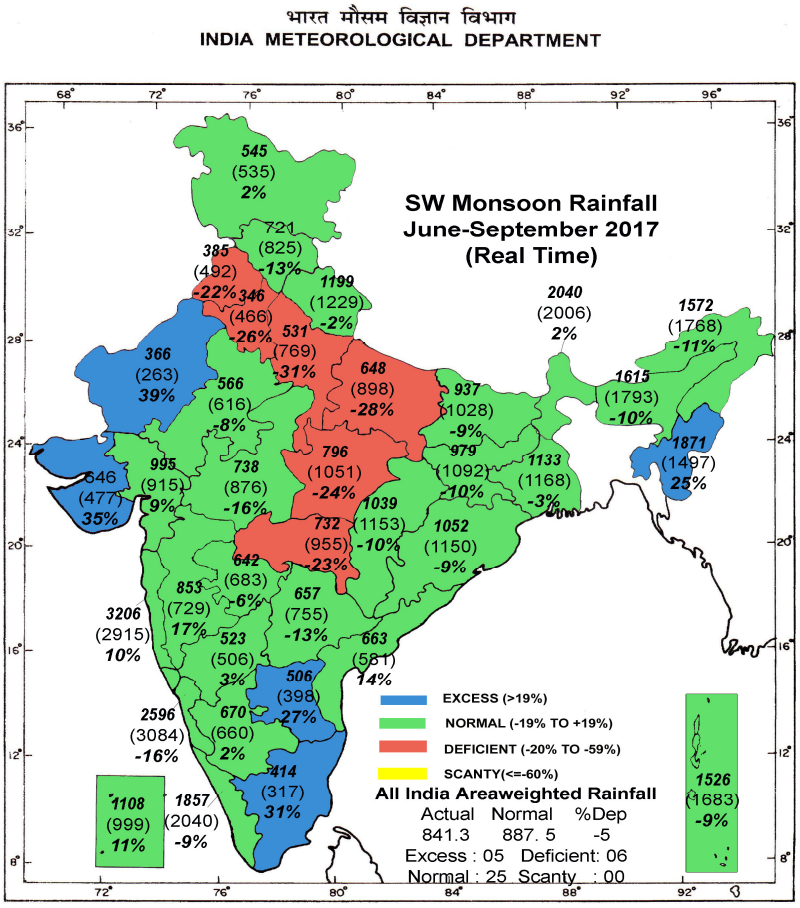


Fig.5: Sub-divisionwise rainfall distribution over India during southwest monsoon season (June to September) – 2017.

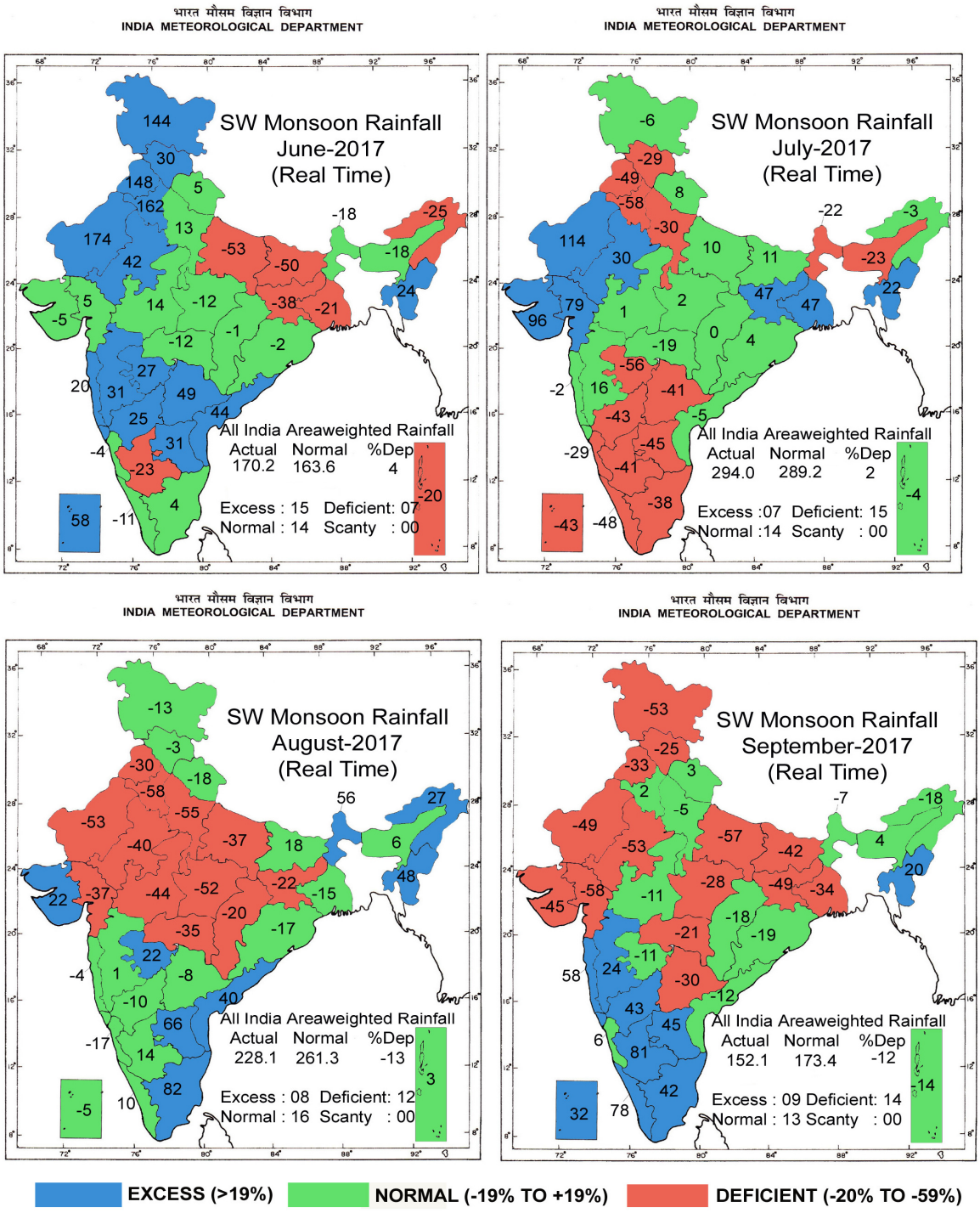


Fig.6: Sub-division wise monthly rainfall distribution over India during southwest monsoon season – 2017

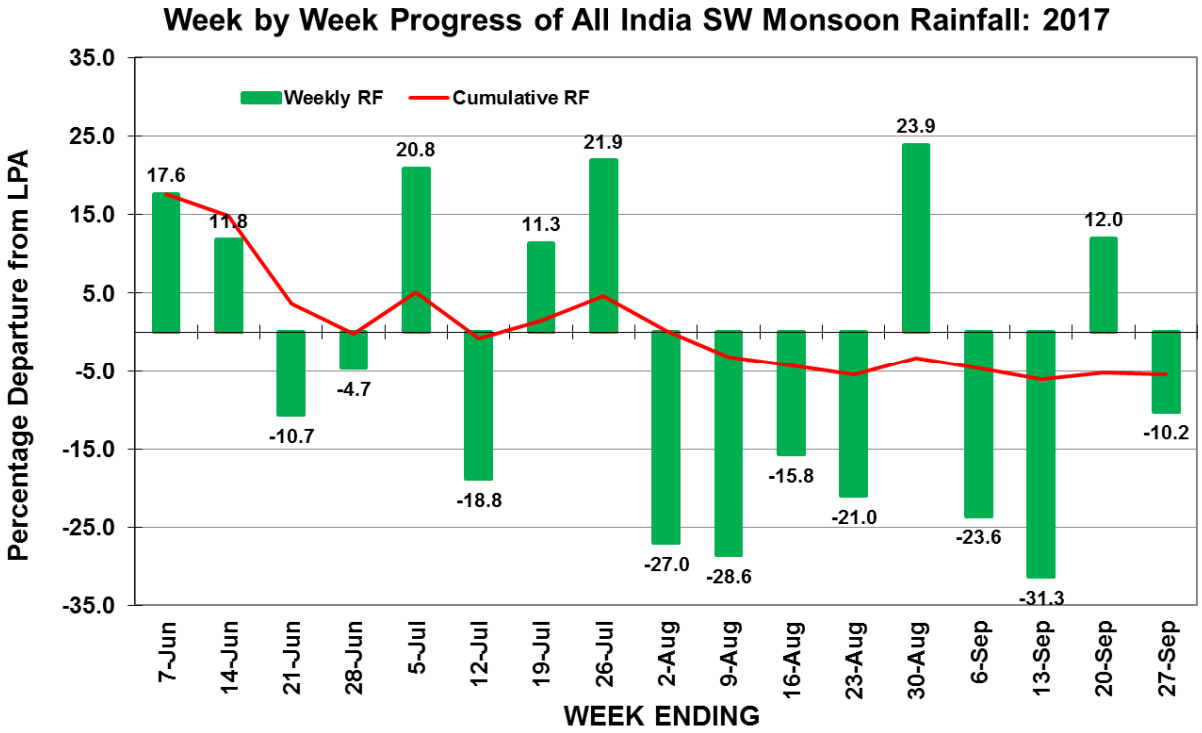


Fig.7: Week - by - Week Progress of the all India weekly and cumulative weekly monsoon rainfall anomalies during the 2017 southwest monsoon season. The rainfall anomalies are expressed as the percentage departure from long period average (LPA).