Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
India Meteorological Department
2023 Southwest Monsoon End of Season Report

HIGHLIGHTS

- Rainfall over the country as a whole during monsoon season (June-September), 2023 was 94% of its long period average (LPA).
- Seasonal rainfalls over Northwest India, Central India, South Peninsula and Northeast (NE) India were 101%, 100%, 92% and 82% of respective LPA.
- The southwest monsoon seasonal (June to September) rainfall over the monsoon core zone, which consists of most of the rainfed agriculture regions in the country received 101% of LPA and thus was normal (94-106% of LPA).
- Out of the total 36 meteorological subdivisions, 3 subdivisions constituting 9% of the total area of the country received excess, 26 subdivisions received normal rainfall (73% of the total area) and 7 subdivisions (18% of the total area) received deficient season rainfall. The 7 Meteorological subdivisions which got deficient rainfall are Nagaland, Manipur, Mizoram & Tripura (NMMT), Gangetic West Bengal, Jharkhand, Bihar, East UP, South interior Karnataka and Kerala.
- Monthly rainfall over the country as a whole was 91% of LPA in June, 113% of LPA in July, 64% of LPA in August, and 113% of LPA in September.
- Southwest monsoon current advanced to the south Andaman Sea and Nicobar Islands in time (on 19th May, 3 days ahead of its normal date). However, further advance thereafter was sluggish. It set in over Kerala on 8th June, 7 days behind the normal date and covered the entire country by 2nd July, 6 days ahead of normal date. Monsoon withdrawal commenced from west Rajasthan on 25th September (with a delay of 8 days).
- The forecast for monsoon onset over Kerala for this year was correct, which is the seventeenth consecutive correct forecast for this event except the year 2015 since the commencement of this forecast in 2005. The Forecast date of onset of monsoon over Kerala was 4th June with a model error of ± 4 days and the monsoon set in over Kerala on 8th June.
- The forecasts for the rainfall over the country during the season as a whole could be predicted well as the realized rainfall is 94% of LPA against the forecast of 96% ± 4%.

1. Onset and Advance of Southwest Monsoon

The advance of the Southwest Monsoon began on May 19th in the southeast Bay of Bengal, Nicobar Islands, and south Andaman Sea, due to persistent south-westerly winds and widespread rainfall. By 30th May, it had extended its reach to the southwest Bay of Bengal, more parts of the southeast Bay of Bengal, the Andaman Sea, Andaman and Nicobar Islands, and portions of the east-central Bay of Bengal. Continuing its advance, the monsoon covered areas such as the south Arabian Sea, Maldives, and the Comorin region on 1st June, followed by additional parts of the south Bay of Bengal and east-central Bay of Bengal on 2nd June 2023.

The monsoon reached Kerala on 8th June, 7 days after the normal date of onset over Kerala. From there, it progressed further, encompassing the central Arabian Sea, the remaining parts of Kerala, portions of Karnataka, most of the north-eastern states, Goa, Konkan, Tamil Nadu, Puducherry, many parts of Andhra Pradesh and many parts of Bay of Bengal by the second week of June. On 19th June, it extended to more areas, including parts of Karnataka, Andhra Pradesh, some more parts of the Bay of Bengal, and parts of Gangetic West Bengal and Jharkhand. During the last week of June, it covered a vast area, including Odisha, Telangana, Chhattisgarh, Jammu and Kashmir, Ladakh, Uttar Pradesh, Himachal Pradesh, Vidarbha, Haryana, north Arabian Sea, Gujarat, Rajasthan. On 2nd July, it covered the remaining parts of the country, a remarkable six days ahead of the usual date of 8th July. The onset dates of monsoon 2023 are shown in **Fig.1**.

With the reduction in the rainfall and formation of the anti-cyclonic circulation in lower troposphere, withdrawal of the SW-monsoon 2023 began on 25th September against the normal date of 17th September. The withdrawal dates of the Southwest monsoon season 2023 are shown in **Fig.2**.

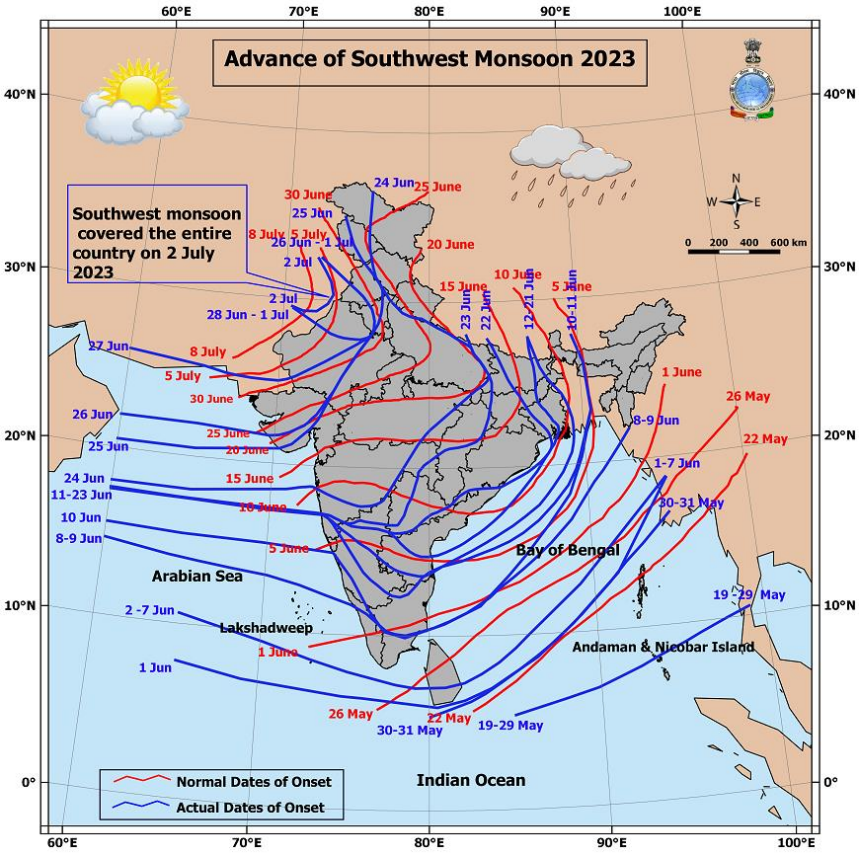


Fig.1: Isochrones of advance of monsoon, 2023

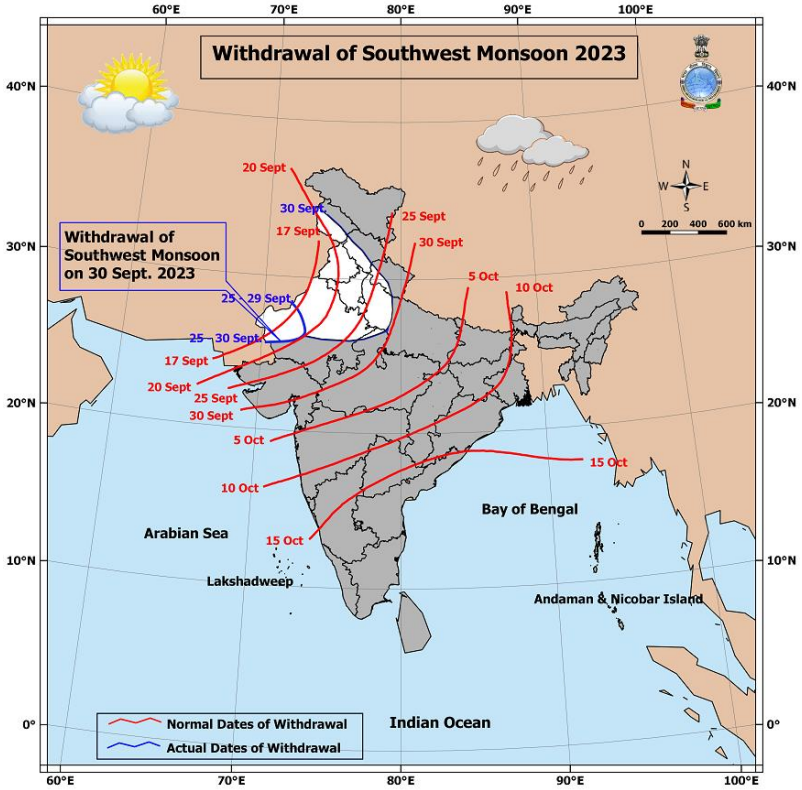


Fig.2: Isochrones of withdrawal of southwest monsoon – 2023 as on 30 Sep. 2023.

2. Chief Synoptic Features

During the season, there were 15 low pressure systems formed in the Indian region. The track of low pressure systems are given in **Fig.3**. Their month-wise frequency and intensity are given in the **Table 1** below.

Table 1. Number of low pressure systems in SW Monsoon 2023

Month	L	WML	D	DD	ESCS	Total
June	0	2	0	0	1	3
July	3	2	0	0	0	5
August	1	0	0	1	0	2
September	1	3	1	0	0	5
Monsoon-23	5	7	1	1	1	15

L : Low, WML: Well marked low, D: Depression, DD: Deep Depression, ESCS: Extremely severe cyclonic storm.

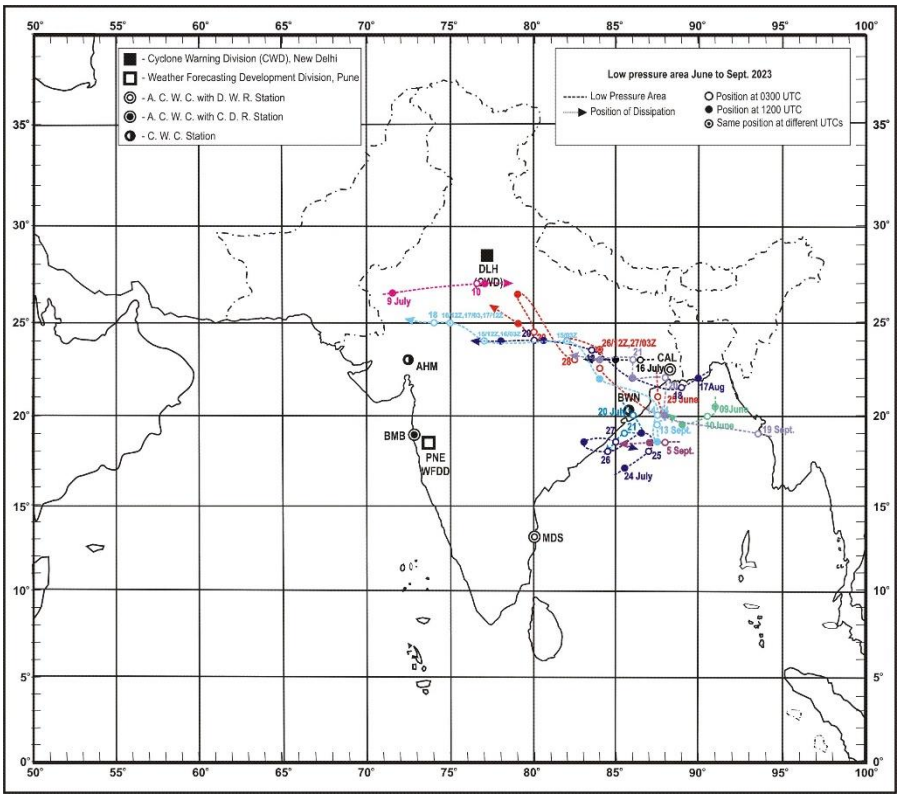


Fig.3: Track of the low pressure systems formed during 2023 monsoon season.

These low pressure systems helped to get a good amount of rainfall in July and September. Out of these low pressure systems one intensified into an extremely

severe Cyclonic storm ("BIPORJOY") that formed over the Northeast Arabian Sea during 6th to 19th June. There were two monsoon depressions during the season , one in August(1-3 August) and another on 30th September against the normal frequency of 6. The tacks of the cyclone and depression formed during the 2023 southwest monsoon season are given in **Fig.4.**

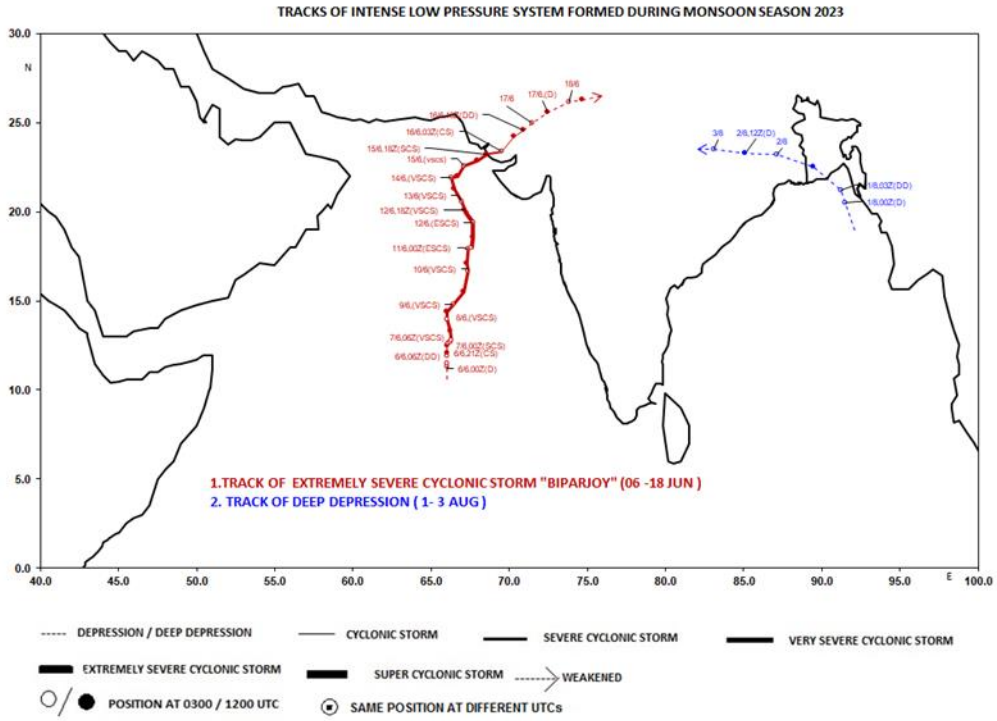


Fig.4: Track of the monsoon Depressions and Cyclonic Storms

5. Rainfall Distribution

The realized 2023 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 **Table 2**.

Table 2. Season (June to September) rainfall

Region	Long Period Average (LPA) (mm)	Actual Rainfall for 2023	
		Rainfall (mm)	Rainfall (% of LPA)
All India	868.6	820.0	94.4
Northwest India	587.6	593.0	101

Central India	978.0	981.7	100.4
East & Northeast India	1367.3	1115.0	82
South Peninsula	716.2	659.0	92
Monsoon Core Zone	832.2	840.4	101

Monthly & second half of the monsoon season rainfall over the country as a whole (All India)

Month	LPA (mm)	Actual Rainfall for 2023	
		Rainfall (mm)	Rainfall (% of LPA)
June	165.4	151.1	91
July	280.5	315.9	113
August	254.9	162.7	64
September	167.9	190.0	113
August + September	422.8	352.7	83

As seen in the table above, the 2023 season rainfall over the country as a whole (94% of LPA) was less than the long period average (LPA). The 2023 season rainfall over two of the four geographical regions of the country (except Northwest India and central India) were also less than the respective LPAs. The highest rainfall (101% of LPA) was received by Northwest India and lowest rainfall (82% of LPA) was received by East & Northeast India. Central India and East & South India received season rainfalls of 100% of LPA and 91% of LPA respectively. The monthly rainfall over the country as a whole was less than LPA during two months of the season (91% of LPA in June , 64 % of LPA in August) and were more than LPA during the months of July (113% of LPA in July) and September (113% of LPA).

The country as a whole received rainfall of 105% of LPA during the first half (91% of LPA in June and 113% of LPA in July), which was more than that during the second half (83% of LPA) with 64% of LPA in August and 113% of LPA in September. Thus, among the four months, rainfall deficiency was highest during August and rainfall was excess in July and September. **Fig.5** shows the subdivision wise season (June to September) rainfall.

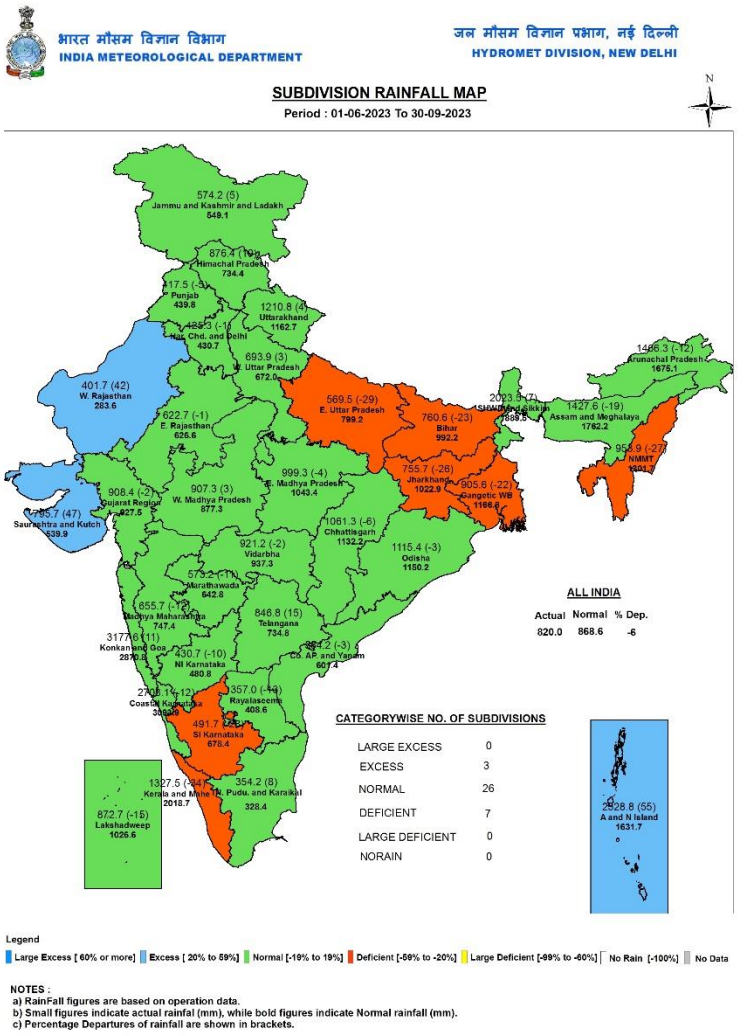


Fig.5: Sub-division wise rainfall distribution over India during southwest monsoon season (June to September) – 2023.

Out of the total 36 meteorological subdivisions, 3 subdivisions constituting 9% of the total area of the country received excess, 26 subdivisions received normal rainfall (73% of the total area) and 7 subdivisions (18% of the total area) received deficient season rainfall (**Fig. 5**). These 7 Met subdivisions which got deficient rainfall are Nagaland, Manipur, Mizoram and Tripura (NMMT), Gangetic West Bengal, Jharkhand, Bihar, East UP, South interior Karnataka and Kerala.

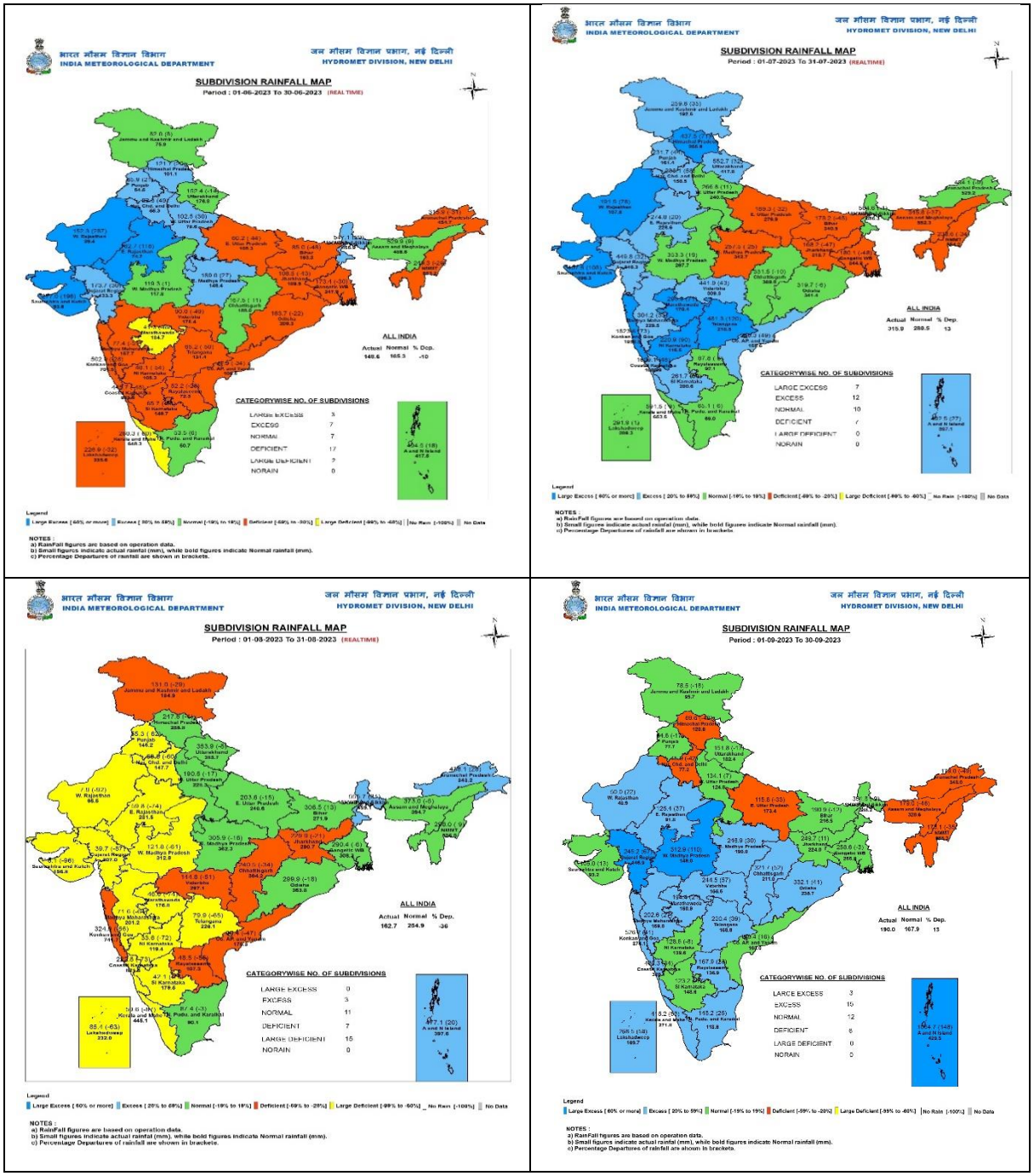


Fig.6: Sub-division wise monthly rainfall distribution over India during southwest monsoon season – 2023

Fig.6 shows the subdivision-wise monthly rainfall. In June, 3 subdivisions received large excess rainfall, 8 subdivisions received excess rainfall, 6 subdivisions received normal rainfall, and 19 subdivisions received deficient rainfall. The most noticeable feature of rainfall distribution during June was the large spatial variability over NW India

with excess rainfall over 7 of the 9 subdivisions and deficient rainfall over 1 subdivision. Region-wise, Northwest India (147% of LPA) received above normal rainfall and South Peninsula (55% of LPA) normal rainfall and the remaining two regions (85% of LPA for Northeast India, 94% of LPA for Central India) have received below normal rainfall.

In July, 07 subdivisions received large excess rainfall, 12 subdivisions received excess rainfall, 10 subdivisions received normal rainfall, 07 subdivisions received deficient rainfall. Region wise, the South peninsula (144% of LPA), Northwest India (125% of LPA) and Central India (122% of LPA) have received above normal rainfall and North & North East India have received below normal rainfall.

In August, 3 sub division received excess, 11 normal, 7 deficient rainfall and 15 large deficient rainfall. Most noticeable feature of rainfall distribution during August was the large rainfall deficiency over most parts of the country, especially over the western part of the country. Region wise, only East & Northeast India received normal rainfall (102% of LPA). All other regions have large rainfall deficiencies. South Peninsula received only 40% of LPA. Central India and Northwest India received 57% and 47% of LPA rainfall respectively.

In September, 30 subdivisions were normal/excess/large excess category and only 6 subdivisions received deficient rainfall. The region that mainly benefited during September was Central India (149% of LPA) and South Peninsula (124% of LPA). It was 89% of LPA for Northwest India (Normal) and 75% LPA for Northeast India (Below normal).

Fig.7 depicts the monthly variation of rainfall for All India and four homogeneous regions during 2023 southwest monsoon season and **Fig.8** depicts weekly and cumulative weekly rainfall anomaly expressed as percentage departure from the LPA.

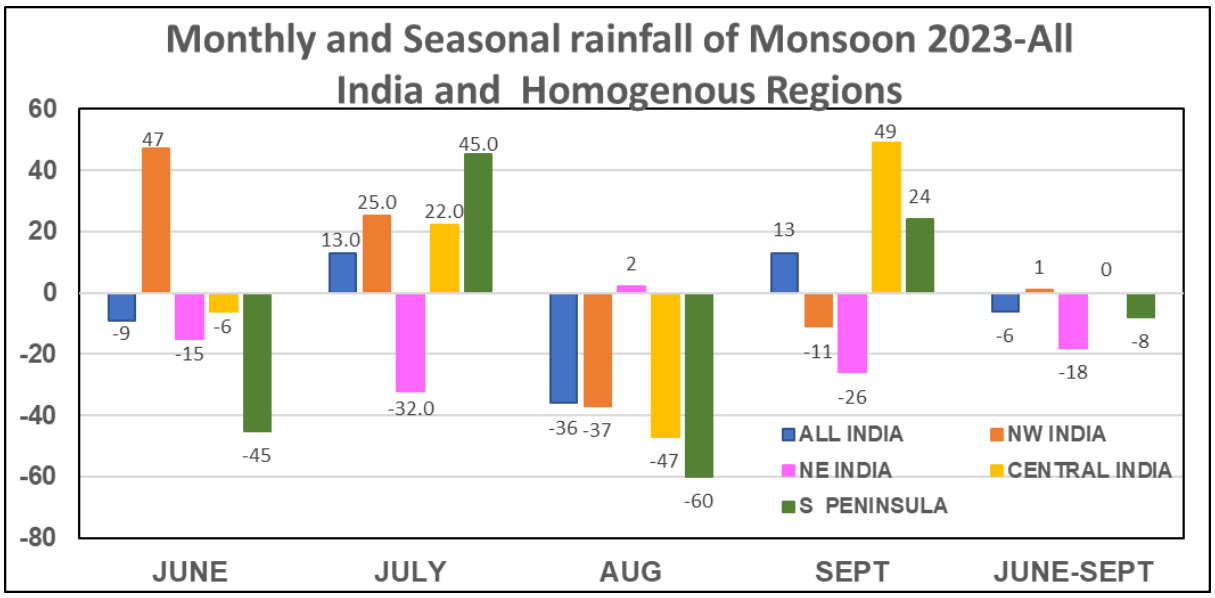


Fig.7. Monthly and seasonal monsoon rainfall of 2023 over Broad homogenous region and Country as a whole in % departure

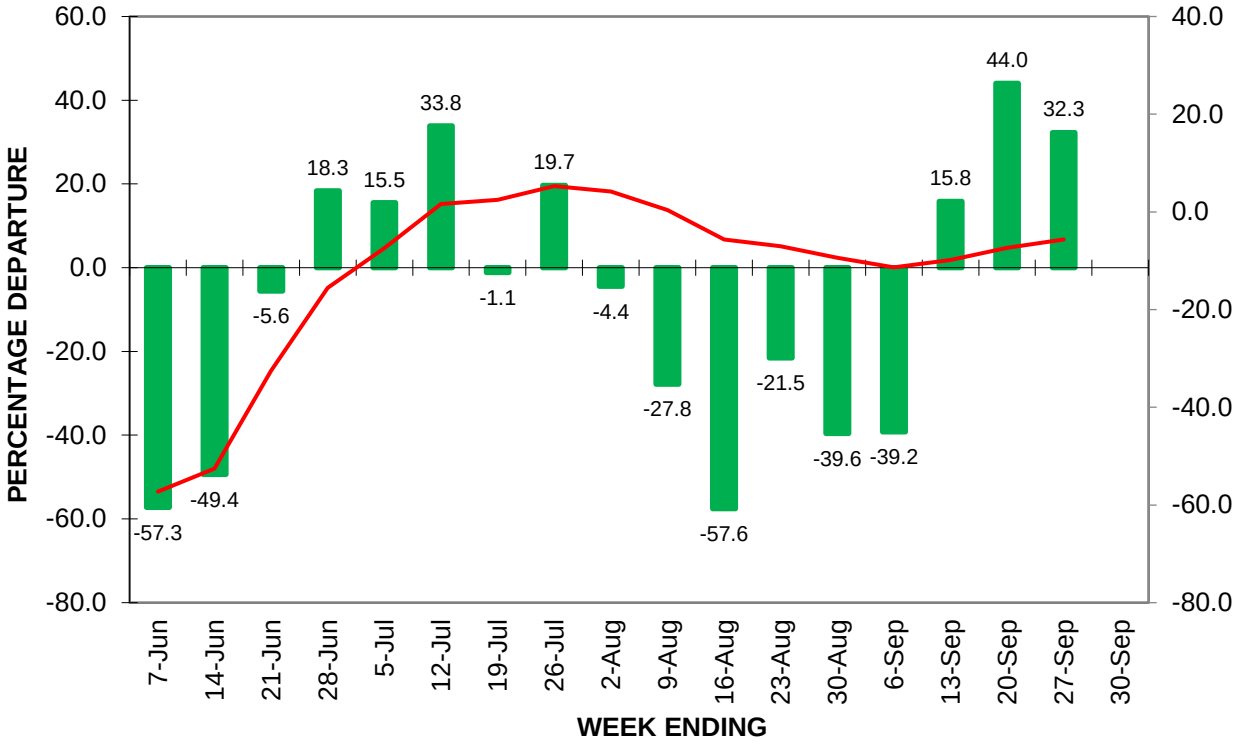


Fig 8. Week by week progress and cumulative rainfall (% departure from normal) over Country as a whole

The all India weekly rainfall anomalies during 10 of the 17 weeks of the monsoon season were negative. Out of the 7 positive rainfall anomaly weeks, 1 was in June, three weeks each in July and September. All weeks from August and the first week of September received negative rainfall anomalies. The highest negative weekly rainfall anomaly was recorded during the week ending 7th June and the week ending 16th August (-57% of LPA each). The highest positive rainfall anomaly was recorded during the week ending 20th September (44% from LPA) followed by the week ending 12thJuly (33% from LPA). The increase in the weekly rainfall during the season was mainly associated with the low pressure systems which moved along the monsoon trough.

6. Heavy and Extreme rainfall events

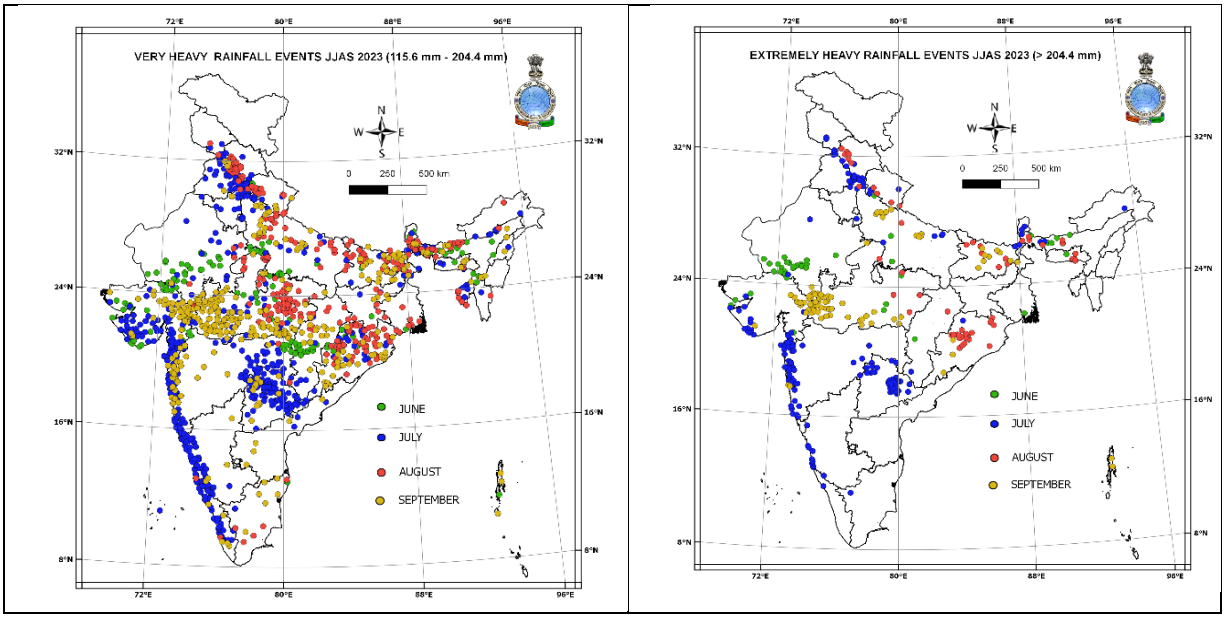


Fig.9: Location of Very Heavy Rainfall (115.6 to 204.4 mm)(left one) and Extremely Heavy Rainfall (more than 204.4 mm) (right one) stations during JJAS 2023.

There were many extreme rainfall events observed during 2023 southwest monsoon season. The location of heavy and extremely heavy rainfall events during 2023 southwest monsoon season is given in **Fig.9**. extremely heavy rainfall events were observed in June mainly over Rajasthan due to the extremely severe cyclonic storm "BIPARJOY". During July, the extremely heavy rainfall events were more realized over Konkan & Goa, coastal Karnataka, Uttarakhand, Himachal Pradesh, and Telangana due to the formation of low pressure systems. In the month of August, the extremely heavy rainfall events were more realized over Odisha and Gangetic West Bengal due to the formation of one Deep depression and one low pressure area over the Bay of Bengal. Also, two western disturbances (WDs) caused very heavy to extremely heavy

rainfalls and floods over Himachal and Uttarakhand mainly by triggering southerly/southwesterly winds from the Arabian Sea. During September, the extremely heavy rainfall events were more realized over Madhya Pradesh, Bihar and West Uttar Pradesh due to the formation of low pressure areas over the Bay of Bengal. The number of heavy rainfall events during the last five years is given in **Table 2** and a list of stations that received record rainfall (24 hours) during 2023 southwest monsoon season is given in **Table 3**. Significant weather events observed during the 2023 southwest monsoon season are given in **Fig.10**.

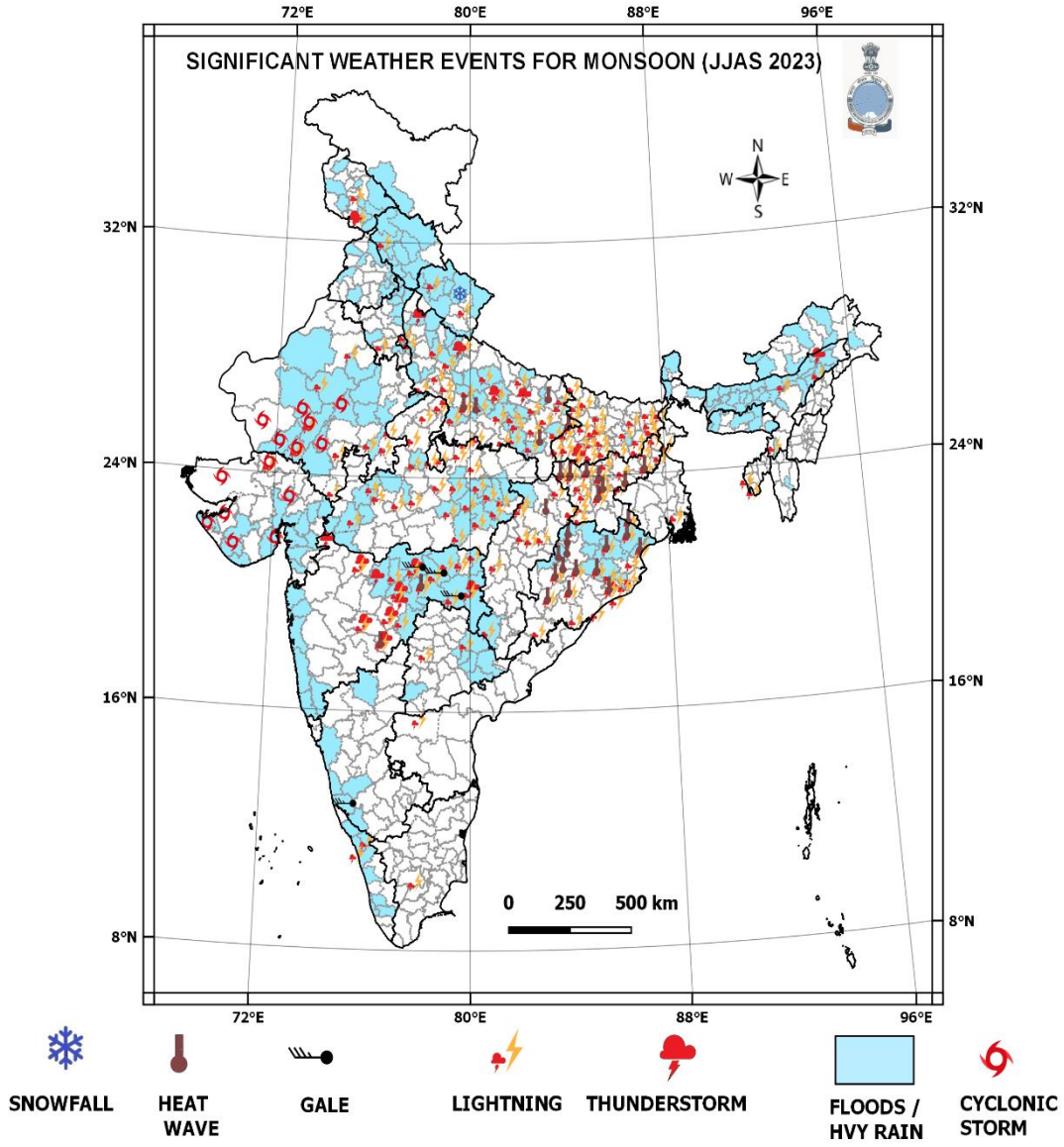


Fig.10: Significant weather events in the southwest monsoon 2023 season causing disastrous situations.

Table 3: The number of heavy rainfall events during the last five years

Year	2019		2020		2021		2022		2023	
Month	>115.6 and <204.5	>204.5	>115.6 and <204.5	>204.5	>115.6 and <204.5	>204.5	>115.6 and <204.5	>204.5	>115.6 and <204.5	>204.5
Jun	211	52	262	36	277	35	237	80	429	65
Jul	753	161	447	90	638	121	829	131	1113	205
Aug	987	282	1008	165	272	28	577	63	402	66
Sep	551	59	308	61	449	89	231	22	377	85
Monsoon	2502	554	1912	341	1636	273	1874	296	2321	421

Table 4: Station received 24 hour record rainfall and its previous record.

STATION	24 HOUR RECORD RAINFALL IN June, July, Aug and Sept 2023(mm)#	DATE	PREVIOUS RAINFALL RECORD (mm)	PREVIOUS RAINFALL RECORD DATE	STATE
ANGUL	170.0	26 Jun	161.2	15-06-1990	Odisha
NAJIBABAD	205.0	25 Jun	93.5	12-06-1984	Uttar Pradesh
SRIGANGANAGAR	109.0	26 Jun	99.1	14-06-1938	Rajasthan
ERINPURA/JAWAI DAM	239.0	19 Jun	78.3	25-06-1977	Rajasthan
NARSINGHPUR	218.0	28 Jun	217.6	27-06-1977	Madhya Pradesh
MAHUVA	225.0	30 Jun	179.6	30-06-1959	Gujarat
OKHA	228.1	17 Jun	190	30-06-1980	Gujarat
UDGIR	66.0	25 Jun	65.4	18-06-2012	Maharashtra
AMBALA	224.1	9 Jul	211.7	16-7-2001	Haryana
DELHI RIDGE	134.5	9 Jul	124	11-7-2003	Haryana
CHANDIGARH	302.2	9 Jul	262	18-7-2000	Chandigarh
BILASPUR SADAR	130	9 Jul	103.2	26-7-2012	Himachal Pradesh
MANALI	131.3	9 Jul	100	13-7-1993	Himachal Pradesh
PAHALGAM	73.3	8 Jul	71.2	27-7-1987	Jammu Kashmir
LEH	17.6	9 Jul	17.4	14-7-1980	Jammu Kashmir
KATRA	315.4	19 Jul	292.4	31-7-2019	Jammu Kashmir
BHIND-AWS	120.0	27 Jul	79	6-7-1970	Madhya Pradesh
MAHUVA	302.0	28Jul	167.9	15-7-1957	Gujarat
VERAVAL	520.2	19 Jul	503.8	16-7-2009	Gujarat
YEOTMAL	236.2	22Jul	196.4	28-7-2005	Maharashtra
HANAMKONDA	242.2	27Jul	227.8	13-7-1903	Telangana
BHIND-AWS	120.0	27Jul	79	6-7-1970	Madhya Pradesh
BHUBANESWAR AERO	259.2	1 Aug	254.2	20-8-1997	Odisha

BILASPUR SADAR	180.8	23 Aug	154	8-8-2019	Himachal Pradesh
BHIND-AWS	90	3 Aug	80.4	4-8-1975	Madhya Pradesh
SABOUR	187.0	22 Sep	162.5	28-9-1995	Bihar
SUPAUL	217.4	24 Sep	167	27-9-1975	Bihar
MALANJKHAND	166.6	15 Sep	140.3	11-9-1992	Madhya Pradesh
DHAR-AWS	301.3	17 Sep	161.4	8-9-2010	Madhya Pradesh
MANDVI	64.0	7 Sep	61	14-9-1961	Gujarat
BILASPUR	135.6	15 Sep	83.8	19-9-2008	Chhattisgarh
DURG	170.4	23 Sep	130.4	15-9-1983	Chhattisgarh

7. Inter annual variability of southwest Monsoon season rainfall and influence of large-scale climate drivers (ENSO/IOD)

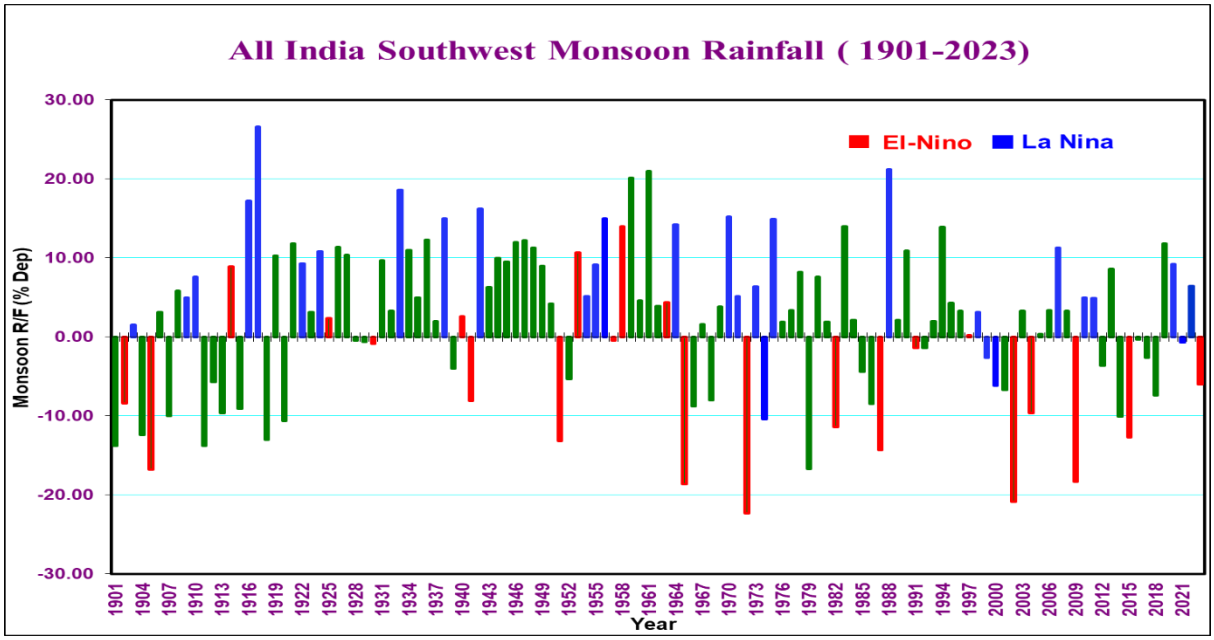


Fig.11: Inter-annual variability of All India Summer Monsoon Rainfall.

Historically, El Niño events have often been linked to below-average rainfall in India, while most La Niña years correlate with above-average precipitation (as depicted in **Fig.11**). This can be attributed to the warming of sea surface temperatures in the central and eastern Pacific during El Niño events, leading to shifts in atmospheric circulation patterns that can subsequently impact the Indian monsoon. **Fig.12** illustrates the spatial rainfall pattern over India during El Niño events, indicating decreased rainfall across most parts of the country. An exception is northeast India, where above-average rainfall is observed. In contrast, La Niña events, characterized by cooler sea surface temperatures in the same regions, are typically associated with above-average rainfall across most of India. Furthermore, a positive Indian Ocean Dipole (IOD) tends to be associated with

above-average rainfall over India (**Fig.13**), whereas a negative IOD often corresponds with below-average rainfall, particularly over central India and the Western Ghats.

The relationship between the El Niño-Southern Oscillation (ENSO) and India's monsoon rainfall isn't always straightforward. While there's a notable connection between ENSO events and monsoon patterns, it's not a consistent one-to-one correspondence. For instance, there have been El Niño years where India received above-normal rainfall, and conversely, some La Niña years resulted in below-normal precipitation. It's essential to note that while there's a statistically significant association between ENSO and the Southwest Monsoon rainfall, it's not the only factor influencing monsoon rainfall over India. Other factors, such as the Indian Ocean Dipole (IOD), Eurasian snow cover, and other regional and global atmospheric patterns, can also play a role.

The year 2023 serves as an illustrative example of this complex interplay. In this El Niño year, India experienced below-average rainfall. Yet, the presence of the IOD during the monsoon's latter phase offset this deficiency, bringing the rainfall anomaly within the standard deviation.

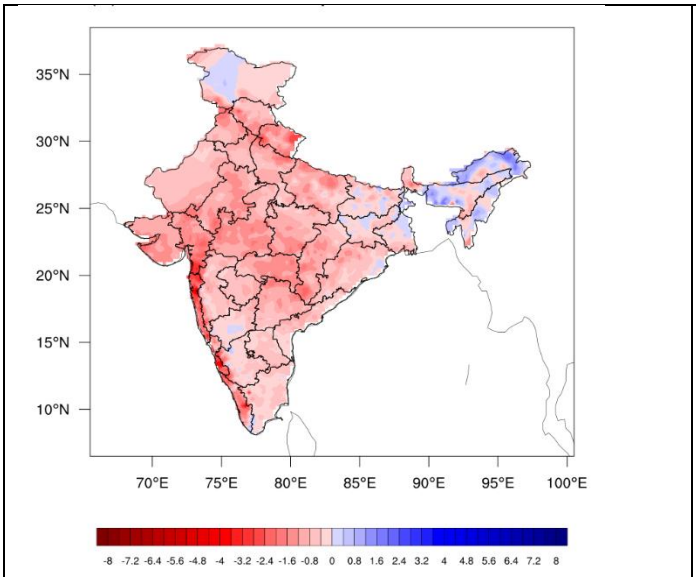


Fig.12(a)Rainfall anomaly composite during southwest monsoon season for the past El Nino events

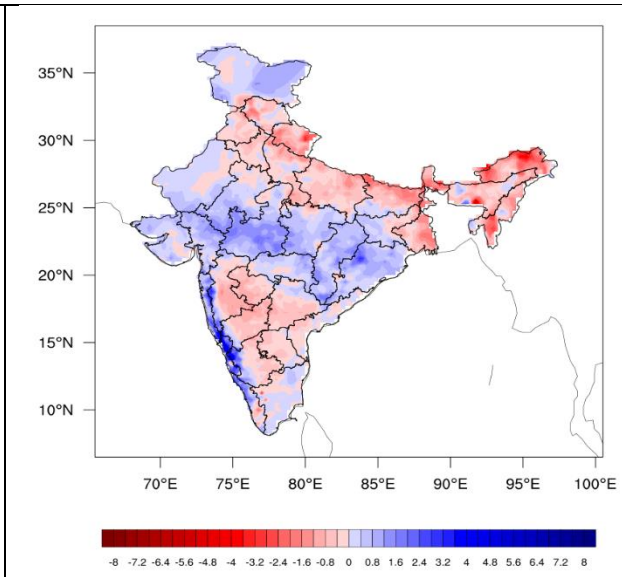


Fig.12(b)Rainfall anomaly composite during southwest monsoon season for past Positive IOD events

8. Intra seasonal variation during the 2023 southwest Monsoon season

The intra-seasonal variation of rainfall during the 2023 monsoon season is depicted in **Fig.13**, which shows the time series of daily rainfall anomaly over the core monsoon zone. It can be observed that from 25th June to 1st July monsoon was very active

after that 2nd July to 4th July 2022, a weak monsoon condition was observed. A prolonged weak monsoon situation was observed during the first week of 5th August to 17th August and 20th August to 2nd September. However, the monsoon again became active after 7th September. Overall, most days of the August and first week of September received very little rainfall. Which resulted in a record monthly rainfall deficiency (-36% of LPA) in August 2023.

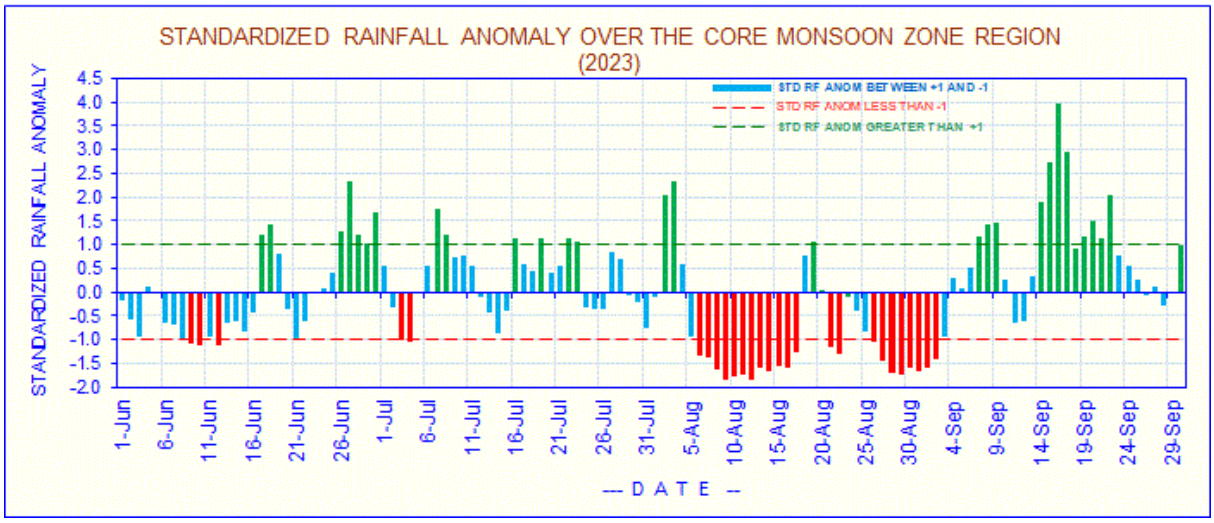


Fig.13. Time series of standardized rainfall anomalies for the core monsoon zone during the 2023 monsoon season.

These rainfall features are associated with the Madden Julian Oscillation (MJO), which has a significant influence on the intra-seasonal variability of the monsoon. The phase-space diagram depicts the MJO index during the monsoon season of 2023 as given in **Fig.14**. The MJO has remained locked in Western hemisphere and Africa in June and August and over the Indian Ocean and Maritime containment during most of the days of July and September 2023. The El Nino Condition over the equatorial Pacific is one of the reasons for not allowing MJO propagation to the Pacific Ocean region. In July it was active over the Indian Ocean region (in Phases 2 and 3). The MJO over the Indian Ocean region was favorable for monsoon onset activity over Peninsular India. However not much impact on summer monsoon rainfall in June as it was not in a favourable phase thereafter in the month. In August the MJO remained in Western Hemisphere and Africa (Phase 8 & 1) which was quite unfavorable for rainfall over the Indian monsoon region. During the beginning of September, it was seen to be active over the Maritime Continent (Phase 3 & 4) which is favorable for monsoon rainfall and helped to revive the monsoon

circulation and rainfall over India. The influence of MJO on monsoon rainfall was clearly visible in rainfall anomaly composite map of August and September as given in **Fig.15**.

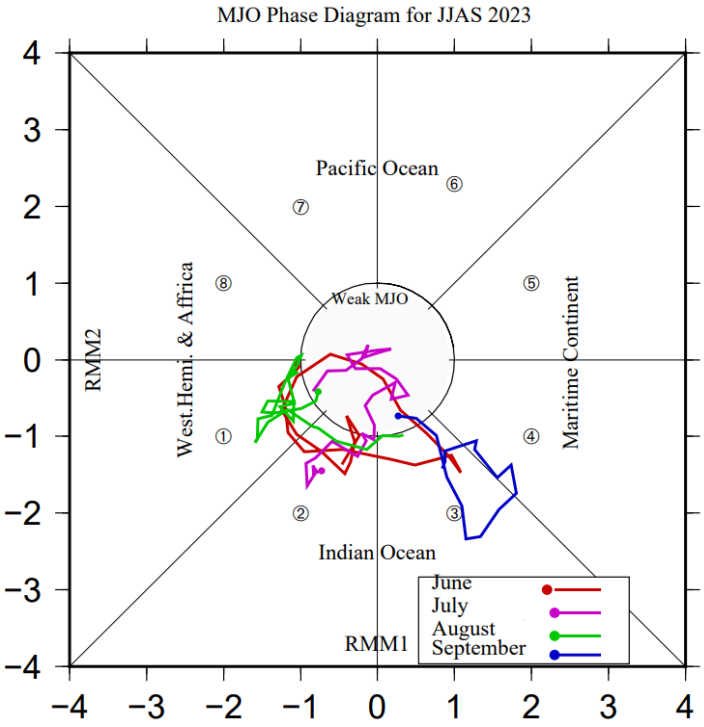


Fig. 14: Phase-space diagram depicting the MJO index during monsoon season of 2023. The numbers inside the encircled sectors of the diagram represent the eight phases of the MJO.

9. Verification of the Long Range Forecasts

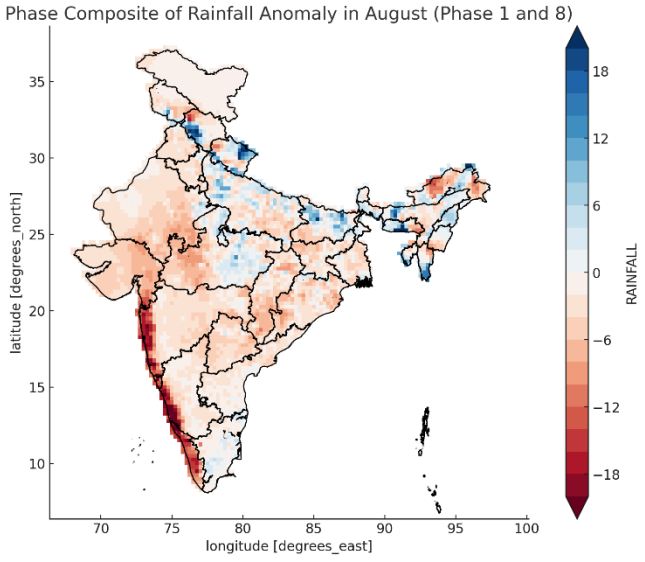


Fig.14(a)Rainfall Anomaly Composite of MJO Phase 1 & 8 8 during August 2023

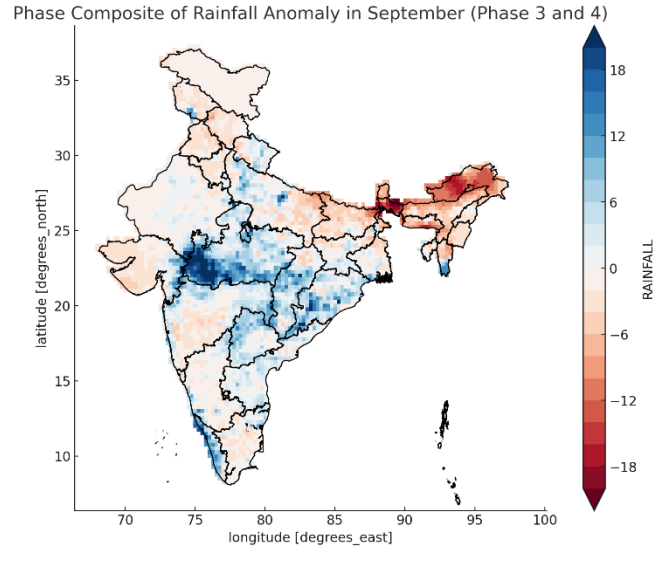


Fig.14(b)Rainfall Anomaly Composite of MJO Phase 3 & & 4 during Sept. 2023

India Meteorological Department (IMD) uses statistical and dynamical (Climate Models) methods, to issue seasonal forecasts. Since 2021, IMD has adopted a new strategy for issuing monthly and seasonal operational forecasts for the southwest monsoon rainfall over the country. This new strategy involves modifying the existing two-stage forecasting approach and is based on both the existing statistical forecasting system and the newly developed Multi-Model Ensemble (MME) based forecasting system introduced in 2021. The MME approach utilizes coupled global climate models (CGCMs) from various global climate prediction and research centers, including IMD's Monsoon Mission Climate Forecasting System (MMCFS) model.

9.1 Verification of Monsoon onset forecast 2023 :

Based on an indigenously developed statistical model, it was predicted on 15th May 2023 that monsoon will set in over Kerala on 4th June with a model error of ±4 days. The actual monsoon onset over Kerala was on 8th June and therefore the forecast was correct.

9.2 Verification of Monsoon rainfall forecast 2023 :

The long range forecast for the 2023 southwest monsoon rainfall was issued in 2 stages. The first stage long range forecast issued on 11th April consisted of only forecast for the season (June-September) rainfall over the country as a whole. In the second stage (26th May), along with the update for the April forecast, forecast for seasonal rainfall over the four broad geographical regions (Northwest India, Central India, South Peninsula and Northeast India) and for monthly rainfall over the country as a whole for the months of July, August and September were issued. In the 3rd stage (31st July), 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 ± 5% of LPA. The update issued on 26th May for this forecast was (96% of LPA) with a model error of ± 4% of LPA. The actual season rainfall for the country as a whole was 94% of LPA. Thus, both the forecasts were within forecast limits and therefore the forecast was correct.

Considering the four broad geographical regions of India, the forecasts issued in 26th May, the southwest monsoon seasonal rainfall was most likely to be below normal over Northwest India (<92% of LPA) and normal over other three broad homogeneous regions; central India (94-106% of LPA), North East India (94-106% of LPA) and South Peninsular India (94-106% of LPA). The southwest monsoon seasonal rainfall over the monsoon core zone consisting of most of the rainfed agriculture areas in the country was most likely to be Normal (94-106% of LPA. The actual rainfall departure over Northwest India, Central India, Northeast India, South Peninsula and Monsoon Core Zone were 1%, 0%, -18%, -9% and 1% of the LPA respectively. Thus, rainfall over northwest and northeast India were underestimated and overestimated respectively.

The forecasts for the monthly rainfall over the country as a whole for the months of June and August were below Normal (<92% of LPA) and (<94% of LPA) respectively and observed rainfall was 91% & 64% respectively. For the month of July, it was predicted that rainfall for the country as a whole would be on positive side of normal (94-106% of LPA) and September Normal (91-109% of LPA). Based on extended range forecast issued on 30 September, it was stated that there would be good rainfall in September. The observed rainfall in July and September was 113% of LPA each. The realised spatial rainfall pattern matched well for all the individual months except September. In the second half of the monsoon season (August –September) rainfall was below normal against the prediction of rainfall on the negative side of the normal rainfall. Thus, the trend of rainfall in the second half of the monsoon season was well predicted. It was also predicted since April that El Nino would have no impact in the first half and could adversely impact in the second half of the monsoon season, which is found to be correct.

Table 5 below gives the summary of the verification of the long-range forecasts issued for the 2023 Southwest monsoon.

Table 5(a). Performance of Long Range Forecast of Southwest Monsoon 2023

FORECAST			OBSERVED
11 April 2023-1st Stage For Season as a whole	26th May 2023-2nd stage -Updated(For Season as whole)	31 July -3rd Stage (For 2nd half of Monsoon 2023 (Aug-Sept)	

• El Niño conditions are likely to develop during the monsoon season • Positive IOD conditions are likely to develop during the southwest monsoon season. • It was stated that Eurasia snow cover has been less during December to February 2022-2023, which will favour the Monsoon over India in spite of IOD conditions also will counter the adverse impact of El-Nino. • Based on the above, it was predicted that in spite of El-Nino, the monsoon will not be affected severely and Quantitatively seasonal rainfall was predicted to be 96 % of Long Period Average (LPA) with a model error of ± 5%(Normal). • It was also told that monsoon would get impacted "in the 2nd half of monsoon season and not likely in the 1st half of the season."	• El Niño conditions during monsoon season. • Development of positive IOD conditions over the Indian Ocean during monsoon season. • Same rainfall forecast was reiterated in 2nd Stage LRF issued on 26th May 2023 96 ± 4%. • It was also told that monsoon would get impacted "in the 2nd half of monsoon season and not likely in the 1st half of the season."	• Weak El Niño conditions are prevailing over the equatorial Pacific region. The El Niño conditions are likely to intensity further and continue up to early next year. • Neutral IOD conditions are prevailing over the Indian Ocean and the positive IOD conditions are likely to develop during remaining part of the monsoon season. • Rainfall to be normal but on negative side of the normal (94 to 99% of LPA).	• Weak El Niño conditions developed in July became moderate in Aug & Sept. • IOD remained neutral till 3rd week of Aug and became positive thereafter. • Rainfall is below normal (94% of LPA). • 1st half of the monsoon season 2023 got more rainfall (10%, above normal). It was below normal during 2nd half the season (17% below normal)

Table 5(b) Performance of monthly Rainfall Forecast during Monsoon 2023

Month	Forecast	Realized
June 2023	Rainfall to be below normal (<92 % of LPA).	91% of LPA
July 2023	Rainfall to be normal but on positive side of the normal (100-106 % of LPA).	113% of LPA
Aug 2023	Rainfall to be below normal (<91 % of LPA).	64% of LPA
Sept 2023	Rainfall to be normal (91-109 % of LPA). However extended range forecast indicated good rainfall in Sept. Also predicted formation of Low Pressure Systems one after another to cause good rainfall over Central & South India	113% of LPA
Aug-Sept 2023	Rainfall to be normal but on negative side of the normal (94 to 99% of LPA	83% of LPA

9.3 Spatial probability rainfall forecast Verification of Monsoon forecast 2023

The verification of the spatial probability rainfall forecast that was issued by IMD during the 2023 Southwest monsoon season is presented in **Fig.15**. It shows that the forecast could capture the spatial pattern reasonably well except for northwest India where it was underestimated.

Fig.15a

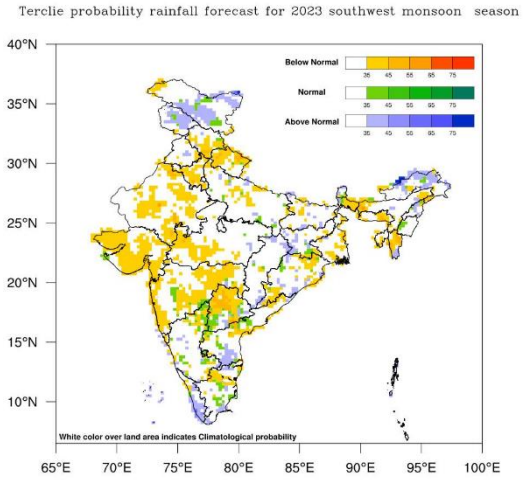


Fig.15c

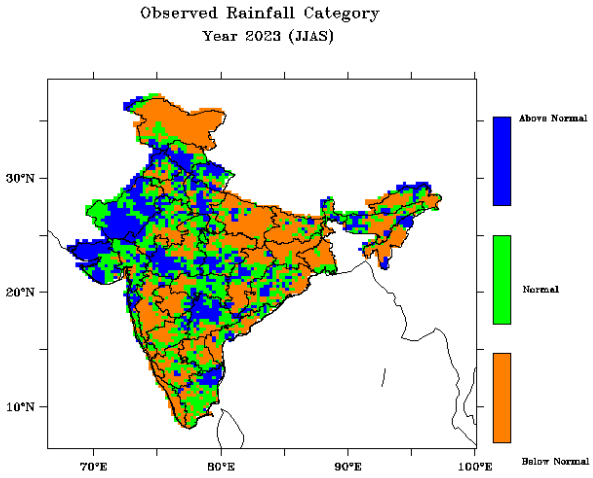


Fig.15b

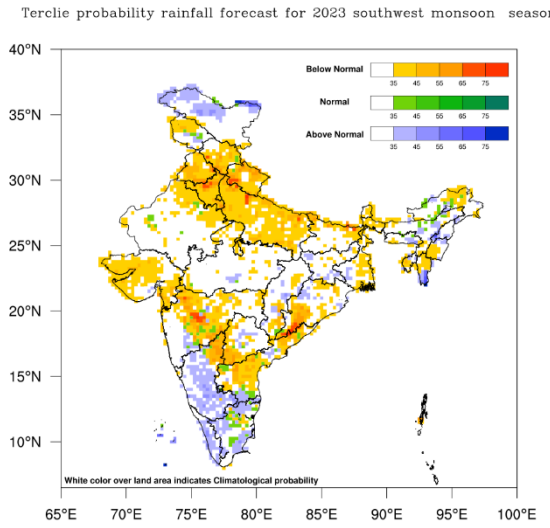


Fig.15. (a and b). Spatial forecast for the seasonal rainfall from June to September 2023, corresponding to the first stage (issued in April) and second stage (issued in May), respectively, (c) observed rainfall category.

9.4 Monthly Probability Forecast (spatial) Verification during Southwest Monsoon season 2023.

The verification of the spatial monthly probability forecast is presented in **Fig.16.**

Fig.16a

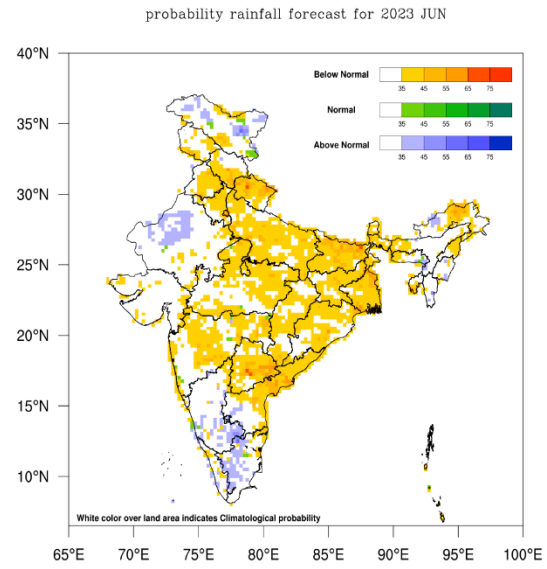


Fig.16b

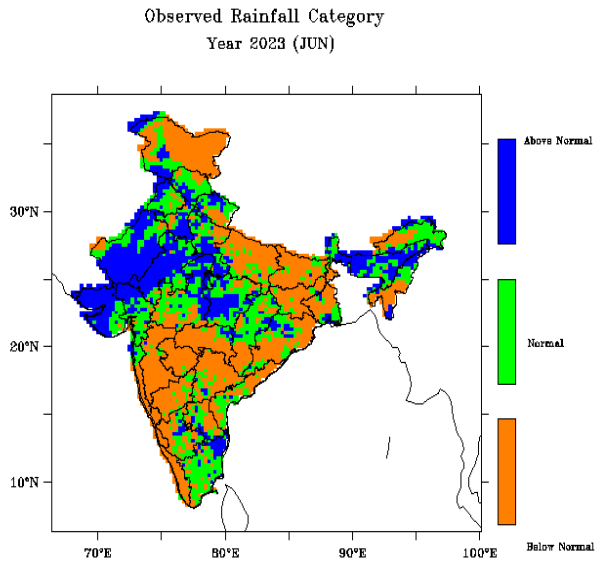


Fig.16c

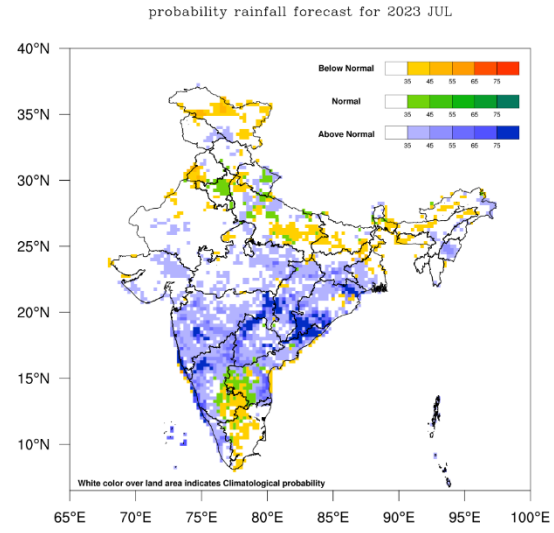
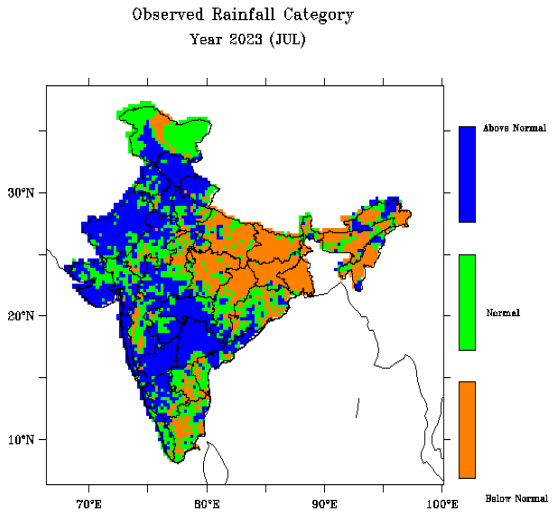


Fig.16d



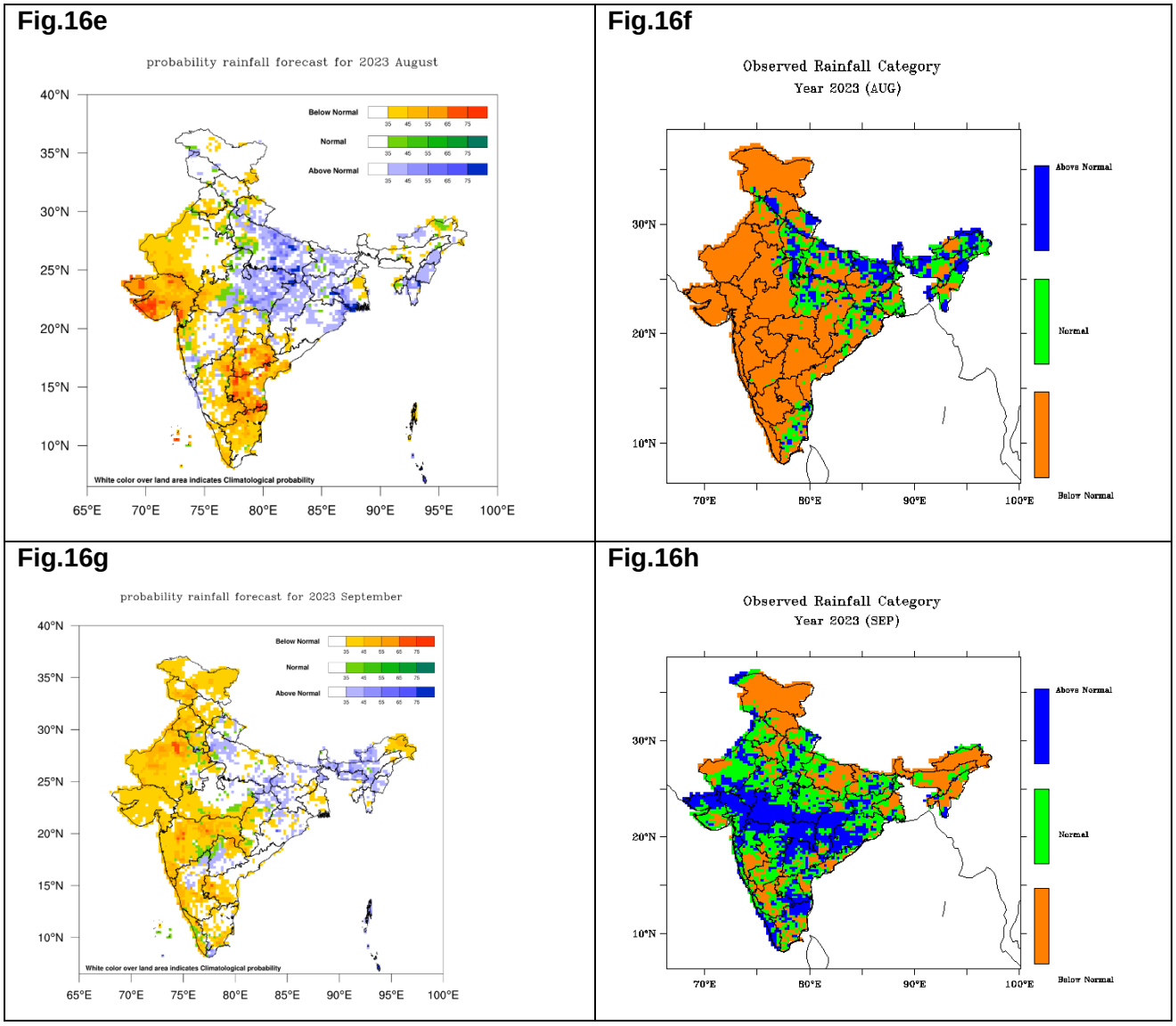


Fig.16. Verification of the spatial forecast for monthly rainfall from June to September 2023, with corresponding observed rainfall categories provided in (a and b) for June, (c and d) for July, (e and f) for August and (g and h) for September 2023.

It can be seen that the spatial patterns of rainfall in all individual monsoon months could be predicted well except for September.

9.5. Verification of forecast of El Nino, IOD and MJO conditions

While issuing the long range forecast in the month of April, ENSO Neutral conditions prevailed over Pacific Ocean. IMD correctly predicted development of weak/moderate El Nino condition during the monsoon season and the emergence of positive Indian Ocean Dipole (IOD). In the first state of long range forecast IMD indicated normal rainfall (96 % +/- 4% of LPA) likely to be during the southwest monsoon season

and also indicated the negative impact of El Nino will be compensated by other factors like IOD. The observed seasonal rainfall was 94% of LPA which is very close to the lower limit of normal rainfall category and within the error limit of the forecast. It may be noted that the Core Monsoon Zone (the area where agriculture mainly depends on rainfall) received 101% of LPA and IMD correctly indicated the rainfall situation over the region. The emergence of the positive IOD during end of August was predicted in the press release issued on 31 August. The favourable and unfavourable phases of MJO were predicted every Thursday for the next two weeks and hence the dry and wet spells of monsoon.

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30 Sept, 2023
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