INDIA METEOROLOGICAL DEPARTMENT

2012 SOUTHWEST MONSOON
END OF-SEASON REPORT

HIGHLIGHTS

- For the country as a whole, the rainfall for the season (June-September) was 92 % of its long period average (LPA).

- Seasonal rainfall was 93% of its LPA over Northwest India, 96% of its LPA over Central India, 90% of its LPA over south Peninsula and 89% of its LPA over Northeast (NE) India.

- Out of the total 36 meteorological subdivisions, 23 subdivisions constituting 67.3% of the total area of the country received excess/normal season rainfall and the remaining 13 subdivisions (32.7% of the total area of the country) received deficient season rainfall.

- Monthly rainfall over the country as a whole was 72% of LPA in June, 87% of LPA in July, 101% of LPA in August and 111% of LPA in September.

- Southwest monsoon current advanced over the Andaman Sea on 23rd May with a delay of about 3 days and set in over Kerala on 5th June, 4 days later than its normal date of 1st June. However, the southwest monsoon covered the entire country by 11th July, 4 days earlier than its normal date of 15th July. The withdrawal of monsoon from west Rajasthan commenced only on 24th September compared to its normal date of 1st September.

- As in the recent past years of 2002 & 2010, none of the 10 low pressure systems formed this year intensified into depressions as against the normal frequency of 4-6 monsoon depressions per season.

- The forecast for monsoon onset over Kerala for this year was correct, which is the eighth consecutive correct forecast for this event.

- Most of the operational long range forecasts for the 2012 southwest monsoon season rainfall (except for northeast India) were accurate. The forecast for August rainfall over the country as a whole was also correct. However, the forecast for July rainfall over the country as a whole was an overestimate and that for rainfall during the second half of the monsoon season was an underestimate. Forecast for the three broad homogenous regions viz. Northwest India, Central India and south Peninsula was also correct. However, it was slightly an overestimate for Northeast India.

1. Onset of SW Monsoon

This year, the arrival of southwest monsoon current over the south Bay of Bengal and south Andaman Sea was delayed by 3 days due to non-conducive conditions for the development of convection over the region and it set in over the region on 23rd May. With the strengthening of cross equatorial flow over the Arabian Sea from 4th June, the rainfall activity over Kerala increased and the monsoon set in over Kerala on 5th June. The SW Monsoon also covered remaining parts of south Arabian Sea, southern parts of central Arabian Sea, remaining parts of Maldives-Comorin areas, entire Kerala, some parts of coastal Karnataka and south Tamil Nadu and some more parts of south & east central Bay of Bengal on 5th June itself.

With the formation of a vortex in the form of an embedded upper air cyclonic circulation off Karnataka coast (6 -7th June) in the trough off the west coast, the monsoon covered entire Goa and some parts of Konkan on 6th June. Thus the advance of SW Monsoon along the west coast of India was very rapid. The monsoon also covered entire northeast India and some parts of Sub- Himalayan West Bengal & Sikkim on the same day. Thereafter, there was a hiatus of 6 days, during which, the off-shore trough was feeble and the vortex also became less marked. Again with the strengthening of the Arabian Sea branch of the monsoon current, the SW monsoon advanced into most parts of peninsular India including interior Maharashtra by 17th June. Also, due to the formation of an upper air cyclonic circulation over the northwest Bay of Bengal & neighbourhood, the eastern branch of the monsoon advanced further during the subsequent days and covered Vidarbha, West Bengal & Sikkim and Odisha on 19th June and Chhattisgarh, Jharkhand and Bihar on 21st June.

The shifting of east-west trough at sea level close to foot hills of Himalayas from 25thJune–3rdJuly caused prolonged stagnation of the Northern Limit of Monsoon (NLM) and there was a hiatus for about 11 days from 22nd June – 2nd July. A break like situation prevailed during 25th-29th June. During the period of hiatus, systems in westerlies gave rainfall over the northeast India and the feeble off-shore trough prevailing off the west coast gave rise to rainfall along the west coast. Due to the sluggish advance, there was a lag of nearly 2 weeks in the advance of the SW Monsoon over the west central and parts of east Uttar Pradesh for the monsoon rainfall to commence. Heat wave to severe heat wave conditions prevailed over the northern plains during this period.

With the formation of upper air cyclonic circulations over northeast Bay of Bengal as well as over the Arabian Sea off Gujarat coast during the 1st week of July and a low pressure area over north Madhya Pradesh and adjoining South Uttar Pradesh and east Rajasthan during the 2nd week of July, the east-west trough shifted southwards and became more pronounced and made conditions favourable for further advance of monsoon. Thus, there had been a rather steady advance from 3rd July and the southwest monsoon covered the entire country on 11th July, 4 days earlier than its normal date of 15th July.

Fig. 1 depicts the isochrones of advance of 2012 southwest monsoon.

2. Chief Synoptic Features

The Mascarene HIGH displayed large oscillations in its position and intensity, especially during the first half of the season. The Cross Equatorial Flow (CEF) over the Arabian Sea also varied accordingly. This feature, in combination with a suppressed convection over the Arabian Sea, during major parts of June & July caused the monsoon flow pattern to remain weak during the initial half of the season.

The monsoon trough displayed rapid north-south oscillations soon after it was established in July. It then lay close to foot hills of Himalayas during 17th-19th July. The trough was generally in its near normal position and extended up to lower tropospheric levels without its characteristic southward tilt during July and August. Towards the end of August, the monsoon trough shifted southwards in association with the two low pressure systems (formed during 30th–31st August & 3rd-10th September) embedded in the monsoon trough that formed in succession over west central and adjoining northwest Bay of Bengal off north Andhra Pradesh – south Odisha coasts. The trough exhibited its characteristic southward tilt with height only during the first week of September. With the dissipation of the low pressure areas, the monsoon trough was seen at its normal position. It then shifted northwards but remained active during the third week of September. Its interaction with mid-latitude westerlies over Western Himalayan Region resulted in active to vigorous monsoon conditions over the parts of northwest India and east & northeast India during many days of the week. The monsoon trough became less marked on 20 September.

Though there had been extended periods of subdued rainfall activity during the season in different spatial scales, rather un-organized convective activity, which is a characteristic of weak monsoon phases, contributed significantly to the seasonal rainfall. Many a times, when the circulation features indicated break like situations,

rainfall distribution along the monsoon trough zone were not as per the break monsoon conditions.

Ten low pressure areas formed during the season. However, none of the low pressure areas intensified into depression (normally 4-6 monsoon depressions forms in monsoon season) as in the recent past years 2002 and 2010. Of the 10 low pressure areas formed during the season, 2 were in July, 5 were in August and 3 were in September. Five low pressure areas formed in succession during August. However, no low pressure areas formed during June. This year was the first occasion during the period 1981-2012, when no low pressure area formed during June. During July, August and September, one low pressure area each formed over land and the remaining low pressure areas formed over Bay of Bengal. No low pressure areas formed over the Arabian Sea.

The first low pressure area of the season which formed over Northeast Madhya Pradesh and adjoining south Uttar Pradesh (7^{th} -11^{th} July) facilitated the advance of monsoon to cover the entire country. The second low pressure area (20^{th}-22^{nd}July) formed over Bay of Bengal and was short lived. Moving in a northwesterly direction, it merged with the monsoon trough on 23^{rd}. Under the influence of five low pressure areas that formed during successive weeks of August (3^{rd} -9^{th} August, 12^{th}-14^{th} August, 17^{th}-22^{nd} August, 25^{th}-27^{th} and 30^{th}-31^{st} August), the rainfall activity over the monsoon trough zone got enhanced. Towards the end of the August, the systems and their remnants caused active to vigorous monsoon conditions over major parts of the country.

A well-marked low pressure area formed over during 3^{rd}–11^{th} Sept. It had a long travel along the monsoon trough zone and dissipated over southeast Pakistan and adjoining southwest Rajasthan. The cyclonic circulation associated with it extended up to 7.6 km a. s. l. till 5^{th} Sept and then up to mid tropospheric levels till 15^{th} Sept. The low pressure area became less marked on 16 Sept. It tilted southwestwards with height. Under its influence, the monsoon continued to be active / vigorous over major parts of the country. The largely rain deprived western parts of Gujarat State also received rainfall during the first fortnight of September. With this, the cumulative rainfall departure category of the sub-division Saurashtra & Kutch which had remained scanty since 1^{st} June, improved significantly. Another low pressure area formed over Chhattisgarh and adjoining Odisha, but was short lived (10^{th} Sept. evening – 12^{th} Sept.). A well-marked low pressure area formed towards the end of the season (on 27^{th} Sept) over west central Bay of Bengal and

neighbourhood. An east west shear zone which formed with the cyclonic circulation associated with this low pressure area along with another cyclonic circulation over east central Arabian Sea off south Maharashtra coast on 28th, resulted in widespread thundershower activity on the last day of the season over the Peninsular India.

3. Flood Situation

Incessant rainfall associated with the monsoon low pressure systems and active monsoon conditions in the presence of strong cross equatorial flow and deep monsoon trough, often caused flood situations over various states during different parts of the season. Some of the sub-divisions/states which experienced flood situations are Arunachal Pradesh, Assam, West Bengal & Sikkim, Jammu & Kashmir, Uttar Pradesh, Gujarat, Madhya Pradesh, Rajasthan, coastal Karnataka and Kerala.

4. Withdrawal of SW Monsoon

During the third week of September, a rapid weakening of the semi-permanent features associated with monsoon circulation pattern was seen and the water vapour from western India decreased considerably.

Dry weather conditions over many parts of northwest India and Kutch area, presence of a persistent ridge over northwest India and an anti-cyclonic circulation in the lower levels over south Rajasthan and adjoining Gujarat, in lower tropospheric levels, initiated the withdrawal of southwest monsoon from 24 September.

The southwest monsoon withdrew from extreme parts of west Rajasthan on 24th September with a delay of more than 3 weeks as the normal date of withdrawal from extreme western parts of Rajasthan is 1st September. On the same day, it also withdrew from some parts of northwest India, Saurashtra & Kutch and north Arabian Sea. It further withdrew from some more parts of northwest India, Gujarat State, west Madhya Pradesh on 26 September and from most part of Uttar Pradesh, some parts of Bihar, some more parts of Madhya Pradesh and Gujarat on 8th October.

As on 10th October, the withdrawal line of southwest monsoon pass through Raxaul, Varanasi, Jabalpur, Hoshangabad, Vadodara, Porbandar, (21.0° N & 67.0° E) and (21.0°N & 60.0°E).

Fig. 2 shows the isochrones of withdrawal of 2012 southwest monsoon.

5. Rainfall Distribution

The actual season (June to September) rainfall over the country as a whole and four broad geographical regions during the 2012 SW monsoon season are given in the table below along with respective long period average (LPA) values. The rainfall during the 4 monsoon months and the second of the monsoon season (August + September) over the country as whole are also given.

Season (June to September) rainfall			
Region	**LPA (mm)**	**Actual Rainfall for 2012 SW Monsoon Season**	
		Rainfall (mm)	**Rainfall (% of LPA)**
All India	887.5	819.8	92
Northwest India	615.0	569.3	93
Central India	975.5	935.5	96
Northeast India	1438.3	1275.3	89
South Peninsula	715.5	643.9	90
Monthly & second half of the monsoon season rainfall over the country as a whole (All India)			
Month	**LPA (mm)**	**Actual Rainfall for 2012 SW Monsoon Season**	
		Rainfall (mm)	**Rainfall (% of LPA)**
June	163.6	117.8	72
July	289.2	250.4	87
August	261.3	264.7	101
September	173.4	192.0	111
August + September	434.7	453.7	104

As seen in the table above the season rainfall over the country as whole and four geographical regions of the country were less than the respective LPAs. Month wise the rainfall during the first two months (June and July) was below its LPA values. However, monthly rainfall for August and September as well as total rainfall during the second half monsoon season was higher than its LPA values.

Fig.3 shows the subdivision wise season (June to September) rainfall.

The season rainfall from 1st June to 30 September 2012 was excess only in one subdivision (Andaman & Nicobar Islands) which constitutes 0.3% of the total area of the country, normal in 22 meteorological subdivisions (67% of the total area of the country) and deficient in 13 meteorological subdivisions (32.7% the total area of the country).

Fig.4 shows the subdivision wise monthly rainfall.

In June, deficient or scantly rainfall was observed over most of the subdivisions (27 out of 36). Excess rainfall was observed over 2 subdivisions (Sub Himalayan West Bengal & Sikkim and Assam & Meghalaya) and normal over Andaman & Nicobar Islands, Lakshadweep, Konkan & Goa, Coastal Karnataka, Telangana, Arunachal Pradesh and NMMT (Nagaland, Manipur Mizoram, and Tripura). During July, the rainfall over most of the subdivisions from northwest India except 2 subdivisions (east Uttar Pradesh and Uttarakhand) was deficient or scantly. Other subdivisions that received deficient/ scantly July rainfall were Kerala, all 3 subdivisions from Karnataka, Andaman and Nicobar Islands, subdivisions from Gujarat and NMMT. The remaining 19 subdivisions received normal and 2 subdivisions (west Madhya Pradesh and Rayalaseema) excess rainfall. In August, rainfall activity picked up and rainfall over 19 subdivisions was normal and 7 subdivisions received excess rainfall. However, the August rainfall in 10 subdivisions (mostly from east and northeast India and Gujarat along with Marathwada) was deficient or scanty. In September, normal/excess rainfall was observed over 28 subdivisions. However, NMMT, Haryana, west Uttar Pradesh and 5 subdivisions from interior and eastern part of south Peninsula were deficient.

From monthly distribution, it can be clearly seen that most of the subdivisions from northwest India was deficient/scantly in the first two months of the season and excess/ normal during the later two months of the season. Gujarat state was deficient/scanty during the first 3 months and excess in September. There were only three subdivisions (Konkan & Goa, Telangana and Arunachal Pradesh) that were normal/excess throughout the season.

Figures 5 and 6 depict the all India weekly and cumulative weekly rainfall anomaly expressed as percentage departure from the LPA.

The weekly rainfall anomaly from first week to week ending 22nd August was negative. However, the rainfall anomalies from week ending 29th August to week ending 19th September were positive and that during the remaining two weeks of the season were again negative. As a result, the all India cumulative weekly rainfall anomalies were negative throughout the season.

6. Verification of the Long Range Forecasts

Based on an indigenously developed statistical model, it was predicted on 15th May 2012 that monsoon will set in over Kerala on 1st June with a model error of ±4days. The forecast came correct as the actual monsoon onset over Kerala took place on 5th June, four days later than the forecasted date. Thus this is the eight consecutive correct operational forecasts for the date of monsoon onset over Kerala since issuing of operational forecast for the event was started in 2005.

As per the first stage long range forecast issued on 26th April, the season (June-September) rainfall for the country as a whole was expected to be 99% ± 5% of LPA. In the updated forecast issued on 22nd June, the forecast for the country as a whole was revised to a lower value of 96% ± 4% of LPA. However, the actual season rainfall for the country as a whole (92% of LPA) was less than the forecast but it was within the lower forecast limit (96%-4% of LPA) of the second stage forecast. The forecast for the second half of the monsoon season (August – September) for the country as a whole issued in August was 91% with a model error of 8% of LPA. This forecast was an underestimate as the actual rainfall over the country as a whole during the second half of the season was 104% of LPA.

The forecasts for monthly rainfall over the country as a whole for the months of July, August issued in June were 98% & 96% respectively with a model error of ± 9%. The July month forecast was an overestimate to the the actual rainfall (87% of LPA) but the rainfall forecast for August was accurate as the actual rainfall was 101% of LPA which is well within the upper forecast limit (96% + 9 % of LPA).

Considering the four broad geographical regions of India, the season rainfall was expected to be 93% of its LPA over northwest India, 96% of LPA over Central India, 99% of LPA over northeast India and 95% of LPA over South Peninsula all with a model error of ± 8%. The actual rainfalls over northwest India, central India, northeast India and south Peninsula were 93%, 96%, 89% and 90% of the LPA respectively. Thus both forecast and actual rainfall over northwest India and central India were exactly the same. The actual rainfall over south Peninsula was within the lower forecast limit (95% - 8% of LPA). On the other hand, the actual rainfall over northeast India was slightly (2% of LPA) below the lower forecast limit (99% - 8% of LPA). The Table below gives the summary of the verification of the long range forecasts issued for the 2012 Southwest monsoon.

Table: Details of long range forecasts and actual rainfall.

Region	**Period**	Date of Issue	**Forecast (% of LPA)**	**Actual Rainfall (% of LPA)**
All India	June to September	26th April	99 ± 5	92
All India	June to September	22nd June	96 ± 4	
Northwest India	June to September		93 ± 8	93
Central India	June to September		96 ± 8	96
Northeast India	June to September		99 ± 8	89
South Peninsula	June to September		95 ± 8	90
All India	July		98 ± 9	87
All India	August		96 ± 9	101
All India	August to September	2nd August	91 ±8	104

As seen in the table, most of the operational long range forecasts for season rainfall (except for northeast India) were accurate. The forecast for August rainfall over the country as a whole was also correct. However, the forecast for July rainfall over the country as a whole was an overestimate and that for rainfall during the second half of the monsoon season was an underestimate. The main reason for the underestimation of the forecast for the second half of the monsoon season was delay in the establishment of El Nino conditions in the Pacific and sudden emergence of positive phase of India Ocean Dipole during later part of the monsoon season. Both of these large scale features may have contributed increased rainfall activity particularly during second half of the monsoon season.

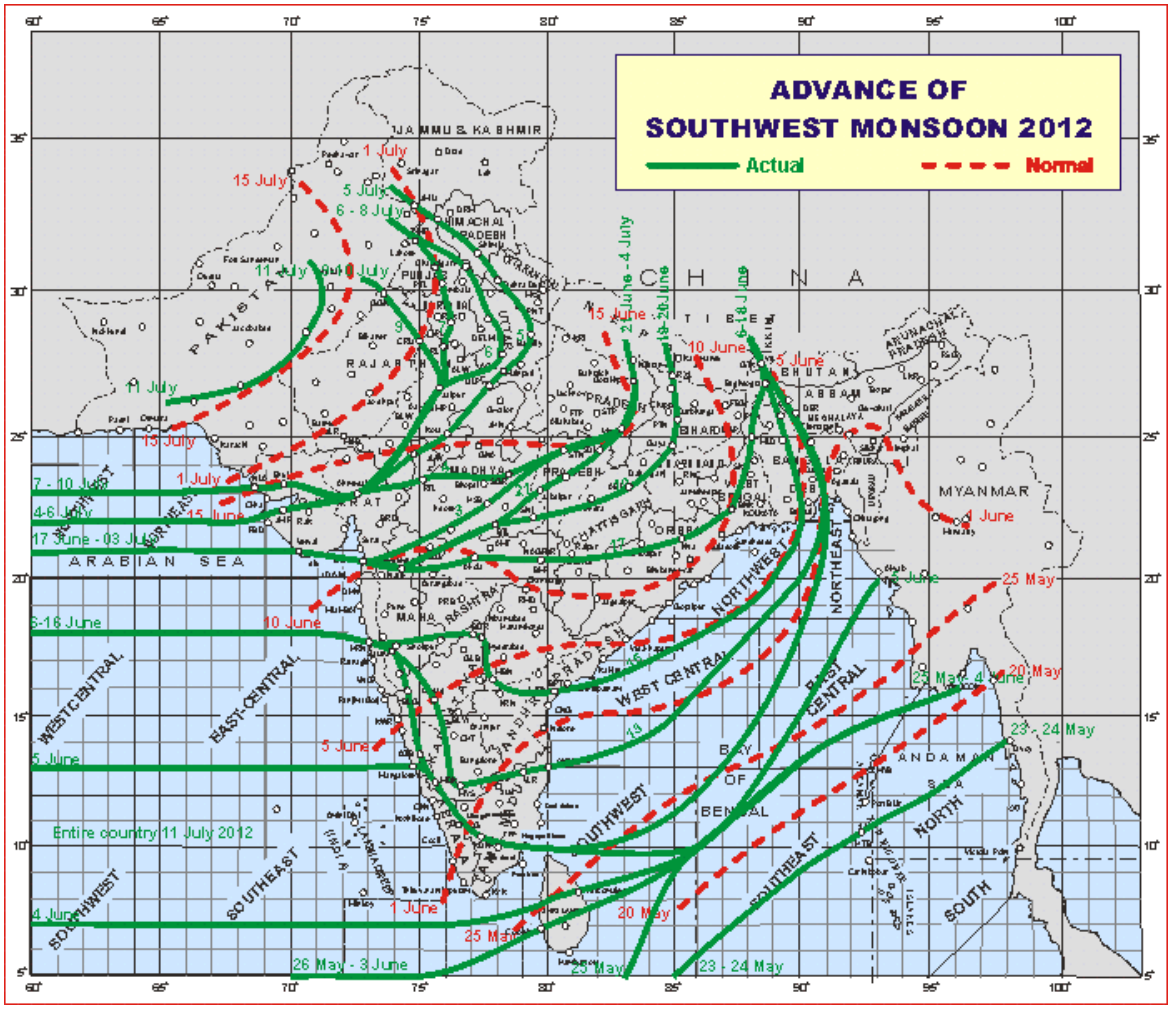

Fig.1: Progress of Southwest Monsoon – 2012

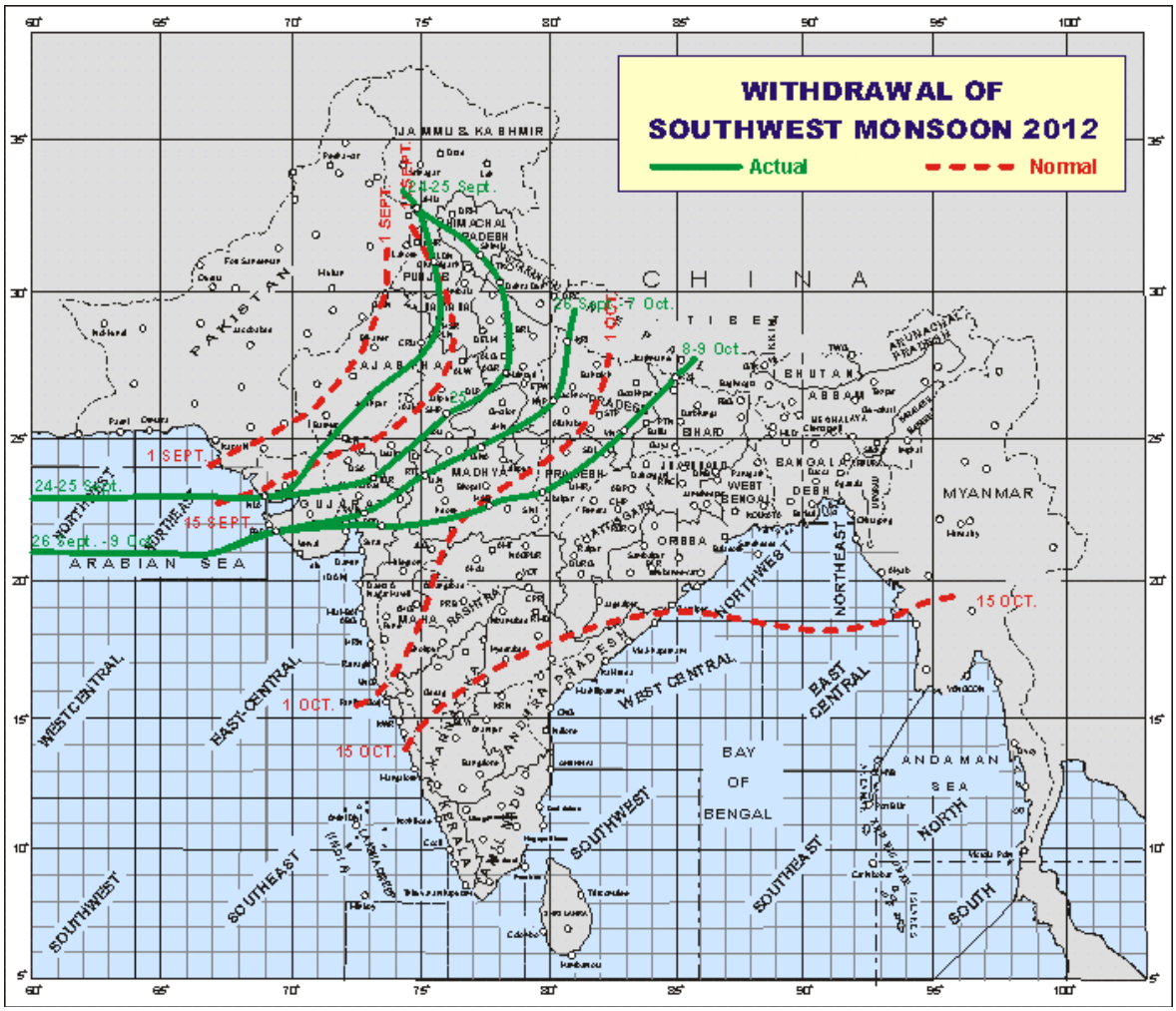

Fig.2: Isochrones of withdrawal of southwest monsoon - 2012.

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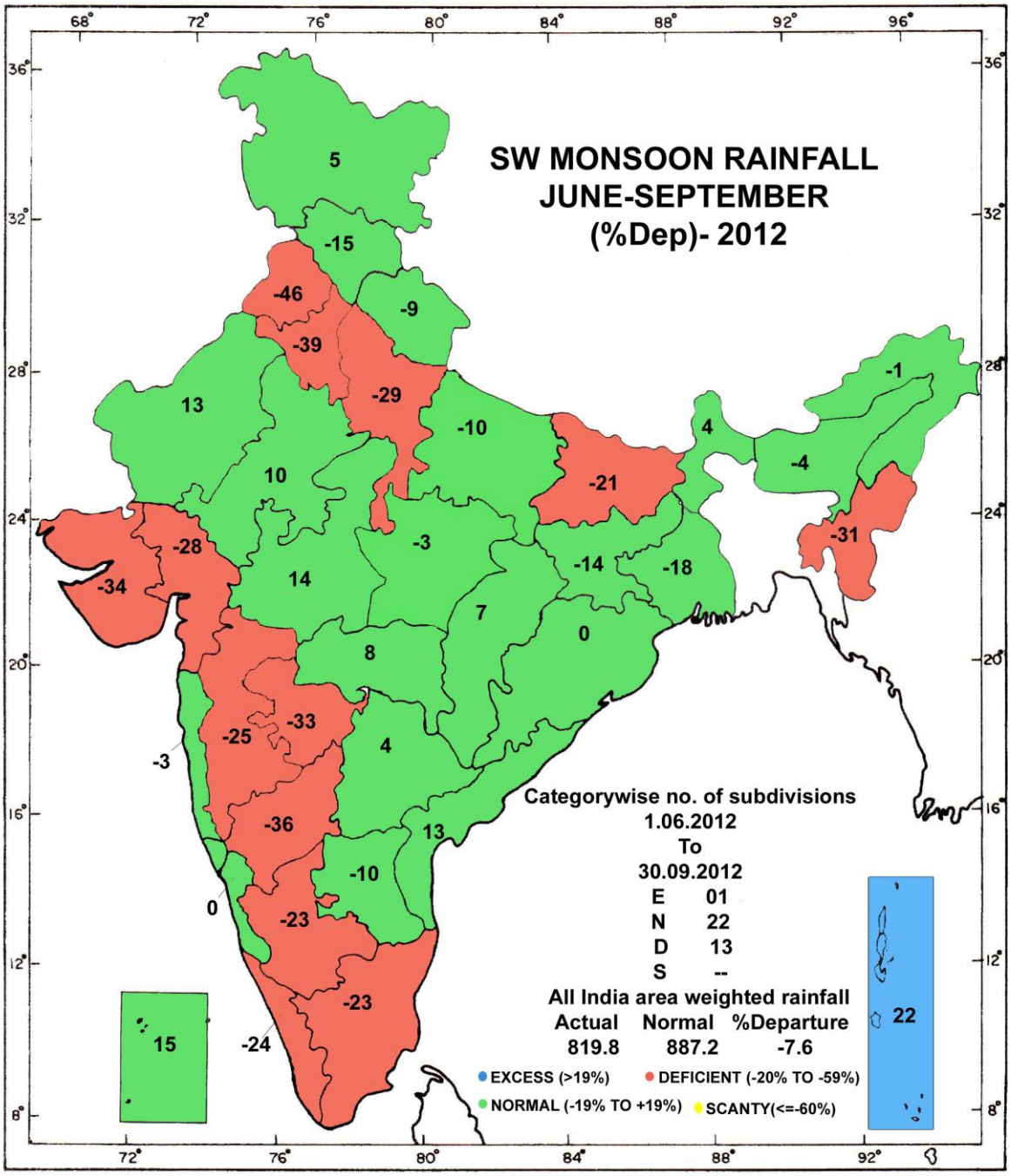

Fig.3: Sub-divisionwise rainfall distribution over India during southwest monsoon season (June to September) – 2012

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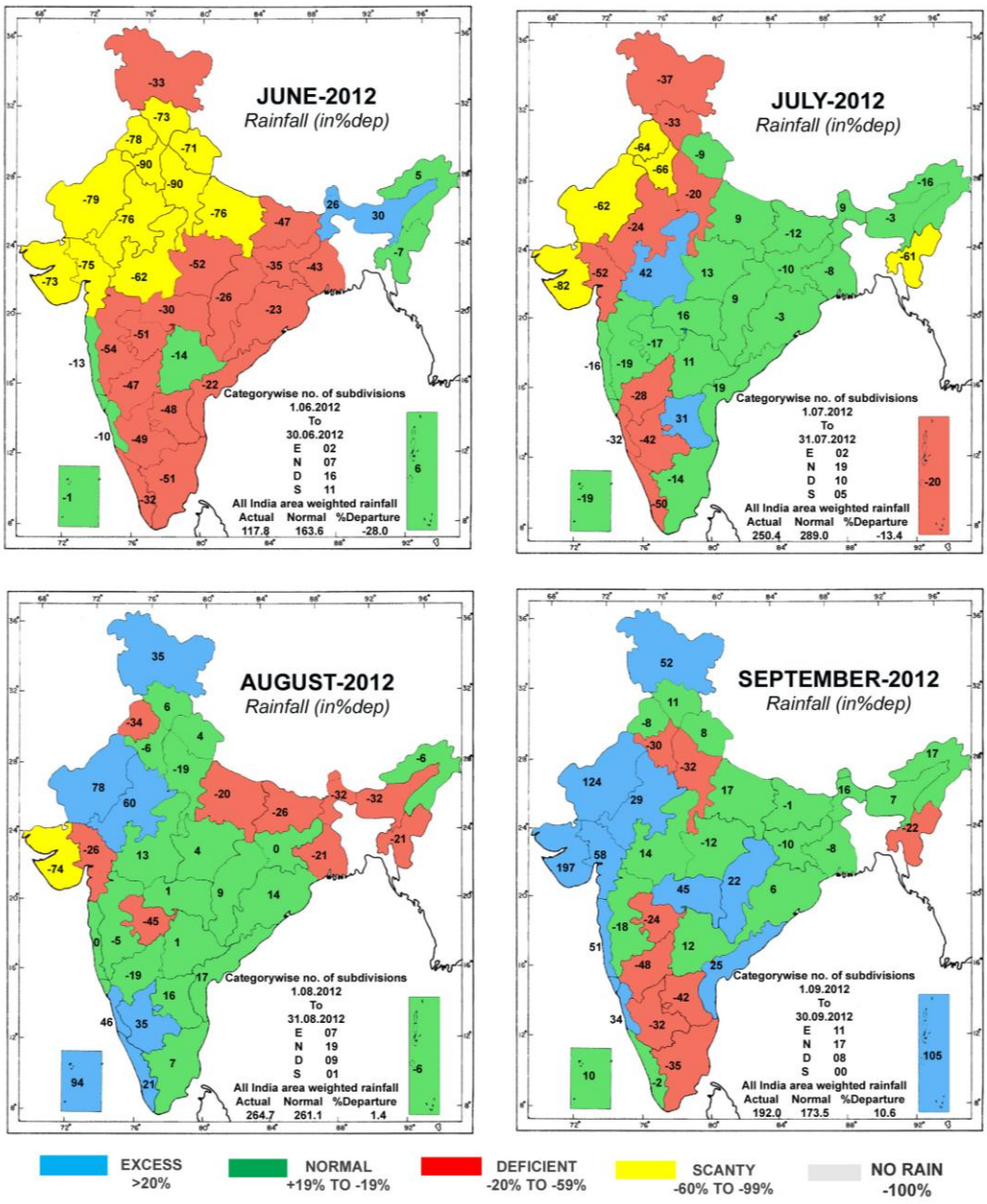

Fig.4: Sub-divisionwise monthly rainfall distribution over India during southwest monsoon season – 2012

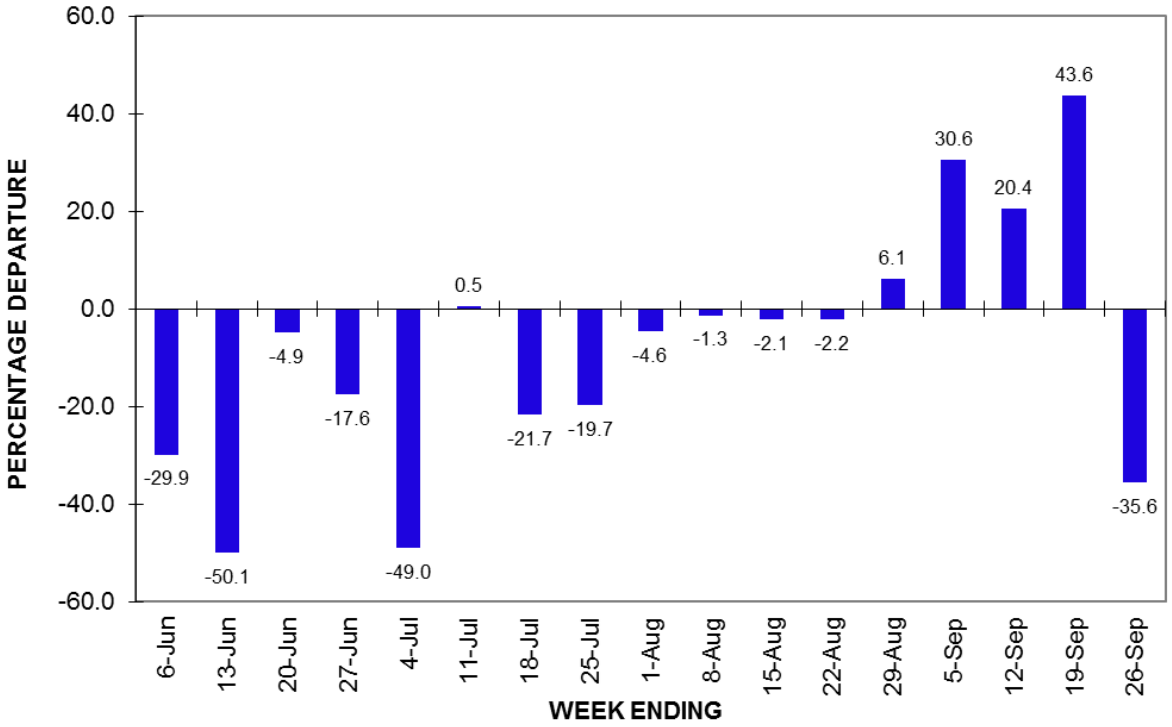

Fig.5: Week - by - Week Progress of the Monsoon Rainfall – 2012

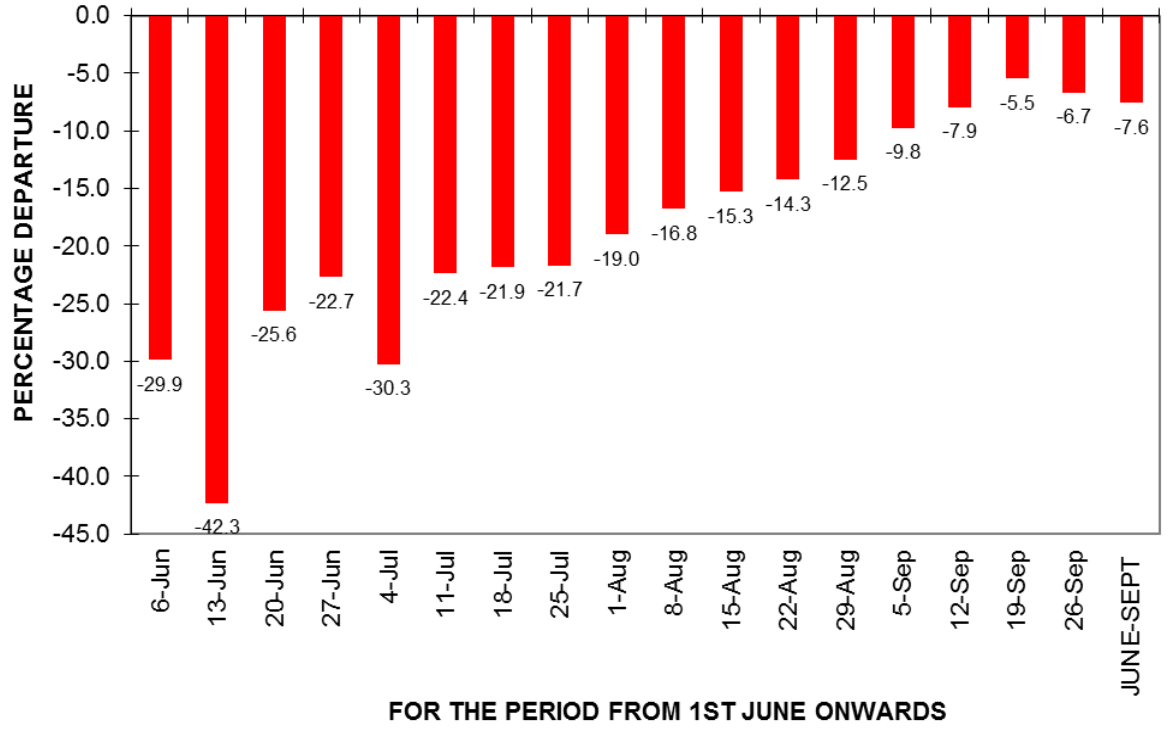

Fig.6: Week - by - Week Progress of the Monsoon Rainfall - 2012 (Cumulative)