



Ministry of Earth Sciences (MoES)
India Meteorological Department
2019 Southwest Monsoon End of Season Report

HIGHLIGHTS

- The seasonal (June-September) rainfall over the country as a whole was 110% of its long period average (LPA).
- Seasonal rainfall over Northwest India, Central India, South Peninsula and Northeast (NE) India were 98%, 129%, 116% and 88% of respective LPA.
- Out of the total 36 meteorological subdivisions, 19 subdivisions constituting 54% of the total area of the country received normal seasonal rainfall, 10 subdivisions received excess rainfall (22% of the total area), 5 subdivisions (15% of the total area) received deficient seasonal rainfall and 2 subdivisions (8% of the total area) received large excess rainfall.
- Monthly rainfall over the country as a whole was 67% of LPA in June, 105% of LPA in July, 115% of LPA in August, and 152% of LPA in September.
- Southwest monsoon current reached south Andaman Sea and Nicobar Islands in time (on 18th May, 2 days ahead of its normal date), but further advance was sluggish. It set in over Kerala on 8th June, 7 days behind the normal schedule and covered the entire country by 19th July, 4 days behind normal. Though the withdrawal commenced from northwest India only on 9th October as against the normal date of 1st September, it withdrew on a rapid phase from the entire country by 16th October (against the normal date of 15th October), giving way to simultaneous commencement of northeast monsoon rains.
- During the season, 2 very severe cyclonic storms, viz., “VAYU” (during 10-17 June) & “HIKAA” (during 22-25 September) formed over the Arabian Sea. Also, a Deep Depression (during 6-9 August) formed over the Bay of Bengal and a Depression (during 29 September – 1 October) formed over the Arabian Sea.
- The forecast for monsoon onset over Kerala for this year was correct, which is the fourteenth consecutive correct forecast for this event except year 2015 since issuance of forecast for the event was started in 2005. The Forecasted date of onset of monsoon over Kerala was 6th June with a model error of ± 4 days and realized date of onset of monsoon over Kerala was 8th June.
- The forecasts for the seasonal rainfalls over two broad geographical regions (Northwest India and Northeast India) and that for July rainfall over the country as a whole were within the forecast limit and were correct. The forecasts for the rainfall over the country as a whole during the season and during second half of the monsoon season and forecast for the Central India and South Peninsula were underestimate to the actual rainfall and were incorrect.

1. Onset and Advance of southwest Monsoon

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

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

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

Further advance took place after the dissipation of VSCS 'VAYU'. SWM further advanced into: some more parts of central Arabian Sea, peninsular India and of Bay of Bengal, remaining parts of northeastern states and some more parts of West Bengal on 20th June; some more parts of peninsular India, some

parts of south Chhattisgarh & Odisha, remaining parts of Bay of Bengal, most parts of West Bengal and some parts of Jharkhand and Bihar on 21st June; some more parts of Maharashtra, remaining parts of Karnataka, Telangana, Odisha, Jharkhand, Gangetic West Bengal & Bihar, most parts of Chhattisgarh and some parts of East Uttar Pradesh on 22nd June; some more parts of Maharashtra and East Uttar Pradesh on 23rd June; some more parts of central Arabian Sea, Konkan, most parts of interior Maharashtra, some parts of Madhya Pradesh, some more parts of Chhattisgarh & Uttar Pradesh and some parts of Uttarakhand on 24th June; remaining parts of central Arabian Sea, Maharashtra, some parts of north Arabian Sea and south Gujarat and some more parts of Madhya Pradesh on 25th June and into some more parts of north Arabian Sea, Gujarat & Madhya Pradesh on 28th June.

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

Fig.1 shows the isochrones of advance of monsoon 2019.

2. Chief Synoptic Features

During the season, 14 monsoon low pressure systems formed in the North Indian Ocean. Their month-wise frequency and intensity is given in the table below.

Systems / Month	VSCS	Deep Depression (DD)	Depression (D)	Well marked low pressure area (WML)	Low pressure area (LOPAR)
June	1	0	0	0	1
July	0	0	0	1	3
August	0	1	0	1	3
Sept.	1	0	1	0	1

This year, June & September witnessed the formation of one Very Severe Cyclonic Storm (VSCS) each, while 1 DD formed during August and 1 D during September. Though the frequency of cyclonic storms is less during the southwest monsoon period, there had been 3 more such years in the recent 30 years, viz., 1996 (2 CS in June, one each over the Bay of Bengal & the Arabian Sea), 2007 (2 in June, both over the Arabian Sea) and 2015 (1 in June over the Arabian Sea and the other in July, over the Bay of Bengal). The tracks of these systems are given in **Fig. 2** and their description below.

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

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

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

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

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

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

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

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

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

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

2.5 Low Pressure Areas/ Well Marked Low Pressure Areas

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

The third low pressure area formed in the evening of 6th July, over western parts of Bihar and adjoining Jharkhand. It became well marked on 9th and became less marked on 11th July. The fourth low pressure area formed over northwest Bay of Bengal and adjoining coastal areas of west Bengal on 26th July. It became less marked on 27th July. Fifth low pressure area also formed over land, ie, over east Madhya Pradesh and adjoining Chhattisgarh on 30th July. This low pressure area became less marked on 31st July.

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

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

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

2.6 Upper Air Cyclonic Circulations

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

2.7 Eastward Moving Cyclonic Circulations/Western Disturbances

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

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

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

3. Withdrawal of southwest Monsoon

Due to the prevalence of an active Inter Tropical Convergence Zone, across central India, north Indian Ocean, extending upto western north Pacific Ocean,

the withdrawal of southwest monsoon was delayed upto the 1st week of October. Anti-cyclonic circulation in lower levels over Rajasthan could only be established after 05th October. This led to the most delayed commencement of withdrawal since 1961. Against normal date of withdrawal of SWM 01st September, the Monsoon Withdrawal commenced only on 09th October. In 1961 it was 01st October followed by 30th September in 2007.

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

Fig.3 shows the isochrones of withdrawal of monsoon 2019.

4. High Impact Weather Events

Fig. 4 depicts the meteorological Sub-divisions or parts thereof, which experienced high impact weather events like, floods, landslides 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 without any reference to the dates of these occurrences.

Several record breaking extreme rainfall and resultant Flood events caused human casualty and property damage in states including Maharashtra, Karnataka, Kerala, West Bengal, Odisha, Uttar Pradesh and Madhya Pradesh from later part of July to September.

5. Rainfall Distribution

The realized 2019 southwest monsoon seasonal (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.

Seasonal (June to September) rainfall			
Region	Long Period Average (LPA) (mm)	Actual Rainfall for 2019	
		Rainfall (mm)	Rainfall (% of LPA)
All India	880.6	968.3	110
Northwest India	599.5	586.0	98
Central India	976.5	1262.8	129
East & Northeast India	1410.3	1240.7	88
South Peninsula	726.2	840.9	116
Monthly & second half of the monsoon seasonal rainfall over the country as a whole (All India)			
Month	LPA (mm)	Actual Rainfall for 2019	
		Rainfall (mm)	Rainfall (% of LPA)
June	166.9	112.1	67
July	285.3	298.3	105
August	258.2	297.8	115
September	170.2	259.3	152
August + September	428.3	557.1	130

As seen in the table above, the 2019 seasonal rainfall over the country as a whole (110% of LPA) was more than the long period average (LPA). South Peninsula and Central India received seasonal rainfall of 116% and 129% of LPA each and Northeast India received seasonal rainfall of 88% of LPA. Northwest India received 98% of seasonal rainfall. However, during 18 of the last 19 years (2001-2019), North-East India has received seasonal rainfall less than LPA with an exception of 2007 (110% of LPA). This indicates that the seasonal rainfall over North-East India is passing through a below normal epoch like it was during early 1950s to mid-1980s.

Month wise, rainfall over the country as a whole were more than LPA during all the months of the season except June where it was below normal. It can be mentioned that, after 1931, this is the first time, season rainfall is more than LPA even after the June rainfall deficiency was more than 30% of LPA. Country as a whole received rainfall of 130% of LPA during the second half (115% of LPA in August and 152% of LPA in September), which was much higher than that during the first half (91% of LPA) with 67% of LPA in June and 105% of LPA in July. Thus among the four months, rainfall deficiency was highest during June and rainfall was excess in September. This is the second highest September rainfall (152 of LPA), after 1917 (165% of LPA). After 2010, this is the first time, rainfall during all the last three months (July to September) were above LPA. It can be also noticed that, the

highest cumulative rainfall during August-September (130 %) has been recorded in 2019 after 1983 (142 %).

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

Out of the total 36 meteorological subdivisions (Fig.5), the seasonal (June-September) rainfall was normal in 19 subdivisions (54% of the total area of the country) and excess in 10 subdivisions measuring 22% of the total area of the country and large excess in 2 subdivisions measuring 8% of the total area of the country. However, the seasonal rainfall was deficient in 5 subdivisions constituting 15% of the total area of the country. Out of the 5 deficient subdivisions, 2 subdivisions were from East & Northeast India {Gangetic West Bengal and Nagaland, Manipur, Mizoram and Tripura (NMMT)}, 3 subdivisions each were from the Northwest India (Jammu & Kashmir, West Uttar Pradesh and Haryana, Chandigarh and Delhi), but the deficiency was in 20s except for Haryana, Delhi and Chandigarh where the deficiency was 42%.

Fig.6 shows the subdivision wise monthly rainfall.

In June, only one subdivision received large excess rainfall, 5 subdivisions received normal rainfall, and 30 subdivisions received deficient or scanty rainfall. Out of the 5 normal subdivisions, one each from South Peninsula and Central India and 3 subdivisions from Northwest India. Out of the 28 deficient subdivisions, 6 were from Northwest, 4 from Northeast, 9 from Central India, and another 9 from South Peninsula. Two subdivisions which received scanty rainfall were Haryana, Chandigarh, & Delhi and West Uttar Pradesh (Northwest India). Region wise, all four geographical homogeneous regions have received below normal rainfall (32%, 37%, 31% and 30% in Northwest, Northeast, Central India, and South Peninsula respectively).

In July, 02 subdivisions (Lakshadweep and Madhya Maharashtra) received large excess rainfall, 07 subdivisions received excess rainfall, 16 subdivisions received normal rainfall, 11 subdivisions received deficient rainfall. Out of 11 deficient subdivisions, 4 were from Northwest, 2 from Northeast and 5 were from South Peninsula respectively. Region wise, South peninsula received below normal rainfall (89% of LPA) and other three geographical regions received normal rainfall.

In August, 10 subdivisions (5 from South Peninsula, one from Central India and 4 from northwest India) received large excess, 7 subdivisions (3 from Northwest India, 2 from Central India and 2 from South Peninsula respectively) were excess, 10 subdivisions (4 from Northwest India, 5 from Northeast India and one from Central India) were deficient and remaining 9 subdivisions were normal. Most

noticeable feature of rainfall distribution during August was the large excess/ excess/ normal rainfall over most parts of India except subdivisions from near foothills of Himalaya and Northeast India as monsoon trough remained to its south of normal position during most of the time. Region wise, East & Northeast India received below normal rainfall (88% of LPA) and Central India and South Peninsula received above normal rainfall (139% and 156% of LPA) and Northwest India received normal rainfall.

In September, 4 subdivisions from Northwest were deficient/scanty category, 9 subdivisions received normal rainfall (2 from South peninsula, 2 from Northwest India and 5 from East and Northeast India). Remaining 23 subdivisions received large excess/ excess rainfall. The regions that mainly benefited during September was Central India (207% of LPA) and South Peninsula (149% of LPA). All the other 2 geographical regions also experienced above normal rainfall (112% of LPA for Northwest India and 14% LPA for East and Northeast India).

Thus it is very clear that all the four homogeneous regions have experienced below normal rainfall during the month of June. However, East and Northeast region experienced below normal rainfall during all months of the season except September. At the same time, Central India experienced above normal rainfall and Northwest India received normal rainfall during last 3 months of the season. South Peninsula received above normal rainfall during last 2 months. Thus the seasonal rainfall above normal by 10% of LPA over the country as a whole was caused by the large excess to excess monthly rainfall (more than 50% of LPA) during September month of the season. The above normal rainfall over Central India and South Peninsula mainly during August and September was also another contributing 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 10 positive rainfall anomaly weeks, 2 weeks were from July (weeks ending 10th & 31st) and three weeks from August (weeks ending 7th, 14th & 21st). However, all weeks from September have positive rainfall anomaly. The highest negative weekly rainfall anomaly was recorded during the week ending 12th June (-49% from LPA) followed by the week ending 19th June. Highest positive rainfall anomaly was recorded during the week ending 30th September (181% from LPA) followed by the week ending 14th August (45% from LPA). The increase in the weekly rainfall during the season mainly associated with the low pressure systems which moved along the monsoon trough region.

The all India cumulative weekly rainfall anomaly was positive from the second week of the August till the end of the season {week ending 14th August (0.7% from LPA) to the 10% of LPA (week ending on 30th September)}. It can be seen that negative cumulative anomaly has reduced significantly from the 8th week (week ending on 31st July (-9% of LPA)). There was increment in the cumulative rainfall during 17th and 18th weeks (in September). The season ended with all India cumulative rainfall anomaly of 10% of LPA.

6. Verification of the Long Range Forecasts

Based on an indigenously developed statistical model, it was predicted on 15th May 2019 that monsoon will set in over Kerala on 6th June with a model error of ± 4 days. The actual monsoon onset over Kerala was on 8th June and therefore the forecast was correct.

The long range forecast for the 2019 southwest monsoon rainfall was issued in 3 stages. The first stage long range forecast issued on 15th April consisted of only forecast for seasonal (June-September) rainfall over the country as a whole. In the second stage (31st May), along with the update of the forecast issued in April, 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 (1st 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 96% of LPA with a model error of $\pm 5\%$ of LPA. The update issued in May for this forecast was (96% of LPA) with a model error of $\pm 4\%$ of LPA. The actual seasonal rainfall for the country as a whole was 110% of LPA. Thus the both the forecasts were not within forecast limits and were underestimated the rainfall value.

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 94%, 100%, 91% & 97% of the LPA respectively all with model errors of $\pm 8\%$. The actual rainfalls over Northwest India, Central India, Northeast India and South Peninsula were 98%, 129%, 88% and 116% of the LPA respectively. Thus the forecasts of season rainfall over the Central India and South Peninsula regions were underestimate to the actual season rainfalls. However, forecast for Northwest India and Northeast India are within the forecast limits and were correct. The actual rainfalls of Central India and South Peninsula were more

than the forecasted values by 29% and 16% LPA respectively. Whereas, the actual season rainfall over Northwest India and Northeast India were 2% and 12% less than forecasted value. Thus, the forecasts of the seasonal rainfalls for the two of the four geographical regions were correct.

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 130% of LPA, which is 22% more than the upper forecast limit of (100%+8% = 108% of LPA). Thus, the forecast for the rainfall during the second half of the monsoon season over the country as a whole was also underestimate to the actual rainfall and was not correct.

The forecasts for the monthly rainfall over the country as a whole for the months of July & August issued in June were 95% & 99% of LPA respectively with a model error of $\pm 9\%$. Thus the monthly forecasts for the July and August rainfalls were also underestimate to the actual monthly rainfalls (105% & 115% of LPA respectively). But the actual rainfalls during July is 1% more than the upper forecast limit and that of August is 7% more than the upper forecast limit and the forecasts were therefore not correct.

The Table below gives the summary of the verification of the long range forecasts issued for the 2019 Southwest monsoon.

Table: Details of long range forecasts and actual rainfall.

Region	Period	Forecast (% of LPA)			Actual Rainfall (% of LPA)
		15 th April	31 st May	1 st August	
All India	June to September	96 \pm 5	96 \pm 4	96	110
Northwest India	June to September		94 \pm 8		98
Central India	June to September		100 \pm 8		129
Northeast India	June to September		91 \pm 8		88
South Peninsula	June to September		97 \pm 8		116
All India	July		95 \pm 9		105
All India	August		99 \pm 9		115
All India	August to September			100 \pm 8	130

As seen in the table, the forecasts for the season rainfalls over two of the four broad geographical regions were correct. However, the forecasts for the seasonal rainfall over the country as a whole & and for Central India and South Peninsula, and the rainfall during second half of the monsoon season over the country as a whole as well as July and August monthly forecast were not correct.

From the discussions in the section 5, it is very clear that Central India and South Peninsula experienced excess/ normal rainfall during second half of the season and large excess rainfall in the month of September. East and Northeast

region experienced below normal rainfall and northern part of northwest India also experienced below normal rainfall during most of the monsoon season. The seasonal rainfall was 10% above of LPA over the country as a whole was mainly caused by the large monthly excess rainfall (more than 50% of LPA) during September month. The above normal rainfall over South Peninsula and Central India during August was also another factor.

While issuing the long range forecast in the month of April, El Nino conditions were prevailed over Pacific Ocean. IMD's analysis of weakening of El Nino episode prevailing since first quarter of 2018, to neutral in the second half of the monsoon season and the emergence of positive Indian Ocean Dipole (IOD) in the middle of the monsoon season resulting in increased rainfall activity in the second half of the season came correct. Whereas, the June rainfall was deficient (67% of LPA) due to the negative impact of the prevailing El Nino and delayed onset of monsoon over Kerala (8th June), the monthly rainfalls during the latter 3 months were all above the LPA. It may be noted that IMD forecast for monsoon onset over Kerala (6th June with model error of ± 4 days) was correct. Due to weakening of the El Nino conditions and emergence of the positive IOD during July, rainfall activity increased significantly since last week of July and this momentum of good rainfall activity continued through the second half of the monsoon season. However, the rainfall during the second half was more than expected by IMD mainly due to the longer life of a series of low-pressure systems formed over the region, which mostly moved along the monsoon trough resulting in above normal season rainfalls over Central India & South Peninsula and below normal season rainfall over North-East India. Seasonal rainfall over North-West India was normal. Thus, IMD's forecast for geographical rainfall distribution of highest rainfall over central India and lower rainfall over North-East India also came correct though the received rainfall over Central India and South Peninsula was more than the upper forecast limits. The seasonal forecast issued by IMD was within the forecast limit up to 25th September 2019, but the last week rainfall was 181% of LPA made all India rainfall to above normal category. Overall, the impact of synoptic scale systems on the monsoon performance was very significant this year 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 the reservoir levels and rain-fed sowing trends also give a true picture of the monsoon performance.

The analysis at the end of the monsoon season 2019 reveals that the rainfall is well distributed across the country barring some parts of north India and east & North East India. The acreage data of the Ministry of Agriculture suggest that overall crop acreage during the Kharif season 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 2019- 20.

Figure 8 indicates higher soil moisture quantum all over India except for west Rajasthan and adjoining areas of Haryana and Punjab and also over small areas in interior Tamil Nadu suggests that rainfall received is homogenously distributed across the country.

Such reasonably good distribution of the soil moisture across country is the primary reason for the good acreage of rainfed crops during kharif-2019. Based on the realized rainfall distribution, the response of the agricultural operations in terms of overall kharif crop acreage in 2019 with regard to kharif in 2018 is presented in the table below:

Progress of Area Coverage under Kharif crops as on 27.09.2019

Area: In lakh hectare

S. No.	Crop	Normal Area (DES)	Normal of Corresponding week	Area Sown		Increase(+)/Decrease(-) over	
				2019	2018	Normal of Corresponding week	2018
1	Rice	396.25	380.21	382.34	386.92	2.13	-4.58
2	Pulses	119.89	125.80	134.02	136.40	8.22	-2.38
a	Arhar	43.00	43.71	45.82	45.75	2.11	0.07
b	Urdbean	30.77	34.71	38.83	39.56	4.12	-0.73
c	Moongbean	27.50	29.61	31.16	34.25	1.55	-3.09
d	Kulthi	2.19	0.88	0.78	0.74	-0.10	0.04
e	Other pulses	16.44	16.88	17.43	16.11	0.54	1.31
3	Coarse cereals	188.39	181.41	179.92	176.88	-1.49	3.04
a	Jowar	21.61	18.81	17.10	17.75	-1.71	-0.65
b	Bajra	74.39	68.05	66.05	65.32	-2.00	0.73
c	Ragi	11.53	10.33	9.99	8.69	-0.34	1.30
d	Small millets	6.18	5.15	4.87	5.18	-0.29	-0.31
e	Maize	74.68	79.07	81.91	79.94	2.84	1.97
4	Oilseeds	181.96	181.62	179.48	179.28	-2.14	0.20
a	Groundnut	42.44	40.59	39.32	40.20	-1.27	-0.88
b	Soybean	111.49	112.42	113.99	113.10	1.57	0.89
c	Sunflower	1.84	1.53	1.03	1.12	-0.49	-0.09
d	Sesamum	14.13	15.63	13.72	14.19	-1.92	-0.47
e	Niger	2.41	2.07	2.05	1.90	-0.03	0.14
f	Castor	9.66	9.37	9.38	8.77	0.01	0.62
5	S cane	48.32	50.19	52.45	55.51	2.26	-3.06
6	Jute & Mesta	7.87	7.39	6.84	.20	-0.55	-0.37
7	Cotton	120.93	117.88	127.67	1	9.80	6.62
	Total	1063.61	1044.48	1062.72	1063	18.24	-0.52

Similarly, the reservoir levels monitored by the Central Water Commission (CWC) till 26th Sept., 2019 stands at 121% of the 10-year mean storages and is 17% higher than the storages of corresponding period during 2018. 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
The 31 January, 2020
Magha 1941 (SE)

(M Mohapatra)
Director General of Meteorology

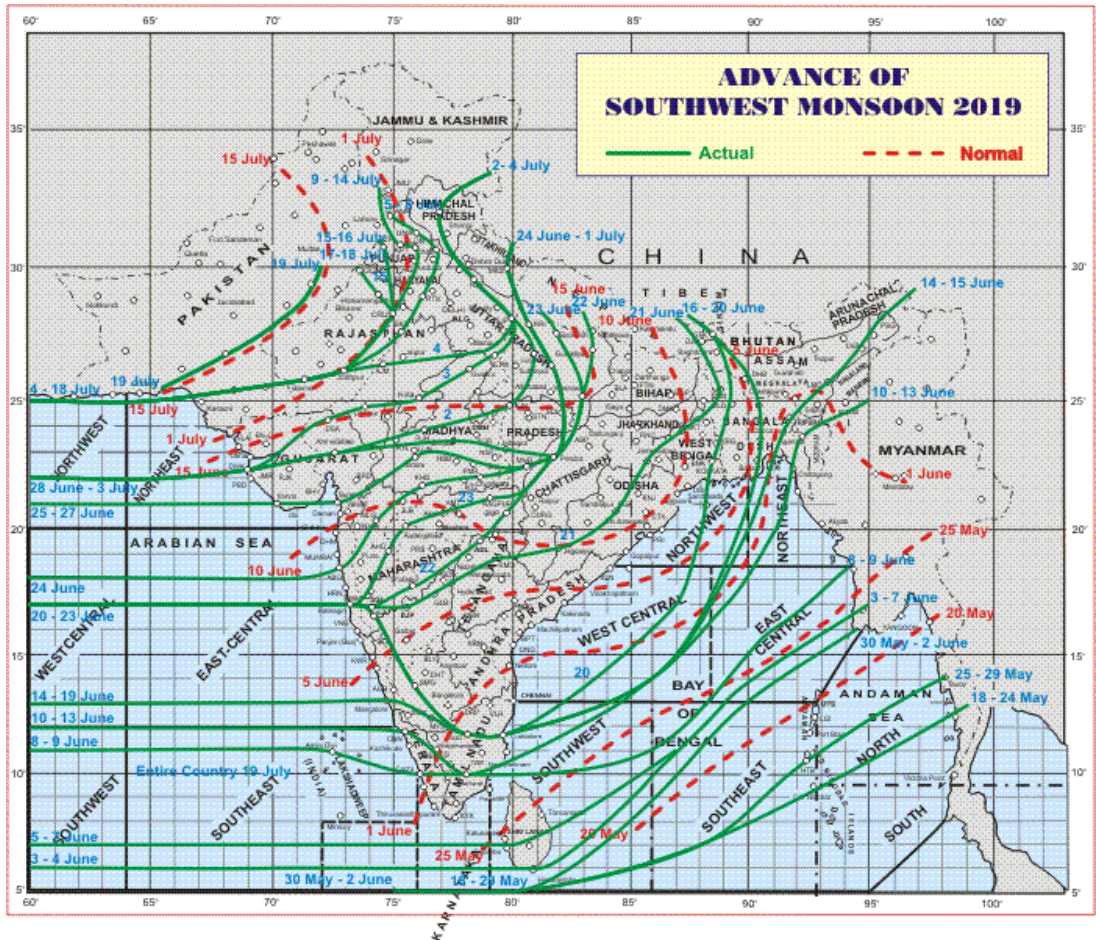


Fig.1: Progress of Southwest Monsoon – 2019

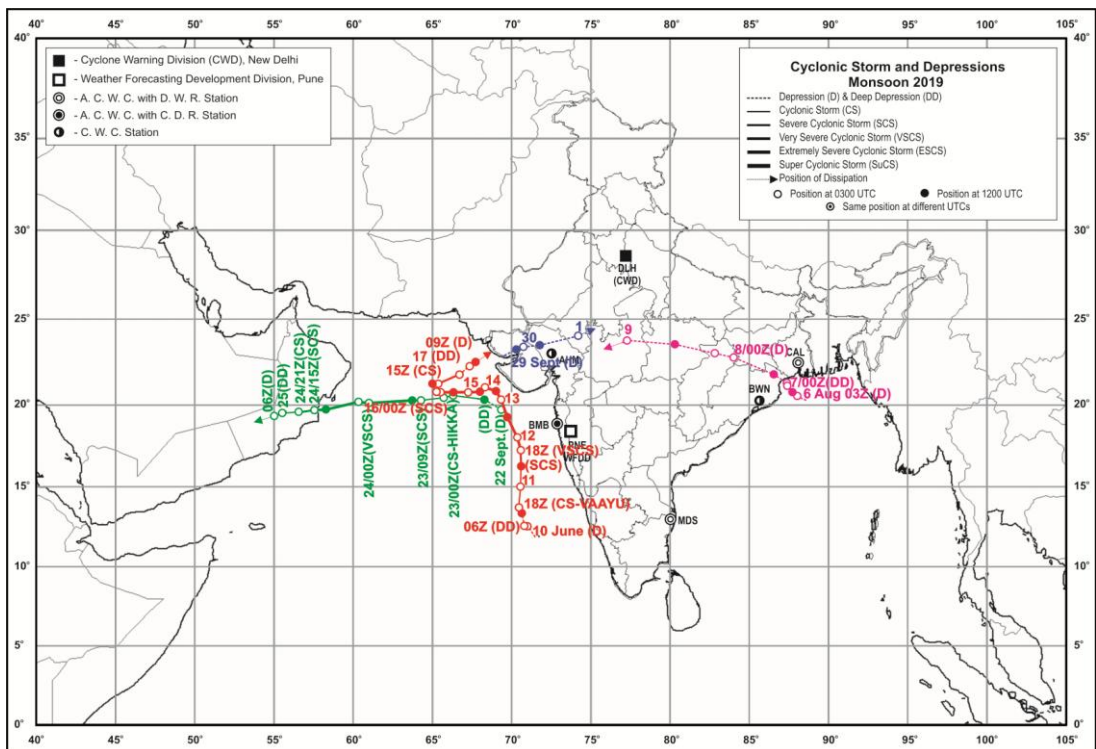


Fig.2: Track of the monsoon Depressions and Cyclonic Storms

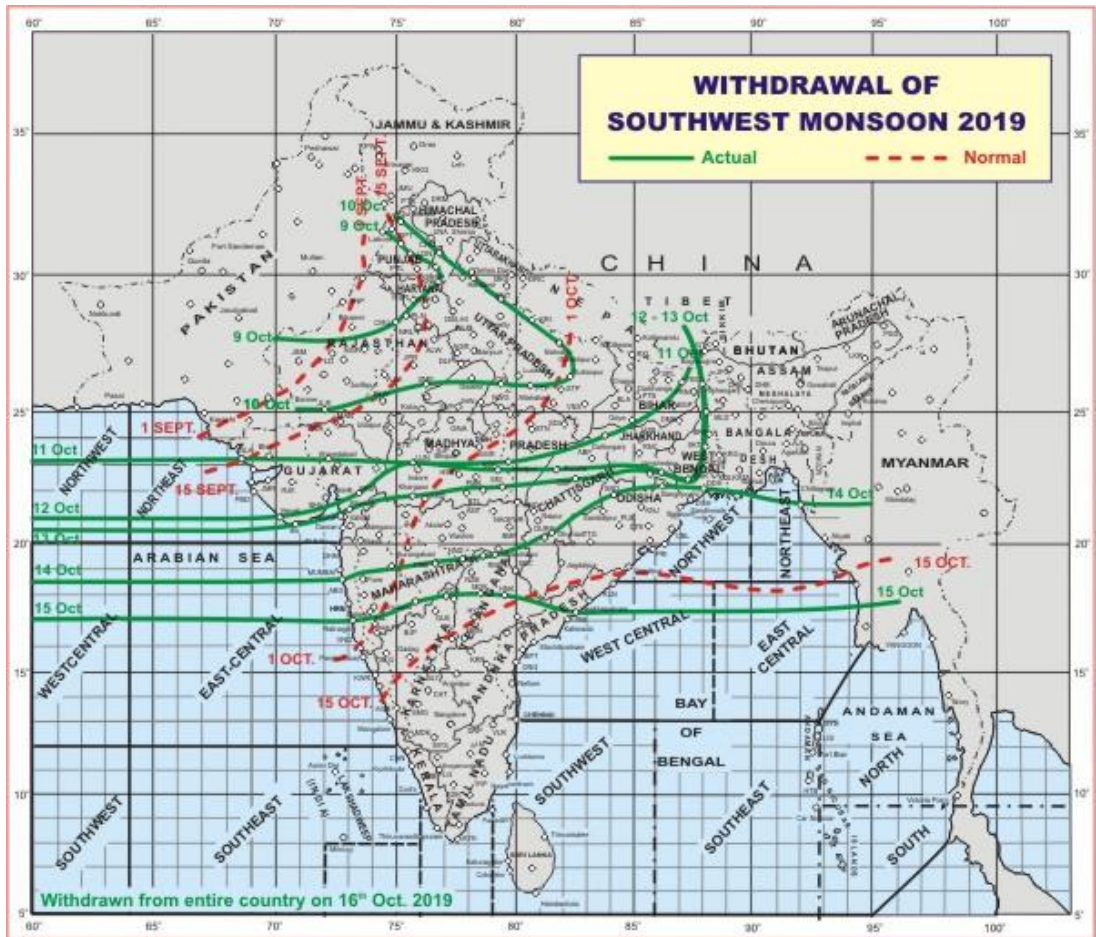
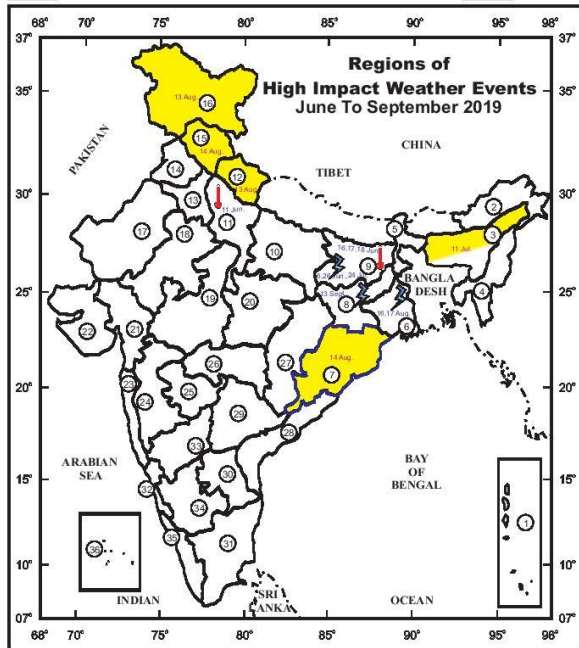
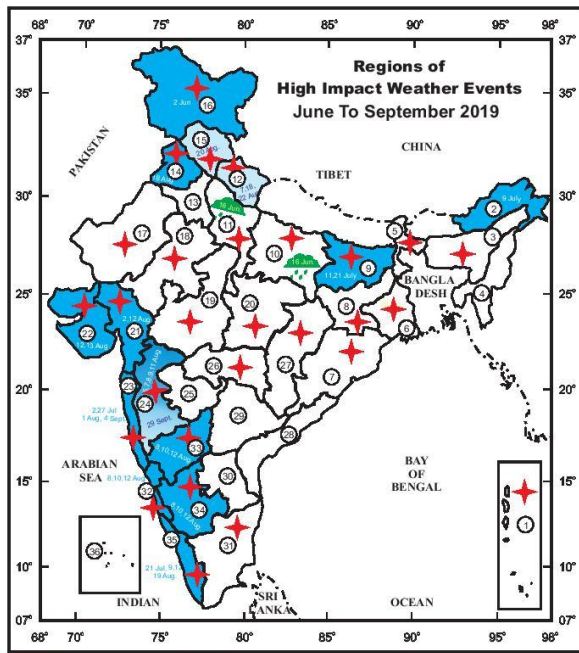


Fig.3: Isochrones of withdrawal of southwest monsoon - 2019.



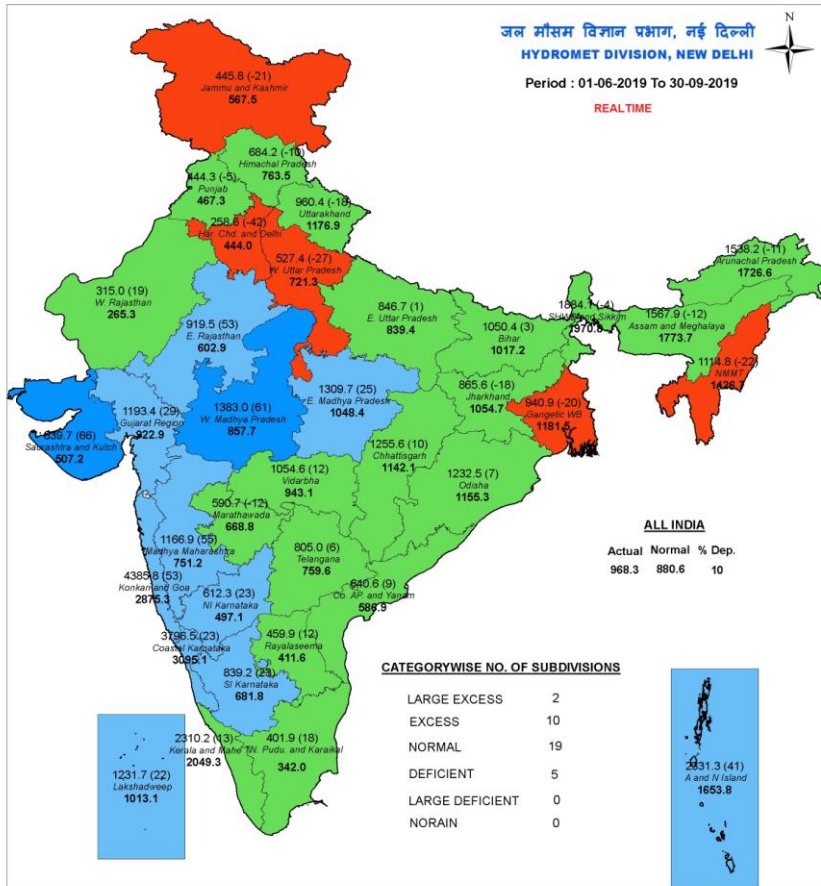
- Rainfall (≥ 25 cm)**
- 01 13 Jun.: - 31 - Long Islands.
 - 03 17 Jun.: - 40 - Cherrapunji (Rkm); 38 - Mawsynram; 36 - Cherrapunji; 26 Jun.: - 32 - Gossaigaon; 30 - Kokrajhar; 27 Jun.: - 40 - Mawsynram; 31 - Cherrapunji (Rkm); 29 - Cherrapunji; 28 Jun.: - 33 - Mawsynram; 31 - Cherrapunji; 26 - Cherrapunji (Rkm); 7 Jul.: - 28 - Mawsynram; 9 Jul.: - 38 - Cherrapunji (Rkm); 33 - Cherrapunji; 29 - Mawsynram; 10 Jul.: - 44 - Mawsynram; 39 - Cherrapunji (Rkm); 26 - Cherrapunji; 11 Jul.: - 40 - Cherrapunji (Rkm); 37 - Cherrapunji; 33 - Mawsynram; 22 Jul.: - 30 - Gossaigaon; 23 Jul.: - 35 - Gossaigaon; 32 - Kokrajhar; 29 - Beki Mathungan; 28 - Kajogaon AWS; 24 Jul.: - 27 - Gossaigaon; 14 Sep.: - 25 - Cherrapunji.
 - 05 16 Jun.: - 26 - Mangal; 25 Jun.: - 31 - Buxaduar; 26 Jun.: - 41 - Alipurduar Cwc and Alipurduar PTO each; 33 - Kumargram; 27 - Barobhisha; 25 - Hasimara; 10 Jul.: - 26 - Kumargram; 22 Jul.: - 27 - Alipurduar Cwc and Alipurduar PTO each; 23 Jul.: - 28 - Buxaduar; 24 Jul.: - 40 - Barobhisha; 29 - Neora; 26 - Murti; 25 - Chepan.
 - 06 26 Aug.: - 25 - Kharagpur (I.T).
 - 07 7 Aug.: - 38 - Lanjigarh; 32 - Kashipur; 31 - Kotaghar; 29 - Phiringia ARG; 26 - Kotraguda; 8 Aug.: - 25 - Lakera and Deogaon each; 13 Aug.: - 45 - Madanpur Rampur; 35 - Kantamati; 32 - Baliguda; 31 - Saintala ARG; 29 - Belgaon; 26 - Bolangir; 14 Aug.: - 55 - Bolangir; 7 Sep.: - 25 - Anandpur.
 - 08 30 Sep.: - 28 - Rajmahal.
 - 09 22 Jun.: - 43 - Bagaha; 12 Jul.: - 36 - Lalbegiaghata; 32 - Dhengbridge; 26 - Mothari and Minapur each; 27 - Maharajganj; 26 - Talpur; 25 - Darauli; 13 Jul.: - 25 - Sonbarsa; 29 Sep.: - 29 - Rosera; 30 Sep.: - 25 - Rosera.
 - 10 11 Jul.: - 26 - Jaunpur Tehsil; 25 - Ballia; 28 Sep.: - 30 - Jaunpur Tehsil.
 - 11 25 Jun.: - 31 - Baheri.
 - 12 6 Aug.: - 27 - Banbasa.
 - 14 18 Aug.: - 27 - Balachaur.
 - 15 18 Aug.: - 36 - Naina Davi; 32 - Ghumarwin; 28 - Berthin AGRO; 27 - Jhandutta.
 - 16 31 Jul.: - 34 - Udhampur IAF; 29 - Katra.
 - 17 16 Aug.: - 28 - Pali.
 - 18 19 Jun.: - 28 - Pratappgarh; 28 Jul.: - 26 - Bundi; 16 Aug.: - 30 - Begu; 26 - Chabra; 14 Sep.: - 27 - Pratappgarh; 22 - Dug.
 - 19 30 Jul.: - 25 - Sehore - AWS; 5 Aug.: - 25 - Thandla; 14 Sep.: - 25 - Susnar.
 - 20 9 Sep.: - 31 - Seoni.
 - 21 29 Jun.: - 31 - Vapi; 30 Jun.: - 26 - Khargam; 1 Jul.: - 29 - Umergam; 28 - Daman FMO, Daman, Khanvel and Valsada each; 25 - Pardi; 7 Jul.: - 38 - Vapi; 30 - Daman FMO and Silvassa each; 8 Jul.: - 31 - Khanvel; 26 Jul.: - 29 - Waghai; 30 Jul.: - 29 - Dharampur; 1 Aug.: - 56 - Vadodara City; 3 Aug.: - 26 - Kaprada; 4 Aug.: - 42 - Umerpada; 39 - Khamhat; 33 - Olpad; 30 - Waghai and Daman each; 27 - Daman FMO and Vandsa each; 26 - Kaprada, Dharampur and Anand each; 25 - Nanipalson and Vapi each; 5 Aug.: - 59 - Umerpada; 45 - Mangrol; 36 - Kaprada; 35 - Hansot; 32 - Dediapada; 28 - Uka; 6 Aug.: - 27 - Waghai; 9 Aug.: - 26 - Quant; 9 Aug.: - 34 - Chhotla Udepur; 28 - Quant; 10 Aug.: - 34 - Mahudha; 32 - Dhandhuka; 30 - Kadi; 26 - Gatteshwar; 5 Sep.: - 27 - Vapi; 10 Sep.: - 39 - Umerpada.
 - 22 10 Aug.: - 38 - Barvala; 29 - Gadhda and Botad each; 26 - Ranpur; 11 Aug.: - 32 - Nakhatrana; 27 - Naliya and Tankara each; 26 - Morbi; 25 - Abdasa; 30 Sep.: - 33 - Bhanvad.
 - 23 29 Jun.: - 45 - Palgharagi; 35 - Matheran; 33 - Khalapur; 32 - Vasai; 29 - Karjatagi; 28 - Pen; 27 - Panvelagi and Bhira each; 25 - Bhiwandi; 1 Jul.: - 34 - Palgharagi; 30 - Dahanu; 29 - Talasan; 2 Jul.: - 38 - Palgharagi; 37 - Mumbai (SCZ); 32 - Vasai; 28 - Thane; 27 - Mangaon; 26 - Mhasla; 23 Jul.: - 28 - Ratnagiri; 25 - Rajapur; 24 Jul.: - 25 - Guhagarhi; 27 Jul.: - 44 - Matheran; 40 - Pen; 33 - Murbad; 30 - Ulhasnagar; 28 - Ambemath; 27 - Karjatagi; 26 - Wakavaliagi; 28 Jul.: - 28 - Karjatagi; 27 - Panvelagi; 3 Aug.: - 33 - Bhira; 29 - Roha; 25 - Poladpur; 4 Aug.: - 49 - Pen; 44 - Matheran; 41 - Alibag; 37 - Thane; 34 - Belapur (Thane); 31 - Kalyan, Vikramgad and Wada each; 29 - Karjatagi; 27 - Bhira, Ambemath and Tala each; 25 - Sudhagad Pali; 5 Aug.: - 45 - Jawhar; 29 - Wada; 28 - Mokhada - FMO; 27 - Ratnagiri; 25 - Matheran; 6 Aug.: - 37 - Sawantwadi; 27 - Kankavli; 26 - Vaibhawadi; 7 Aug.: - 32 - Mangaon; 4 Sep.: - 27 - Khalapur; 26 - Mangaon and Roha each; 5 Sep.: - 27 - Vasai.
 - 24 29 Jun.: - 33 - Lonavalaagi; 11 Jul.: - 29 - Lonavalaagi; 27 Jul.: - 29 - Lonavalaagi; 24 - Mahabaleshwar; 28 Jul.: - 29 - Lonavalaagi; 30 Jul.: - 29 - Lonavalaagi; 2 Aug.: - 27 - Mahabaleshwar; 3 Aug.: - 28 - Mahabaleshwar; 4 Aug.: - 31 - Trimbakshwar and Mahabaleshwar each; 30 - Lonavalaagi; 26 - Harsul - FMO; 5 Aug.: - 40 - Trimbakshwar; 38 - Mahabaleshwar; 37 - Igatpur; 28 - Gaganbawada; 26 - Harsul - FMO; 6 Aug.: - 33 - Gaganbawada and Mahabaleshwar each; 32 - Radhanagari; 7 Aug.: - 28 - Mahabaleshwar; 8 Aug.: - 27 - Mahabaleshwar; 9 Aug.: - 27 - Dhadgaon / Akrani - Hydro; 8 Sep.: - 25 - Gaganbawada.
 - 26 30 Jul.: - 27 - Mulchera; 3 Aug.: - 27 - Pauni; 7 Sep.: - 29 - Bhiwapur.
 - 27 3 Aug.: - 25 - Bijapur; 8 Aug.: - 30 - Deobhog; 27 - Lohandiguda; 6 Sep.: - 29 - Jagdalpur.
 - 31 9 Aug.: - 27 - Chinnakalan; 35 - Valparai; 26 - Valparai Taluk Office and Devalia each; 25 - G Bazar.
 - 32 26 Jul.: - 25 - Kollur; 6 Aug.: - 28 - Siddapur; 27 - Kollur and Manki each; 9 Aug.: - 30 - Yellapur; 10 Aug.: - 31 - Subramanya.
 - 33 8 Aug.: - 27 - Londa.
 - 34 3 Aug.: - 25 - Kottigehara; 6 Aug.: - 28 - Hosanagar; 7 Aug.: - 29 - Bhagamandala; 28 - Kottigehara; 25 - Hosanagar; 8 Aug.: - 31 - Kottigehara and Ponnampet Pwd each; 27 - Bhagamandala; 26 - Kalasa and Stinger HMS each; 9 Aug.: - 40 - Bhagamandala; 29 - Hunchadakkatte; 27 - Kottigehara Virajpet and Kalasa each; 26 - Ponnampet Pwd; 10 Aug.: - 57 - Kottigehara; 39 - Hunchadakkatte; 32 - Kalasa; 29 - Mudgere; 27 - Linganamakki HMS; 26 - Bhagamandala; 5 Sep.: - 26 - Bhagamandala.
 - 35 20 Jul.: - 31 - Kudulu; 28 - Hosdurg; 8 Aug.: - 26 - Mananthavady; 9 Aug.: - 40 - Alathur; 34 - Ottapalam; 32 - Kollamkode; 31 - Mannakudi; 30 - Vadakara; 29 - Angadipuram, Palakkad and Vythiri each; 28 - Perumbikulam; 27 - Peermade To; 26 - Ambalavayal; 25 - Mananthavady; 10 Aug.: - 30 - Vadakara; 29 - Ottapalam.

Fig. 3: Areas and Dates of High Impact Weather Events during the 2019 Southwest monsoon

Fig.4: Areas and dates of high impact weather events during the 2019 southwest Monsoon.



SUBDIVISION RAINFALL MAP



Legend
 Large Excess [60% or more] Excess [20% to 59%] Normal [-19% to 19%] Deficient [-59% to -20%] Large Deficient [-99% to -60%] No Data [-100%] No Rain

NOTES :
 a) Rainfall figures are based on operation data.
 b) Small figures indicate actual rainfall (mm), while bold figures indicate Normal rainfall (mm).
 c) Percentage Departures of rainfall are shown in brackets.

Fig.5: Sub-division wise rainfall distribution over India during southwest monsoon season (June to September) – 2019.

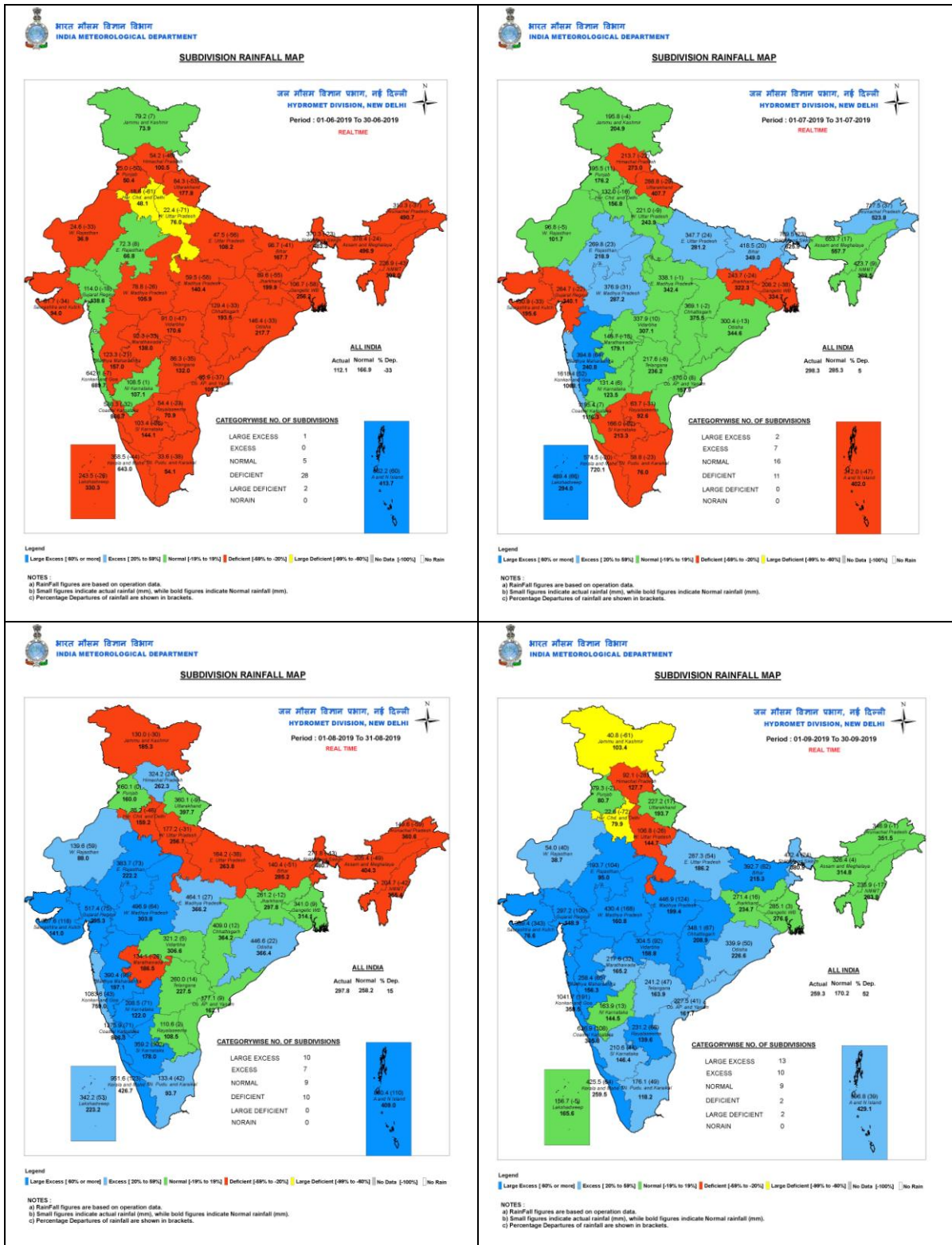
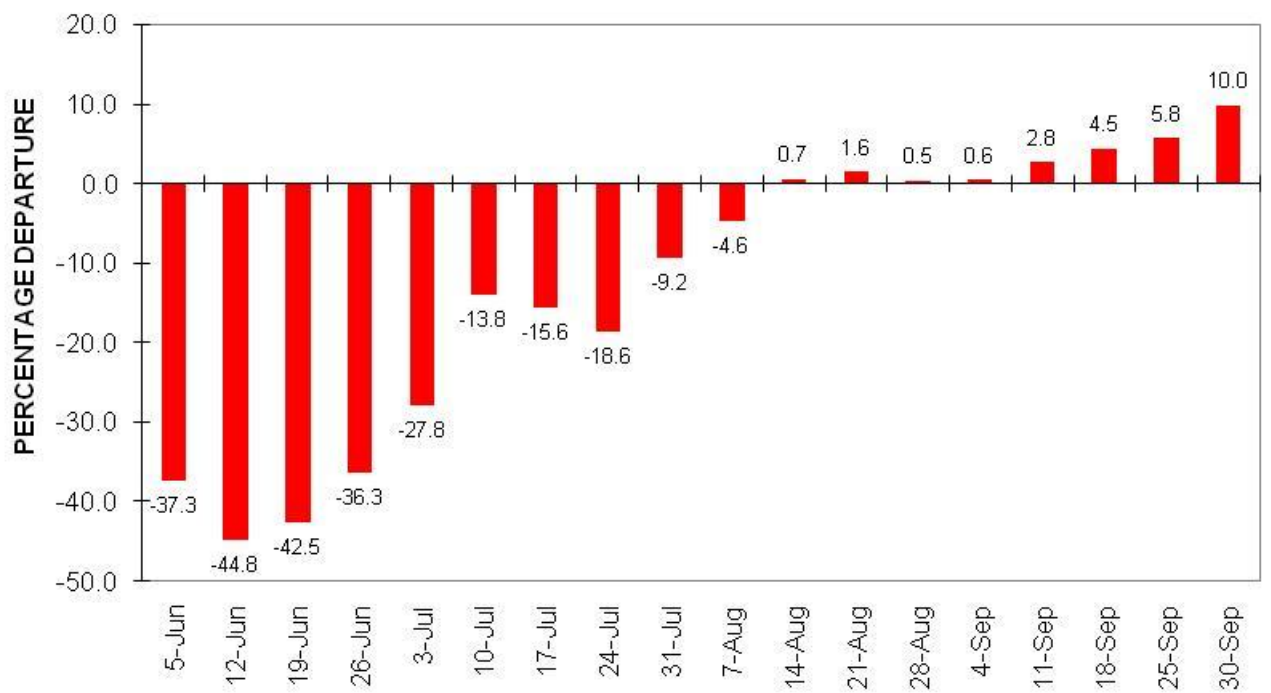
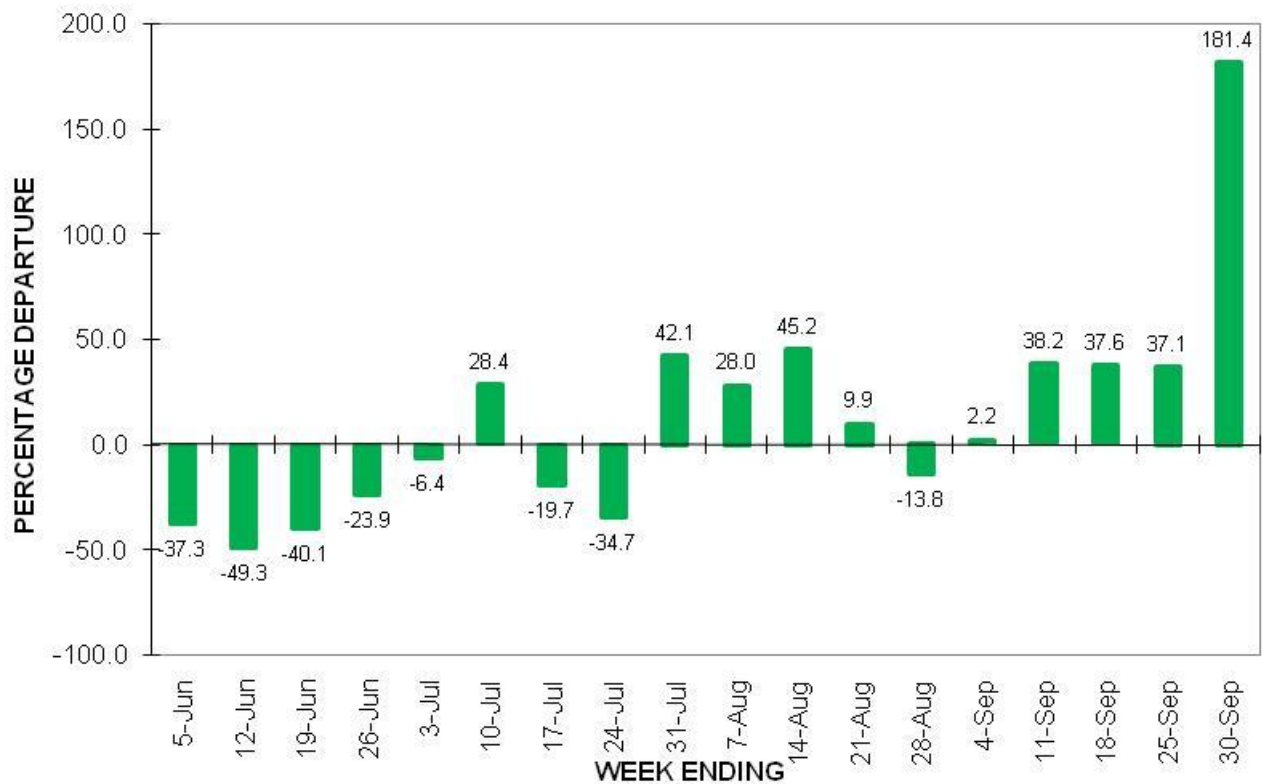
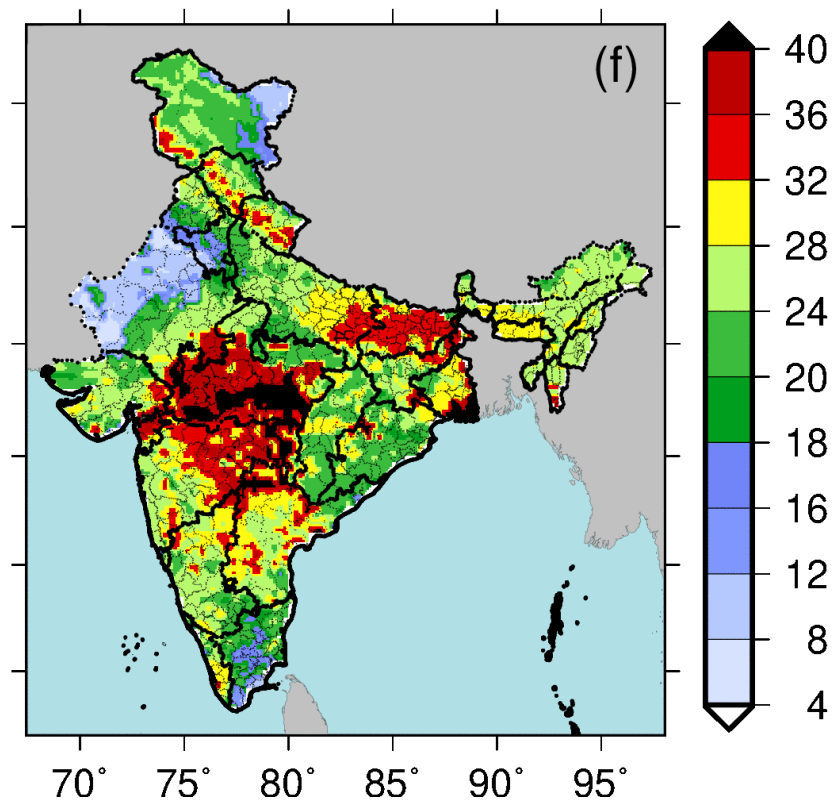


Fig.6: Sub-division wise monthly rainfall distribution over India during southwest monsoon season – 2019



FOR THE PERIOD FROM 1ST JUNE ONWARDS

Fig.7: Week - by - Week Progress of the all India weekly and cumulative weekly monsoon rainfall anomalies during the 2019 southwest monsoon season. The rainfall anomalies are expressed as the percentage departure from long period average (LPA).



(Figure 8: Soil Moisture distribution over India as on 30 September 2019)