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

India Meteorological Department

End of Season Report for the 2018 Southwest Monsoon

HIGHLIGHTS

- The season (June-September) rainfall over the country as a whole was 91% of its long period average (LPA).
- Seasonal rainfalls over Northwest India, Central India, South Peninsula and Northeast (NE) India were 98%, 93%, 98% and 76% of respective LPA.
- Out of the total 36 meteorological subdivisions, 23 subdivisions constituting 68% of the total area of the country received normal season rainfall, 1 subdivision received excess rainfall (1% of the total area), and 12 subdivisions (31% of the total area) received deficient season rainfall.
- Monthly rainfall over the country as a whole was 95% of LPA in June, 94% of LPA in July, 92% of LPA in August, and 76% of LPA in September.
- Southwest monsoon current reached south Andaman Sea and Nicobar Islands on 25th May (5 days later than its normal date), but further advance was relatively faster. It set in over Kerala on 29th May, 3 days ahead of its normal date, thereafter progressed rapidly and covered the entire country in one month (on 28th June) well ahead of its normal schedule. Monsoon withdrawal commenced from west Rajasthan on 29th September (with a long delay of almost one month). However further withdrawal was very rapid as the monsoon withdrew from most parts of northwest India and adjoining central India by 1st October and from major parts of the country outside southern parts of Peninsula by 6th October. Rainfall activity continued over south peninsula due to the presence of an active Inter Tropical Convergence Zone (ITCZ) with embedded easterly wave perturbations. Subsequent to the equator ward shifting of the ITCZ and reduction in rainfall, the southwest monsoon withdrew from the entire country, Bay of Bengal and the Arabian Sea on 21st October 2018, with a delay of 6 days.
- During the season, 10 monsoon low pressure systems (1 cyclone, 1 Deep Depression, 4 Depressions, 2 well marked low pressure areas & 2 low pressure areas) formed against an average of 6 Depressions & 8 low pressure areas.
- 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 29th May.
- Forecasts for the seasonal rainfalls over three broad geographical regions (NW India, Central India and South Peninsula) and that for July and August rainfall over the country as a whole were correct. However, the forecasts for the rainfall over the country as a whole during the season and second half of the monsoon season and forecast for North-East India were overestimates to the actual rainfall.

1. Onset and Advance of southwest Monsoon

This year, the latter half of May remained cyclogenetically active over the north Indian Ocean. After the dissipation of the Cyclonic Storms 'SAGAR' and 'MEKUNU' which formed over the Arabian Sea, southerly to southwesterly winds prevailed over southeast Bay of Bengal and south Andaman Sea from 24th May. In view of the strengthening and deepening of Cross Equatorial Flow (CEF) and enhanced cloudiness and rainfall, southwest monsoon advanced into South Andaman Sea, some parts of South Bay of Bengal and Nicobar Islands on 25th May. It further advanced into some parts of South Arabian Sea and Maldives-Comorin area, some more parts of South Bay of Bengal, Andaman & Nicobar Islands and Andaman Sea on 27th May. Some more parts of southeast Arabian Sea, Maldives-Comorin area and Bay of Bengal, remaining parts of Andaman Sea, Andaman & Nicobar Islands were covered on 28th May.

In association with the genesis of a well-marked low pressure area over southeast Arabian Sea off Kerala – Karnataka coasts and another low pressure area over east central Bay of Bengal and neighborhood on 28th May, the CEF along the Indian longitudes further strengthened and deepened. Consequently the low pressure area over the Bay of Bengal became well marked and concentrated into a Depression on 29th May. The resultant enhanced convection and rainfall caused further advance of southwest monsoon into remaining parts of southeast Arabian Sea, Comorin - Maldives area, entire Lakshadweep, most parts of Kerala, some parts of Tamil Nadu and some more parts of Bay of Bengal on 29th. Thus the southwest monsoon set in over Kerala on 29th May 2018, three days ahead of its normal date of onset.

The southwest monsoon further advanced into some parts of Central Arabian Sea, remaining parts of Kerala, most parts of Coastal Karnataka and some parts of South Interior Karnataka and some more parts of interior Tamil Nadu on 30th May. Subsequently it advanced into parts of Mizoram & Manipur on 1st June and into remaining parts of Nagaland, Manipur, Mizoram & Tripura and parts of Assam and Arunachal Pradesh on 3rd June. More parts of south Peninsula upto southern parts of Karnataka and Andhra Pradesh were covered by 6th June. Further progress in the Arabian Sea branch caused the southwest monsoon to enter into southern parts of

Maharashtra and entire Telangana on 8th June. In a steady progress, the southwest monsoon advanced into most parts of northeast India and also covered parts of West Bengal, Odisha and Chhattisgarh during 9th – 12th June.

Thereafter, monsoon flow pattern weakened in general and this resulted in a 'hiatus' in the advance of southwest monsoon during 13th – 22nd June. This period was characterized by the shifting of the active convection zone over to the Pacific Ocean, which in-turn led to enhanced cyclogenesis and channeling of cross equatorial flow towards that region.

After the hiatus, monsoon gradually progressed into more parts of Maharashtra, Gujarat, Madhya Pradesh and West Bengal on 23rd & 24th June. It further advanced into some more parts of Odisha, most parts of West Bengal and some parts of Bihar and Jharkhand on 25thJune. It further advanced into: more parts of Odisha, remaining parts of West Bengal and most parts of Bihar and Jharkhand on 26th June and into some more parts of Gujarat region, some parts of East Rajasthan, remaining parts of Maharashtra, Chhattisgarh, Odisha, Bihar and Jharkhand, entire Madhya Pradesh & East Uttar Pradesh, most parts of West Uttar Pradesh, Uttarakhand & Himachal Pradesh, entire Jammu & Kashmir and some parts of Punjab on 27thJune. It then advanced into some more parts of Gujarat Region, most parts of East Rajasthan, some parts of West Rajasthan, entire Haryana, Chandigarh & Delhi and remaining parts of West Uttar Pradesh, Uttarakhand, Himachal Pradesh and Punjab on 28th June. It further advanced into remaining parts of Gujarat State, Rajasthan and North Arabian Sea and thus the **Southwest Monsoon covered the entire country on 29th June 2018, two weeks earlier than the normal date of 15th July.**

In the recent past, the years 2015 & 2013 had also witnessed rapid advance of southwest monsoon when it covered the entire country on 26th June & 16th June respectively.

Fig.1 shows the isochrones of monsoon progress during 2018.

2. Chief Synoptic Features

During the season, 10 monsoon low pressure systems formed over the Indian region. Out of these, one system intensified into a Cyclonic Storm, one into a Deep Depression and 4 into Depressions. Their month-wise frequency and intensity are

given in the table below. The season normally witnesses 6 Depressions and 8 low pressure areas.

Systems / Month	Cyclonic Storm	Deep Depression	Depression	Well marked low pressure area	Low pressure area
June	0	0	1	0	0
July	0	0	1	1	1
August	0	0	2	1	1
Sept.	1	1	0	0	0

The first low pressure system of the current monsoon season formed over northeast Bay of Bengal and adjoining Bangladesh coast on 10th June. It crossed Bangladesh coast and weakened over the land during the same night. Also this had been the only intense low pressure system during June. Though short lived, it caused further strengthening of the CEF and enhanced rainfall along the west coast.

The first system in July formed as a low pressure area over northwest Bay of Bengal & neighbourhood on 7th. This too had been short lived and became less marked on 8th. However, the remnant cyclonic circulation moved westwards up to northeast Madhya Pradesh and neighbourhood, providing well distributed rainfall along its track and thereby causing the southwest monsoon to advance over these regions upto 12th June.

The second system of July had been a well-marked low pressure area, during 13th – 19th July. Under the influence of a cyclonic circulation, a low pressure area formed over northwest Bay of Bengal & neighbourhood on 13th. It became a **well-marked low pressure area** over the same region 14th night. It gradually moved westwards up to central parts of north Madhya Pradesh and neighbourhood as a low pressure area and became less marked on 19th July.

The third system of July formed as a low pressure area over northwest Bay of Bengal and adjoining Gangetic West Bengal and Odisha on 19th July which concentrated into a Depression on 21st July morning. It crossed the coast in the evening of 21st July between Balasore and Digha and moved west northwest-wards across the central parts of the country. While moving west northwest-wards it weakened and its remnant lay over northwest Uttar Pradesh and neighbourhood as a low pressure area on 28th July. Under the influence of the system, widespread and

intense rainfall activity occurred over Odisha, Gangetic West Bengal, Chattisgarh, Jharkhand and Madhya Pradesh.

Its persistence over West Uttar Pradesh and neighbourhood for nearly three days caused fairly widespread to widespread rainfall activity with heavy to very heavy and extremely heavy falls over Western Himalayan Region and adjoining plains of northwest India during 26th – 28th July.

The convective phase of Madden Julian Oscillation (MJO) remained nearly stationary over the tropical Pacific Ocean with moderate to high amplitude during the second week of August. The first system of August formed as a Low pressure area over Northwest Bay of Bengal and neighbourhood on 6th August. It subsequently concentrated into a Depression and crossed north Odisha –West Bengal coasts and moved west northwest-wards and weakened into Well Marked Low Pressure Area over Chattisgarh & neighbourhood and finally lay as a low pressure area over north Madhya Pradesh and neighbourhood on 9th August. It caused fairly widespread to widespread rainfall activity with heavy to very heavy and extremely heavy falls over eastern parts of Central India.

Moreover, genesis of this Depression resulted in the strengthening of low level westerlies causing widespread rainfall activity along the west coast. During its westward movement, convergence of easterlies along the foot hills caused fairly widespread to widespread rainfall with isolated heavy to very heavy falls over Western Himalayan Region and adjoining plains of Northwest India.

The second system in August formed as a low pressure area over North West Bay of Bengal and adjoining Coastal areas of West Bengal & Odisha on 13th August. It subsequently concentrated into a Depression and lay over Coastal Odisha and neighborhood on 15th August, moving west-northwestwards, it weakened gradually and lay as a low pressure area over southwest Madhya Pradesh and neighborhood on 17th August. Under its influence, fairly widespread to widespread rainfall activity with heavy to very heavy falls had been reported from parts of east and adjoining central India. Strengthening of the monsoon flow due to the formation of the low pressure system has caused widespread intense rainfall activity over south peninsular India.

Western part of the monsoon trough remained north of its normal position for about three days during 12th, 13th & 14th August. This resulted in fairly widespread to

widespread rainfall activity with heavy to very heavy falls over Western Himalayan Region and adjoining plains of northwest India.

During the above mentioned active phase, vigorous monsoon conditions occurred on 5-6 days over Kerala and southern parts of Karnataka. There had been a few instances of extremely heavy rainfall events over these regions as well as over the Ghat sections of Tamil Nadu. From the 3rd week of August, the rainfall over south Peninsula reduced substantially due to the weakening of the CEF.

The third system in August was a Low Pressure area which formed over northwest Bay of Bengal and neighbourhood on 19th August. It subsequently moved west northwestwards before it became less marked over northwest Madhya Pradesh and neighbourhood on 22nd August. Under its influence, widespread very intense rainfall activity had been reported from parts of central India and adjoining peninsular India. The remnants of the above system also caused fairly widespread to widespread rainfall activity over parts northwest India also.

August witnessed the development of a fourth system, which formed as a Low pressure area over coastal areas of West Bengal, north Odisha and adjoining North West Bay of Bengal on 25th which further developed into a well-marked Low Pressure Area within subsequent 48 hours and lay over Northwest Bay of Bengal and adjoining West Bengal and Odisha coast. Under its influence, Odisha experienced widespread intense rainfall activity during 25th to 27th August .Remnants of this system also caused widespread intense rainfall activity over Chattisgarh and East Madhya Pradesh during 27th to 29th August.

The eastern part of the monsoon trough passed through northeast India on 23rd August and caused fairly widespread to widespread intense rainfall activity over northeastern states for a couple of days. Apart from the above systems, an east–west shear zone in the mid-tropospheric levels across central India and an active monsoon trough with cyclonic circulations in the lower tropospheric levels embedded in that also caused fairly widespread to widespread rainfall activity with isolated heavy falls over parts of central and northwest India during 23rd – 29th August.

In the last few days of August and initial days of September, the monsoon trough remained slightly north of its normal position but remained active with two to three cyclonic circulations in the lower tropospheric levels embedded in it. This situation caused fairly widespread to widespread rainfall with isolated intense rainfall

activity over parts of northwest India (including Western Himalayan Region), east and northeast India and adjoining central India during 30th August to 5th September. However during this period, monsoon activity remained subdued over south peninsular India and over Maharashtra and Gujarat states.

The first system during September formed as a Low pressure area over northwest Bay of Bengal & neighbourhood in the morning of 5th September and became a well-Marked Low pressure area by the evening of the same day. It concentrated into a Depression and further intensified into a Deep Depression on 6th September. It crossed West Bengal coast and moved north-westwards and weakened gradually. Under the influence of the system, widespread and very intense rainfall activity occurred over Odisha. The system also caused widespread and intense rainfall activity over Chhattisgarh, Madhya Pradesh and East Rajasthan.

During 6th – 12th September, the monsoon trough lay to the north of its normal position and its eastern end extended across northeastern states on 10th & 11th. Also a north-south trough in the lower tropospheric levels lay extending from eastern parts of Bihar to West Central Bay of Bengal, causing moisture incursion into northeast and adjoining east India. Widespread intense rainfall activity occurred over northeastern states and Sub-Himalayan West Bengal & Sikkim during this period.

The monsoon trough ran close to the foot hills of the Himalayas during 12th – 14th September. The western part of it continued to run close to the foot hills whereas its eastern part shifted southwards and extended to Northeast Bay of Bengal on 15th &16th September. It got filled up and thus became less marked from 17th September.

Northeastern states and Sub-Himalayan West Bengal had experienced fairly widespread to widespread and intense rainfall activity during 12th–14th September due to the downstream convergence of westerly winds and presence of the trough across the region. Under the influence of a western disturbance, Western Himalayan Region experienced scattered to fairly widespread rainfall with isolated intense activity during 13th–15th September. Subdued rainfall activity prevailed over parts of central, northwest and peninsular India during 13th – 19th September.

The last low pressure system formed as a low pressure area over East Central Bay of Bengal and adjoining Myanmar coast on 18th September, evening. It concentrated into a Depression over east central Bay of Bengal and neighbourhood during the night of 19th. It then intensified further into **Cyclonic Storm 'DAYE'** over

northwest Bay of Bengal on 20th September and crossed south Odisha and adjoining north Andhra Pradesh coasts close to Gopalpur during mid-night of 21st September, gradually weakened into a Depression and moved across central India upto western parts of Madhya Pradesh on 21st & 22nd September. During the traverse, it started interacting with a Western Disturbance and thus the system, after weakening into a well- marked low pressure area, started re-curving northwards. This constructive interaction between the monsoon low pressure system and the Western Disturbance caused a revival of the active to vigorous monsoon conditions over central and northwest India during 21st–25th September. Subsequent to the dissipation of the remnant low pressure area over Haryana and neighborhood on 25th September, a drastic reduction in rainfall activity occurred over northwest and adjoining central India.

Cyclonic Storms affecting the Indian coast during September is not very common. Past such occurrence was in 2005, when Cyclonic Storm 'PYARR' crossed Andhra Pradesh coast on 21st September. Cyclonic vorticity advection from the remnants of Typhoon 'Manghkut' and Tropical Cyclone 'Barijat' formed over west Pacific had contributed to the formation of Cyclonic Storm 'DAYE'.

Tracks of Cyclonic Storm, Depressions & Deep Depression are given in Fig.2.

This year, a few of the monsoon lows had a lengthy track and traversed upto northwest India. The number of Low Pressure System (LPS) [low pressure areas and Depressions combined] days had been 4 in June, 19 in July, 15 in August and 12 in September, against a normal of 11, 14, 17 & 16 during the respective months. The total number of LPS days had been 50 as against the normal of 57.

Apart from the low pressure systems discussed above, a multitude of cyclonic circulations and other features like formation and northward propagation of east-west shear zones in the lower & mid-tropospheric levels on several occasions during 28th May to 31st August also contributed significantly to the rainfall and also aided in maintaining the monsoon trough. Off-shore rough along the west coast remained active only during June & July. This, with embedded cyclonic vortices had caused extremely heavy rains over Kerala, Karnataka and Konkan during 18th – 20th June. However, break monsoon conditions were experienced during 1st -6th August.

3. Withdrawal of southwest Monsoon

Reduction in moisture associated with the monsoon flow and a changeover in the lower tropospheric circulation pattern from 'cyclonic' to 'anti-cyclonic' over Rajasthan and neighbouring areas occurred from 28th September. Thus the southwest monsoon withdrew from parts of west Rajasthan and Kutch on 29th September, with a delay of almost a month as the normal date of commencement of withdrawal from extreme western parts of Rajasthan is 1st September. However, further withdrawal took place rapidly, as the flow pattern change took place in an abrupt manner, when the southward shift of the Inter Tropical Convergence Zone occurred in the beginning of October itself.

The monsoon withdrew from most parts of northwest India and adjoining central India by 1st October and by 6th October, the withdrawal has been completed from major parts of India, outside southern parts of Peninsula, where rainfall activity continued due to the presence of an active Inter Tropical Convergence Zone (ITCZ) with embedded easterly wave perturbations. Subsequent to the equator ward shifting of the ITCZ and reduction in rainfall, the southwest monsoon withdrew from the entire country, Bay of Bengal and the Arabian Sea on 21st October 2018, with a delay of 6 days.

Fig.3 shows the isochrones of withdrawal of southwest monsoon 2018.

4. High Impact Weather Events

Fig. 4 depicts the met. Sub-divisions or parts thereof, which experienced high impact weather events like, floods, landslides, Thunderstorms & Lightning, Dust storms 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 ≥20 cm reported during the 24 hours ending at 0830 hrs IST) events during the season.

The season witnessed a very large number of 'High Impact weather events, of which 'floods' remained to be the most frequent and widespread phenomenon. It may be noted that, almost all meteorological sub-divisions experienced one or other category of severe weather event during the season. Incessant rainfall associated with the formation and movement of the monsoon low pressure systems in the

presence of strong cross equatorial flow often caused flood situations over various areas during different parts of the season. Kerala experienced one of the worst flood situations of the Century, due to frequent heavy rain spells and several extremely heavy rain events, especially during the first half of August.

Ahead of the monsoon current, severe thunder squalls affected parts of northwest India, including Delhi on 9thJune. Parts of Uttar Pradesh and Bihar were also affected by Severe Thunderstorms and Lightning during the second week of June.

5. Rainfall Distribution

The realized 2018 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 a whole are also given.

Season (June to September) rainfall			
Region	**Long Period Average (LPA) (mm)**	**Actual Rainfall for 2018**	
		Rainfall (mm)	**Rainfall (% of LPA)**
All India	887.5	804.0	91
Northwest India	615.0	603.2	98
Central India	975.5	911.3	93
East & Northeast India	1438.3	1087.5	76
South Peninsula	716.1	704.4	98
Monthly & second half of the monsoon season rainfall over the country as a whole (All India)			
Month	**LPA (mm)**	**Actual Rainfall for 2018**	
		Rainfall (mm)	**Rainfall (% of LPA)**
June	163.6	155.3	95
July	289.2	272.4	94
August	261.3	241.4	92
September	173.4	132.4	76
August + September	434.7	373.8	86

As seen in the table above, the 2018 season rainfall over the country as a whole (91% of LPA) was less than the long period average (LPA). The 2018 season rainfalls over all the four geographical regions of the country were also less than the respective LPAs. South Peninsula and Northwest India received season rainfalls of 98% of LPA each and Central India received season rainfall of 93% of LPA.

However, East & Northeast India received the lowest rainfall (76.4% of LPA), which is the 3rd lowest season rainfall ever received by the region with lowest during 2013 (73% of LPA) followed by 2009 (75.9% of LPA). It may be noted that prior to 2018 (during 1901-2017), there were only four years, when the season rainfall over Northeast India was less than 80% of LPA and 3 of these years were from the recent 15 years (2005, 2009 & 2013). It may also be added that during 17 of the last 18 years (2001-2018), Northeast India has received season rainfall less than LPA with an exception of 2007 (110% of LPA). This indicates that the season rainfall over Northeast India is passing through a below normal epoch like it was during early 1950s to mid-1980s.

Month wise, rainfalls over the country as a whole were less than LPA during all the four months of the season. Country as a whole received rainfall of 94% of LPA during the first half (95% of LPA in June and 94% of LPA in July), which was much higher than that during the second half (86% of LPA) with 92% of LPA in August and 76% of LPA in September. Thus among the four months, rainfall deficiency was highest during September. During the period of 1901-2017, there were 22 years when the September rainfall was ≤76% of LPA with lowest in 1907 (55% of LPA) followed by 58% of LPA in 1918.

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

Out of the total 36 meteorological subdivisions (Fig.5), the season (June-September) rainfall was normal in 23 subdivisions (68% of the total area of the country) and excess in 1 subdivision (Kerala) measuring 1% of the total area of the country). However, the season rainfall was deficient in 12 subdivisions constituting 31% of the total area of the country. Out of the 12 deficient subdivisions, 5 subdivisions were from East & Northeast India (Arunachal Pradesh, Assam & Meghalaya, Gangetic west Bengal, Bihar and Jharkhand), 3 subdivisions each were from the Central India (Saurashtra & Kutch, Gujarat region and Marathwada) and South Peninsula (Rayalaseema, North Interior Karnataka and Lakshadweep) and one subdivision (West Rajasthan) from Northwest India.

Fig.6 shows the subdivision wise monthly rainfall.

In June, 11 subdivisions received excess rainfall, 15 subdivisions received normal rainfall and 10 subdivisions received deficient or scanty rainfall. Out of the 11 excess subdivisions, 6, 3 & 2 were from Northwest, Central India and South

Peninsula respectively. Out of the 8 deficient subdivisions, 2, 4, 3 and 1 were from Northwest, Northeast, Central India, and South Peninsula respectively. Two subdivisions which received scanty rainfall were Saurashtra & Kutch and east Uttar Pradesh. Region wise, East & Northeast India received below normal rainfall (73% of LPA) and other three geographical regions received normal rainfall.

In July, 02 subdivisions (west Uttar Pradesh and Odisha) received excess rainfall, 24 subdivisions received normal rainfall, 9 subdivisions received deficient rainfall and one subdivision (Rayalaseema) received scanty rainfall. Out of 10 deficient/ scanty subdivisions, 2, 3, 1 & 4 were from Northwest, Northeast, Central India and South Peninsula respectively. Region wise, East & Northeast India received below normal rainfall (75% of LPA) and other three geographical regions received normal rainfall.

In August, 6 subdivisions (5 from South Peninsula and one from northwest India) received excess, 16 subdivisions (4 each from Northwest India & Northeast India, 5 from Central India and 3 from South Peninsula) were deficient, and remaining 14 subdivisions were normal. Most noticeable feature of rainfall distribution during August was the large spatial variability over South Peninsula with excess rainfall over 5 of the 10 subdivisions including Kerala (196% of LPA) and deficient rainfall over 3 subdivisions. Region wise, East & Northeast India received below normal rainfall (79% of LPA), South Peninsula received above normal rainfall (124% of LPA) and remaining two regions received normal rainfall.

In September, 6 subdivisions were excess (5 from Northwest and 1 (Odisha) from Central India), 23 subdivisions were deficient/scanty (2 from Northwest, 5 from Northeast, 8 each from Central India and South Peninsula). As seen, region that mainly benefited during September was Northwest India (108% of LPA). All the other 3 geographical regions experienced below normal rainfall (62% of LPA for South Peninsula, 69% of LPA for Central India, 72% LPA for East and Northeast India)

Thus it is very clear that East and Northeast region experienced below normal rainfall and northwest India experienced normal rainfall during all the four months of the season. At the same time, Central India and South Peninsula experienced normal rainfall during first 3 months and below normal rainfall during September. Thus the seasonal rainfall deficiency of 9% of LPA over the country as a whole was caused by the large monthly rainfall deficiency (more than 20% of LPA) over

Northeast India during all the four months of the season. The below normal rainfall over South Peninsula and Central India during September was also another factor.

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 13 of the 18 weeks of the monsoon season were negative. Out of the 5 positive rainfall anomaly weeks, 2 weeks were from July (weeks ending 4th & 18th) and one week each from other 3 months (weeks ending 13th June, 22nd August & 26th September). The highest negative weekly rainfall anomaly was recorded during the week ending 19th September (-55% from LPA) followed by the week ending 30th September. Highest positive rainfall anomaly was recorded during the week ending 13th June (38% from LPA) followed by the week ending 22nd August (23% from LPA). The occasional spurt in the weekly rainfall during the season can be associated with the low pressure systems moving along the monsoon trough region.

The all India cumulative weekly rainfall anomaly was positive only during the second week of the season (week ending 13th June (18.8% from LPA)). Thereafter the weekly cumulative rainfall remained negative till the end of the season with rainfall anomaly reaching around -10% from LPA during weeks ending 27th June (-10.2%), 8th August (-9.9%) and 19th September (-10.1%). There was significant improvement in the cumulative rainfall during 3rd & 4th weeks of July when the negative cumulative rainfall anomaly reduced to around -3% of LPA. The season ended with all India cumulative rainfall anomaly of -9.4% of LPA.

5. Verification of the Long Range Forecasts

Based on an indigenously developed statistical model, it was predicted on 18th May 2018 that monsoon will set in over Kerala on 29th May with a model error of ±4 days. The actual monsoon onset over Kerala was also 29th May and therefore the forecast was accurate.

The long range forecast for the 2018 southwest monsoon rainfall was issued in 3 stages. The first stage long range forecast issued on 16th April consisted of only forecast for season (June-September) rainfall over the country as a whole. In the second stage (30th May), along with the update for the April forecast, forecast for season 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 (3rd 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 season (June-September) rainfall over the country as a whole issued in April was 97% of LPA with a model error of ± 5% of LPA. The update issued in May for this forecast was (97% of LPA) with a model error of ± 4% of LPA. The actual season rainfall for the country as a whole was 91% of LPA, which is 1% & 2% of LPA less than lower forecast limits of the April and May forecasts. Thus both the forecasts were not within forecast limits and not correct.

Considering the four broad geographical regions of India, the forecasts issued in May for the season rainfall over northwest India, Central India, northeast India and South Peninsula were 100%, 99%, 93% & 95% of the LPA respectively all with model errors of ± 8%. The actual rainfalls over northwest India, Central India, Northeast India and South Peninsula were 98%, 93%, 76% and 98% of the LPA respectively. Thus the forecasts of season rainfall over all the four geographical regions were overestimates to the actual season rainfalls. The actual rainfalls of Northwest India, Central India and South Peninsula were less than the forecasted values by 2%, 6% and 3% of LPA respectively but within the lower forecast range. However, the actual season rainfall over northeast India was 76% of LPA and the actual value was 9% less than the lower forecast limit. Thus the forecasts of the seasonal rainfalls for the three of the geographical regions (except Northeast India) were correct.

The forecast for the second half of the monsoon season (August –September) for the country as a whole was 95% with a model error of 8% of LPA against the actual rainfall of 86% of LPA, which is 1% less than the lower forecast limit of (95%-8% = 87% of LPA). Thus the forecast for the rainfall during the second half of the monsoon season over the country as a whole was also overestimate to the actual rainfall and was not accurate.

The forecasts for the monthly rainfall over the country as a whole for the months of July & August issued in June were 101% & 94% (updated in August to 96%) of LPA respectively with a model error of ± 9%. Thus the monthly forecasts for the July and August rainfalls were also overestimates to the actual monthly rainfalls

(94% & 92% of LPA respectively). But the actual rainfalls during July and August were within the forecast limits and the forecasts were therefore correct.

The Table below gives the summary of the verification of the long range forecasts issued for the 2018 Southwest monsoon.

Table: Details of long range forecasts and actual rainfall.

Region	Period	Forecast (% of LPA)			Actual Rainfall (% of LPA)
		16th April	30th May	3rd August	
All India	June to September	97 ± 5	97 ± 4		91
Northwest India	June to September		100 ± 8		98
Central India	June to September		99 ± 8		93
Northeast India	June to September		93 ± 8		76
South Peninsula	June to September		95 ± 8		98
All India	July		101 ± 9		94
All India	August		94 ± 9	96 ± 9	92
All India	August to September			95 ± 8	86

As seen in the table, the forecasts for the season rainfalls over three of the four broad geographical regions as well as that for the July & August rainfall over the country as a whole were correct. However, the forecasts for the season rainfall over the country as a whole & that over the Northeast India and the rainfall during second half of the monsoon season over the country as a whole were not correct.

From the discussions in the section 5, it is very clear that East and Northeast region experienced below normal rainfall and northwest India experienced normal during all the four months of the season. At the same time, Central India and South Peninsula experienced normal rainfall during first 3 months and below normal rainfall during September. Thus the seasonal rainfall deficiency of 9% of LPA over the country as a whole was caused by the large monthly rainfall deficiency (more than 20% of LPA) over Northeast India during all the four months of the season. The below normal rainfall over South Peninsula and Central India during September was also another factor.

During the 2018 southwest monsoon season, though the warming trends in the sea surface temperatures (SSTs) over equatorial Pacific indicated evolving El Nino, SSTs remained below the El Nino threshold value. Hence, warm ENSO neutral conditions prevailed over the equatorial Pacific. The atmospheric conditions were also indicating neutral ENSO conditions. The observed seasonal rainfall spatial

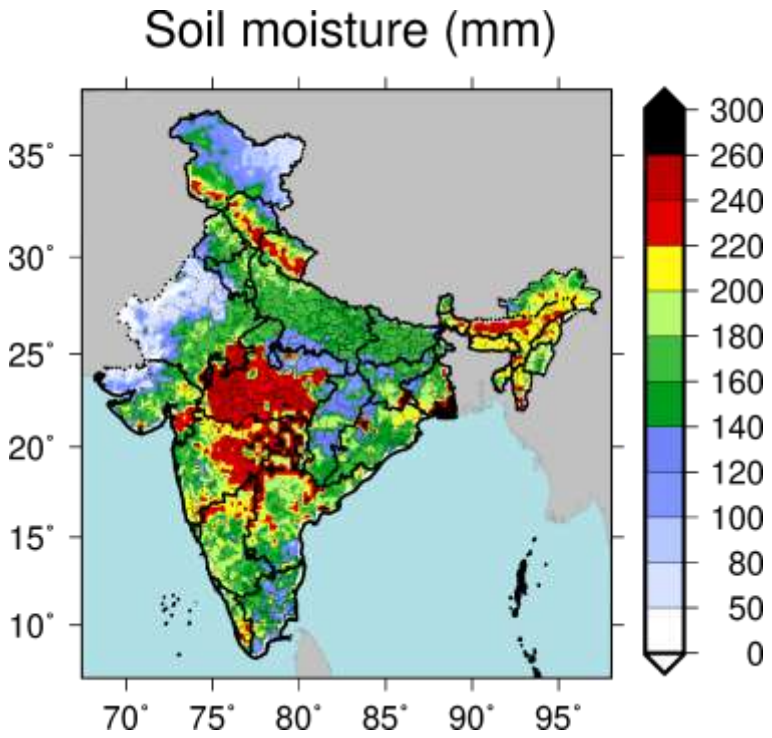
pattern over India with below normal rainfall over Northeast India and normal rainfall over remaining areas (exactly opposite to the generally expected El Nino associated pattern) indicates that the direct impact of the evolving El Nino on the performance 2018 monsoon season was limited. As Indian Ocean Dipole (IOD) conditions were also neutral during the season, it can be assumed that the direct impact of the large scale SST forcings from Pacific and Indian oceans were not much. However, the large rainfall deficiency over Northeast India during the entire season and that over large parts of the country during the second half of the monsoon season (particularly during September) was caused by the above normal convective activity over tropical northwest Pacific due to the above normal SSTs over most parts of the region associated with evolving El Nino. The above normal convective activity over northwest Pacific during the second half of the season caused dragging of Bay of Bengal branch of the monsoon flow towards the region and weakening of Arabian Sea branch of monsoon circulation. During the season, 10 low pressure systems (1 cyclone, 1 deep depression, 4 depressions and 4 low pressure areas) formed over the Indian monsoon region which mostly followed a northwest ward track along the monsoon trough across central India causing active monsoon conditions over the region. The strong moisture convergence associated with these systems resulted in good rainfall over the trough region during their life span. At the same time, strengthening of low level winds associated with the presence of these systems along the monsoon trough also resulted active monsoon conditions and increased rainfall activity along the west coast. On the other hand, presence of these systems over central India reduced the moisture supply to Northeast India by way of diverting monsoon flow towards the systems resulting in conditions less conducive for strong rainfall activity over Northeast India. Thus this year, the impact of synoptic scales systems on the monsoon performance was significant resulting in increased uncertainty in the predictability of monsoon at extended and seasonal scales.

Summer Monsoon rainfall distribution decides the direction of agriculture in India and also the fate of impact on allied sectors. Despite the advances made in irrigation techniques, Indian agriculture has remained highly dependent on monsoon rainfall distribution, both temporal and spatial, for the lifesaving irrigation to the crops, recharging aquifers and reservoirs, and most importantly providing an assurance of a good crop production for the year. In fact, the agriculture calendar of the country has

been built around the onset and withdrawal of monsoon. Hence, it is not only rainfall averages alone but reservoir levels and rain-fed sowing trends that give a true picture of the monsoon performance.

The analysis at the end of the monsoon season 2018 reveals that the rainfall is reasonably distributed across the country barring East and North East India.

The acreage data of the Ministry of Agriculture suggest that overall crop acreage during the Kharif season is higher by 2.6% as compared to the highest ever acreage/record food production that India experienced during 2017. The resultant acreage is largely manifested by the good soil moisture distribution across the country. Adequate soil moisture available over northern parts of India may help the Rabi crops during 2018- 19.



(**Fig: Soil Moisture distribution over India as on 30 September 2018)**

The higher soil moisture quantum over NE India despite -25% departure from normal rainfall suggests that whatever rainfall received so far is fairly above the optimal requirement for the soil to support the agriculture operations. Same is true over other parts of Jharkhand, Bihar etc. Such reasonably good distribution of the soil moisture across country is the primary reason for the good acreage of rainfed

crops (very close to normal acreage of such as pulses, oil seeds and cereals during kharif-2018). Based on the realized rainfall distribution, the response of the agricultural operations in terms of overall kharif crop acreage in 2018 with regard to kharif in 2017 is presented below:

(In lakh hectares)

Crop Name	Normal Area for whole Kharif Season	Area sown reported			
		1st Advance Estimates 2018-19	% of Normal for whole season	4th Advance Estimates 2017-18	Last Year
Rice	395.39	384.19	97.2	393.52	-9.3
Jowar	22.34	17.77	79.5	18.99	-1.2
Bajra	74.03	65.76	88.8	73.83	-8.1
Maize	74.22	76.88	103.6	76.23	0.7
Total Coarse Cereals	188.55	175.35	93.0	186.29	-10.9
Total Cereals	583.94	559.54	95.8	579.81	-20.3
Tur	41.90	45.41	108.4	44.31	1.1
Urad	27.00	38.61	143.0	44.95	-6.3
Moong	24.93	32.65	131.0	32.86	-0.2
Others	15.83	18.85	119.1	18.71	0.1
Total Pulses	111.93	135.52	121.1	140.83	-5.3
Total Foodgrains	695.87	695.06	99.9	720.64	-25.6
Groundnut	42.01	38.90	92.6	41.02	-2.1
Soyabean	112.51	109.60	97.4	104.71	4.9
Sunflower	2.24	1.43	64.0	1.35	0.1
Sesamum	17.50	14.73	84.2	15.62	-0.9
Nigerseed	2.70	2.08	77.1	2.25	-0.2
Castorseed	10.51	9.18	87.4	8.26	0.9
Total Oilseeds	187.47	175.92	93.83	173.19	2.7
Cotton	119.75	122.38	102.2	124.29	-1.9
Sugarcane	48.84	51.59	105.6	47.32	4.3
Jute & Mesta	8.11	7.43	91.6	7.35	0.1
All- Crops	1060.04	1052.38	99.3	1072.79	-20.4

Source: Crops & TMOP Divisions, DAC&FW

Note: Area figures are as per eye assessment of State Agriculture Departments.

Normal Area: 5 years average of the area during the period of 2012-13 to 2016-17.

Similarly, the reservoir levels monitored by the Central Water Commission (CWC) till 30th September, 2018 stands at 5% higher than 10-year mean storages and 17% higher than the storages of corresponding period during 2017. It is to further suggest that current higher level storages are recorded after meeting the irrigation requirements of the season owing purely to the excellent spatial rainfall distribution across the country.

New Delhi **(K J Ramesh)**

the 02nd November, 2018 **Director General of Meteorology**

11th Kartika 1940 (SE)

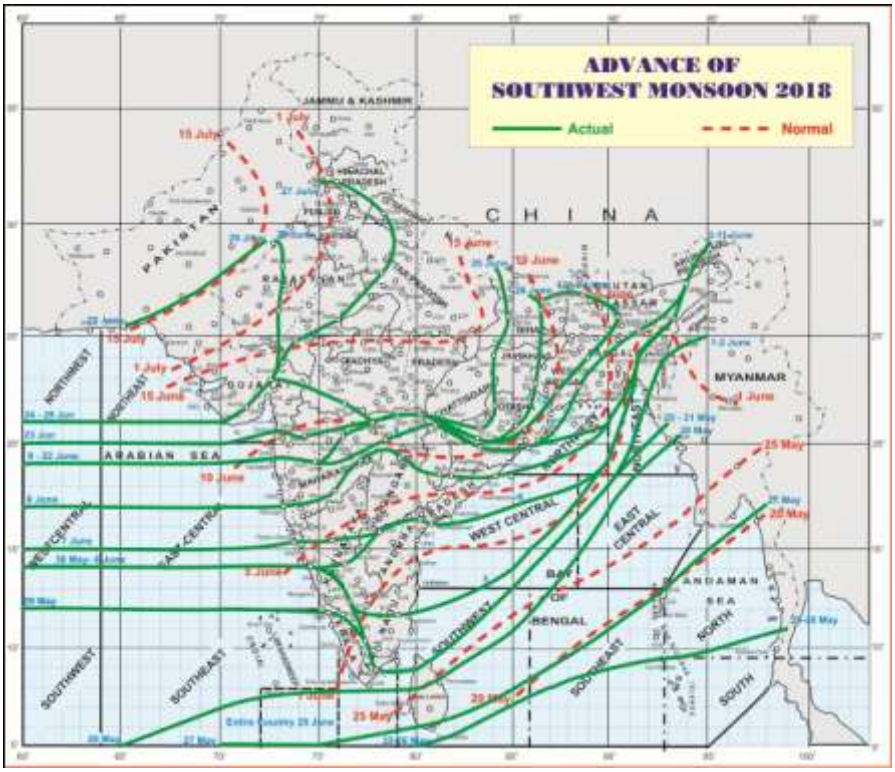


Fig.1: Progress of Southwest Monsoon – 2018

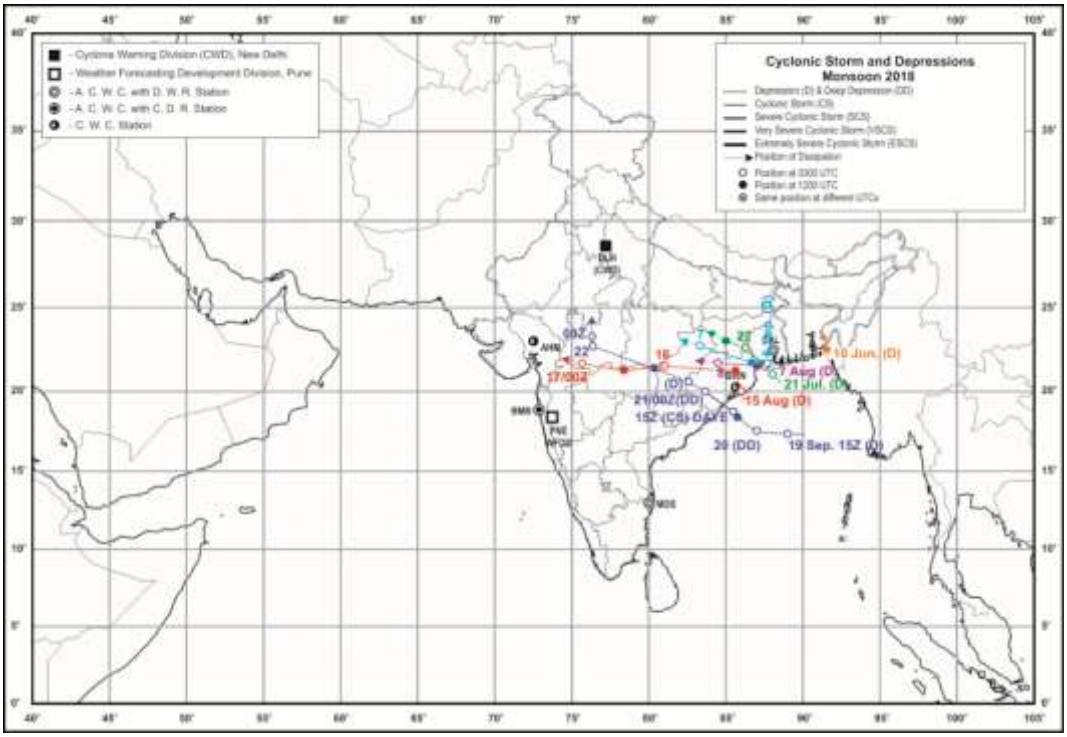


Fig.2: Track of the monsoon Depressions and Cyclonic Storms

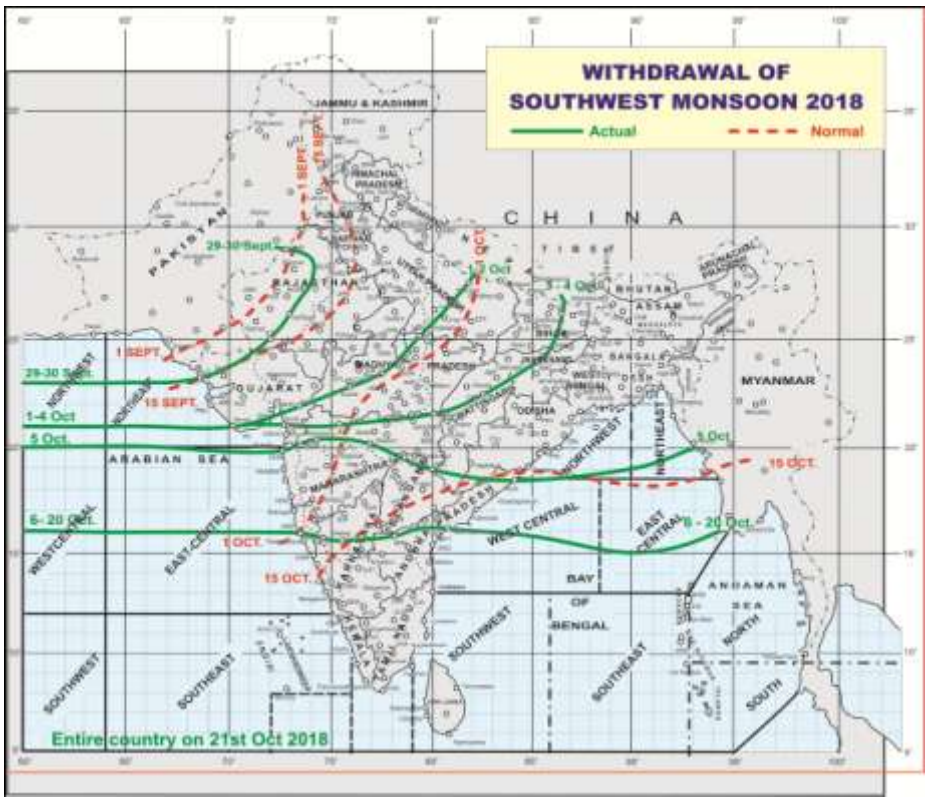
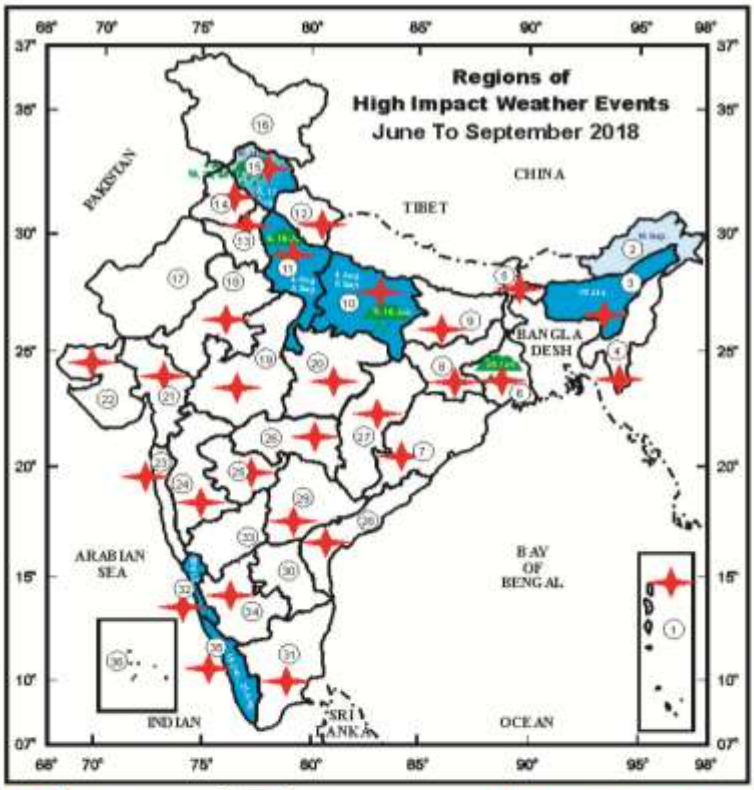
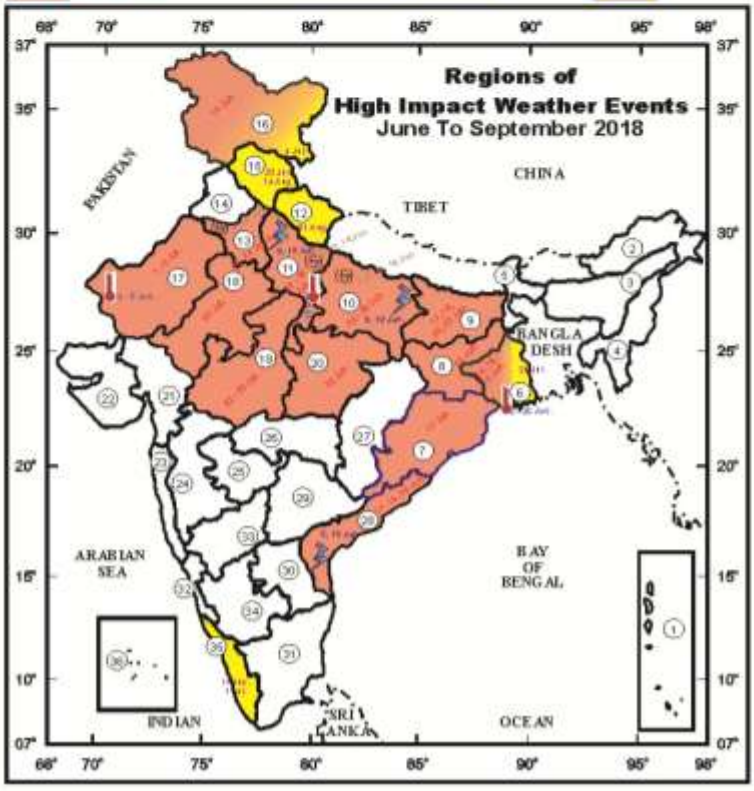


Fig.3: Isochrones of withdrawal of southwest monsoon - 2018.





Extremely Heavy Rainfall (>=21 cm)

(1) **13 Jun.:** 21 - Sohara; **14 Jun.:** 26 - Sohara; **24 Jun.:** 38 - Sohara (Rkm); 23 - Sohara; **30 Jun.:** 21 - Sohara (Rkm); **1 Jul.:** 23 - Gossaigaon; 22 - Kokrajhar and Sohara (Rkm) each; **2 Jul.:** 23 - Sohara; 21 - Sohara (Rkm); **4 Jul.:** 23 - Sohara (Rkm) and Sohara each; **12 Aug.:** 23 - Gossaigaon; **16 Aug.:** 22 - Sohara (Rkm); **24 Aug.:** 27 - Sohara; 22 - Sohara (Rkm); **24 Sep.:** 21 - Beki Mathungari; **26 Sep.:** 23 - Panbari.

(4) **12 Jun.:** 27 - Sabroom; 24 - Serchip (Hydro); **15 Jun.:** 25 - Kamalpur; 21 - Chhamonu; **17 Aug.:** 21 - Kamalpur.

(5) **22 Jun.:** 21 - Cooch Behar; **23 Jun.:** 25 - Gajoldoba; 22 - Nh31 Bridge; **24 Jun.:** 23 - Buxaduar; **1 Jul.:** 23 - Domohani; 22 - Mohitnagar; 21 - Jalpaiguri; **4 Jul.:** 26 - Alipurduar CWC; 26 - Hasimara and Chepan each; 23 - Kumargram; 21 - Buxaduar; **10 Sep.:** 35 - Murti; 32 - Nagarkata; 29 - Chengmari / Diana and Hasimara each; 28 - Bagrakota; 27 - Neora; 25 - Busaduar and Gajoldoba each; 24 - Salbari; **15 Sep.:** 28 - Sevoke.

(6) **27 Jun.:** 25 - Kanksa BSF; **6 Aug.:** 36 - Bankura; 27 - Jhargram; 22 - Bankura CWC; **21 Sep.:** 25 - Contai.

(7) **15 Jul.:** 23 - Kotraguda; 22 - Krishnaprasad; **16 Jul.:** 30 - Bhavani P; 25 - Narla ARG; **21 Jul.:** 27 - Puri; 26 - Junagarh; 24 - Tentulikhunti ARG, Pipli and Kesinga ARG each; 22 - Kashipur; 21 - Narla ARG, Cuttack and Jaipatna each; **22 Jul.:** 62 - Burla ARG; 57 - Sambalpur; 43 - Birmaharajpur ARG; 40 - Hirakud; 38 - Boudhgarh; 35 - Ababira ARG; 31 - Bargarh; 30 - Rairakhol; 26 - Ullunda ARG; 22 - Jujumura ARG; 21 - Sonepur, Binka, Khairiamal and Athmalik each; **7 Aug.:** 39 - Puri; **15 Aug.:** 28 - Lanjigarh; 25 - Madanpur Rampur; 24 - Ambadola and Narla ARG each; 22 - Bhavani P; **20 Aug.:** 23 - Panposh; **27 Aug.:** 21 - Junagarh; **1 Sep.:** 23 - Jajpur; 21 - Pattamundai; **6 Sep.:** 41 - Paradip; 37 - Hujanga ARG; 34 - Kendrapara and Marsaghai ARG each; 31 - Pattamundai; 30 - Derabis ARG; 27 - Bari ARG; 26 - Tirtol ARG; 25 - Salepur ARG; 24 - Binjharpur ARG and Garadapur ARG each; 21 - Raghunathpur ARG and Alipingal each; **21 Sep.:** 29 - Jajpur; 28 - Malkangiri.

(8) **27 Jul.:** 24 - Mathon.

(9) **24 Aug.:** 30 - Rosera.

(10) **27 Jun.:** 24 - Birdghat; 23 - Gorakhpur; **2 Jul.:** 25 - Kakerdarighat; 24 - Nghasan; 23 - Bhinga; 22 - Bhinga Hmo; **26 Aug.:** 24 - Kannauj; **1 Sep.:** 21 - Gyanpur.

(11) **26 Jul.:** 21 - Orai; **28 Jul.:** 23 - Meerath; 21 - Budhana; **30 Jul.:** 21 - Karhal; **25 Aug.:** 21 - Bareilly and Bareilly Tehsil each.

(12) **2 Jul.:** 25 - Munsyari; **10 Jul.:** 28 - Kapkot; **31 Aug.:** 27 - Hardwar.

(13) **27 Jul.:** 22 - Ballabgarh.

(14) **24 Sep.:** 24 - Pathankot and Gurudaspur each; 23 - Kapurtala; 21 - Taran Taran.

(15) **27 Jul.:** 21 - Gohar; **13 Aug.:** 31 - Sujanpur Tira; 30 - Arki; 29 - Nadaun; 26 - Gohar; 24 - Paonta; 23 - Bajnath; 21 - Palampur and Bhoranj each.

(16) **27 Jun.:** 23 - Kanra; **3 Sep.:** 27 - Sawaimadhopur Tesil; 24 - Sawai Madhopur.

(17) **17 Aug.:** 23 - Bhikangaon; 21 - Shegaon and Bhabhra each; **2 Sep.:** 29 - Chandari; 21 - Mungaoli; **22 Sep.:** 34 - Khandwa.

(20) **24 Aug.:** 30 - Orchha; **2 Sep.:** 25 - Orchha.

(21) **25 Jun.:** 21 - Umergam; **26 Jun.:** 29 - Kaprada and Valsad each; 24 - Pardi; 22 - Waghai; 21 - Dharampur, Dhansura and Umergam each; **7 Jul.:** 29 - Nanipalsori; 23 - Songadh; **8 Jul.:** 22 - Waghai; 21 - Subir; **12 Jul.:** 21 - Bardoli, Chikhli and Dharampur each; **13 Jul.:** 21 - Waghai; **17 Jul.:** 23 - Dharampur; 22 - Valsad; **18 Jul.:** 25 - Vansda; 21 - Waghai and Mangrol each; **21 Jul.:** 32 - Umerpada.

(22) **14 Jul.:** 22 - Kodinar; **15 Jul.:** 39 - Malia; 28 - Visavadar; 23 - Kodinar; **16 Jul.:** 23 - Jesar; **17 Jul.:** 50 - Gir Gadhada; 45 - Una; 33 - Kodinar; 28 - Jafrabad; 26 - Diu; 25 - Sutrapada; **18 Jul.:** 41 - Khambhalia; 26 - Manavadar.

(23) **9 Jun.:** 49 - Mahvan; 27 - Vengurla; 21 - Bhiwandi; **10 Jun.:** 28 - Devgarh; 27 - Ratnagiri; 26 - Murud; 21 - Rajapur; **11 Jun.:** 22 - Lanja; **18 Jun.:** 21 - Murud; **20 Jun.:** 27 - Devgarh; **21 Jun.:** 35 - RameshwarAgri and Malvan each; 32 - Vengurla; 26 - Rajapur; 22 - Mapusa; **23 Jun.:** 26 - Matheran; 24 - KarjatAgri; 23 - DapoliAgri; 21 - Ratnagiri; **24 Jun.:** 25 - Guhagarh; 24 - Shriwardhan; **25 Jun.:** 27 - Devgarh; 23 - Mumbai (SCZ) and Dahanu each; 21 - Talasari and Thane each; **6 Jul.:** 21 - Ponda; **7 Jul.:** 23 - Wada; 22 - Murbad; **8 Jul.:** 30 - Bhiwandi; 25 - Mangaon and Kalyan each; 24 - Mahad; 23 - KarjatAgri; 22 - Khalapur; **9 Jul.:** 35 - Dahanu; 23 - Vasai and Mhasla each; 22 - Murud and PalgharAgri each; **10 Jul.:** 30 - Vasai; 29 - PalgharAgri; **16 Jul.:** 26 - Matheran; 23 - Talasari; 22 - Ulhasnagar; **22 Aug.:** 22 - Murbad.

(24) **7 Jul.:** 21 - LonavalaAgri; **16 Jul.:** 30 - Mahabaleshwar*; 29 - LonavalaAgri; 22 - Igatpuri; **17 Jul.:** 27 - Mahabaleshwar*.

(25) **8 Jun.:** 21 - Umarga.

(26) **7 Jul.:** 28 - Nagpur AP; 27 - Hingna; 21 - Korpana; **12 Aug.:** 22 - Bhamragad; **21 Aug.:** 26 - Mauda; **22 Sep.:** 23 - Hinganghat.

(27) **16 Aug.:** 40 - Bhopalpatnam; 34 - Sukma.

(28) **20 Aug.:** 39 - Koida; 29 - Kukunoor; 28 - Velerpad.

(29) **12 Aug.:** 27 - Luxettipet and Ramagundam each; 25 - Utnur and Venkatapuram each; 23 - Venkatapur; 21 - Dharmapuri; **20 Aug.:** 21 - Aswaraopeta and Aswaraopet AP each; **21 Aug.:** 21 - Navipet.

(31) **15 Aug.:** 27 - Shencottah.

(32) **8 Jun.:** 21 - Siddapura; **13 Jun.:** 22 - Kollur; **21 Jun.:** 22 - Mulki; **28 Jun.:** 26 - Kollur; 21 - Gersoppa; **7 Jul.:** 24 - Sulya; 23 - Udupi and Puttur HMS each; 22 - Bantwal, Mudubidre, Mulki and Mani each; 21 - Karkala; **8 Jul.:** 28 - Mulki; **13 Aug.:** 25 - Kollur; **14 Aug.:** 30 - Kollur; 26 - Siddapura; 24 - Kota; 22 - Kundapur; 21 - Gersoppa; **16 Aug.:** 24 - Subramanya; **17 Aug.:** 23 - Castle Rock.

(34) **12 Jun.:** 26 - Sakleshpura; **13 Jun.:** 23 - Ponnampet PWD; 22 - Kammardi; **20 Jun.:** 30 - Agumbe; **7 Jul.:** 21 - Agumbe; **14 Aug.:** 31 - Agumbe; 25 - Bhagamandala; 21 - Kammardi; **15 Aug.:** 25 - Bhagamandala; 23 - Agumbe; 21 - Medikeri; **16 Aug.:** 26 - Medikeri; **17 Aug.:** 21 - Bhagamandala and Madapura each.

(35) **11 Jun.:** 32 - Peermade To; **14 Jun.:** 23 - Manjeri; 21 - Nilambur; **16 Jul.:** 23 - Kochi AP and Kozha each; 22 - Piravam; **9 Aug.:** 40 - Nilambur; 31 - Mananthavady; 25 - Peermade To and Munnar KSEB each; 21 - Palakkad and MyladumparaAgri each; **15 Aug.:** 27 - Peermade To; 23 - Idukki; 22 - Munnar KSEB; 21 - Kanjar; **16 Aug.:** 35 - Peermade To; 29 - Idukki and Munnar KSEB each; 27 - Ponnani; 26 - Vadakara; 25 - Vellanikkara, Vadakkancherry and Enamakkal each; 24 - Mannarkad; 23 - Alathur, Perumpavur and Kunnamkulam each; 22 - Chalakudi; 21 - Ottapalam and Thrithala each.

Fig.4: Areas and dates of high impact weather events during the 2018 southwest Monsoon.

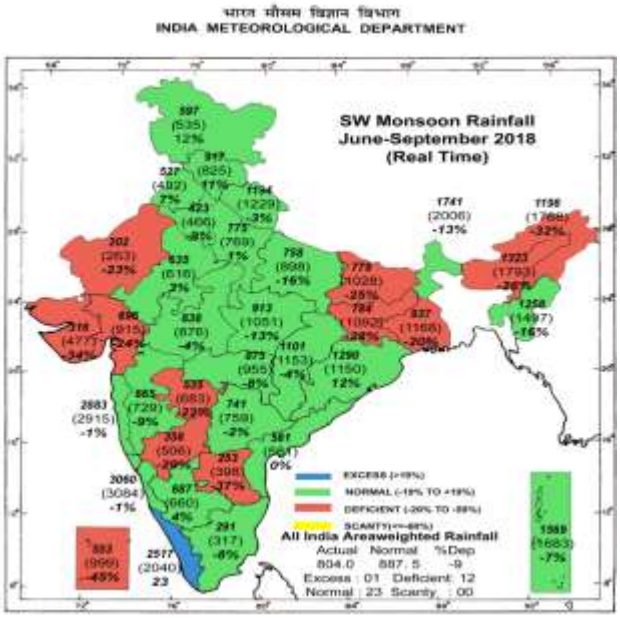


Fig.5: Sub-division wise rainfall distribution over India during southwest monsoon season (June to September) – 2018.

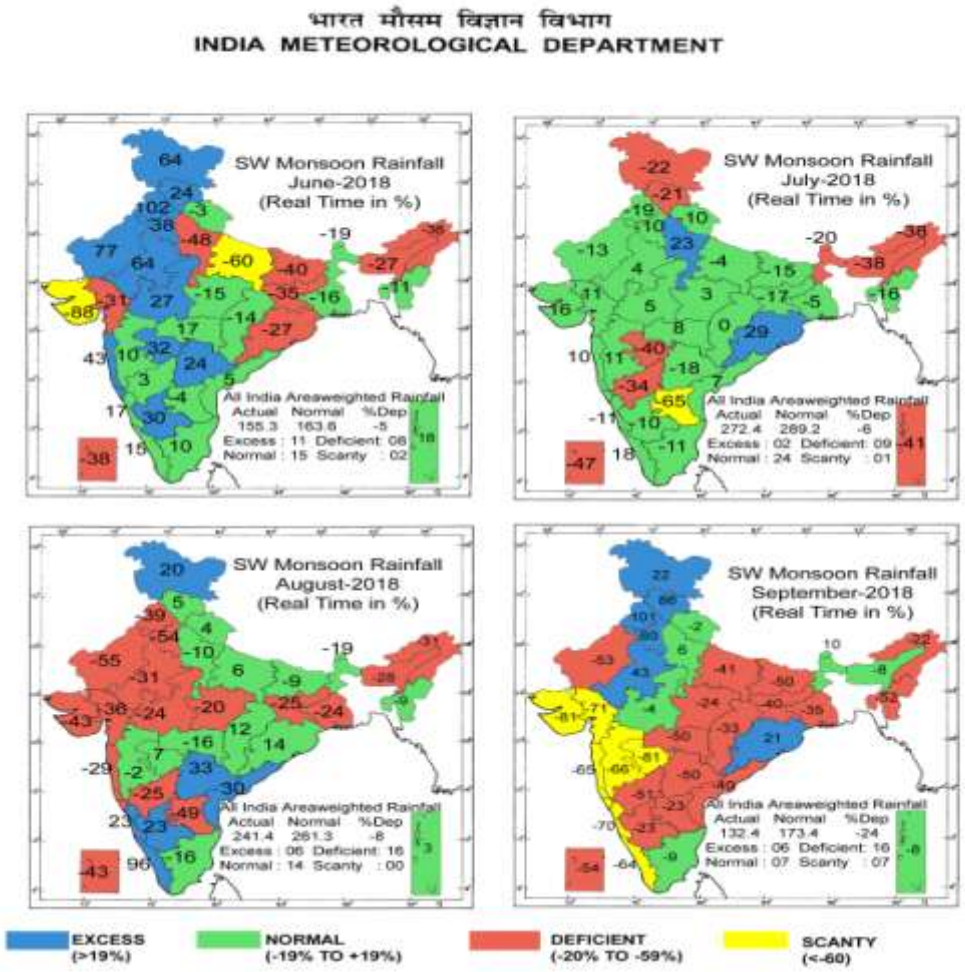


Fig.6: Sub-division wise monthly rainfall distribution over India during southwest monsoon season – 2018

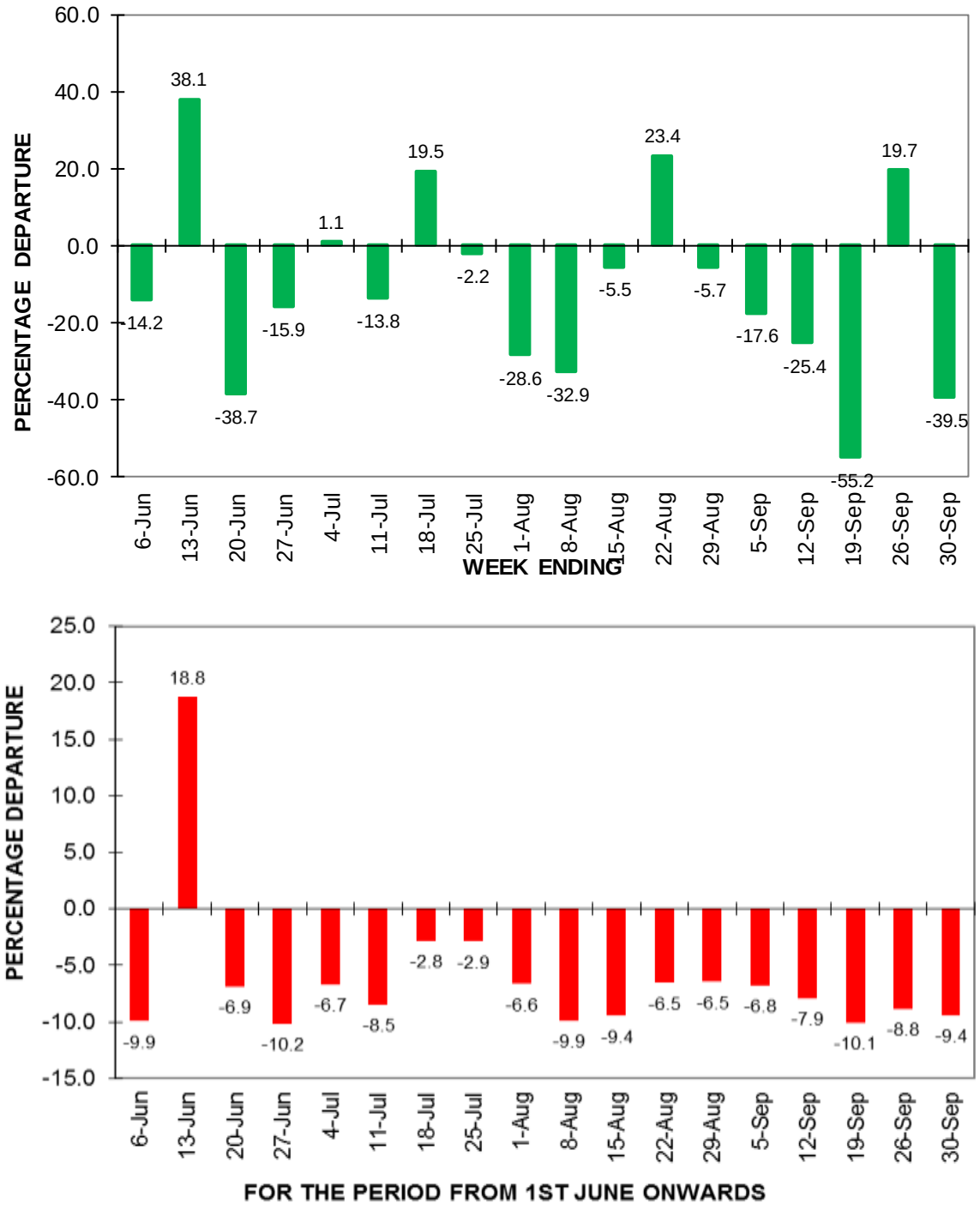


Fig.7: Week - by - Week Progress of the all India weekly and cumulative weekly monsoon rainfall anomalies during the 2018 southwest monsoon season. The rainfall anomalies are expressed as the percentage departure from long period average (LPA).