



## INDIA METEOROLOGICAL DEPARTMENT

### 2013 SOUTHWEST MONSOON END OF-SEASON REPORT

#### HIGHLIGHTS

- For the country as a whole, the rainfall for the season (June-September) was 106 % of its long period average (LPA).
- Seasonal rainfall was 109% of its LPA over Northwest India, 123% of its LPA over Central India, 115% of its LPA over south Peninsula and 72% of its LPA over Northeast (NE) India.
- Out of the total 36 meteorological subdivisions, 14 subdivisions constituting 48% of the total area of the country received excess season rainfall, 16 subdivisions (38% of the total area of the country) received normal season rainfall and the remaining 6 subdivisions (14% of the total area of the country) received deficient season rainfall.
- Monthly rainfall over the country as a whole was 132% of LPA in June, 106% of LPA in July, 98% of LPA in August and 86% of LPA in September.
- Out of the total of 641 districts, 100 were affected by moderate meteorological drought (seasonal rainfall deficiency of 26% to 50%), while 39 were affected by severe meteorological drought (seasonal rainfall deficiency of 51% to 99%)
- Southwest monsoon current advanced over the Andaman Sea 3 days earlier than its normal data of 20<sup>th</sup> May and set in over Kerala on its normal date of 1<sup>st</sup> June. The southwest monsoon covered the entire country by 16<sup>th</sup> June, about 1 month earlier than its normal date of 15<sup>th</sup> July.
- The withdrawal of monsoon from west Rajasthan commenced on 9<sup>th</sup> September compared to its normal date of 1st September. After 19<sup>th</sup>, further withdrawal of southwest monsoon was stalled with the successive formation of two low pressure areas and their westward movement across the central parts of the country.
- During the season, 2 monsoon depressions and 16 monsoon low pressure areas were formed as against the normal of 6 monsoon depressions and 6 monsoon low pressure areas per season.
- The forecast for monsoon onset over Kerala for this year was correct, which is the ninth consecutive correct forecast for this event since issuing of forecast for the event was started in 2005.
- The operational long range forecasts for the 2013 southwest monsoon season rainfall over the country as whole and that over 3 broad geographical regions i.e. Northwest India, Central India and South Peninsula were an underestimate and for Northeast India, it was an overestimate.
- However, forecast for the rainfall over the country as a whole during the monsoon months of July, August and September and that for the second half of the monsoon season were within the forecast limits and accurate.

## 1. Onset and Advance of southwest Monsoon

Associated with the formation of Cyclonic Storm Mahasen (10<sup>th</sup> - 16<sup>th</sup> May) over southeast Bay of Bengal, low level cross equatorial monsoon flow strengthened over south Andaman Sea and adjoining south Bay of Bengal. This subsequently resulted in the advance of southwest monsoon over Andaman Sea and some parts of southeast Bay of Bengal on 17<sup>th</sup> May, 3 days before the normal date of 20<sup>th</sup> May. Cross equatorial flow over the Arabian Sea remained strong since the advance of southwest monsoon over the Andaman Sea.

The southwest monsoon set in over Kerala on 1<sup>st</sup> June, on its normal date. The same day, monsoon advanced over entire south Arabian Sea, Maldives-Comorin area, Lakshadweep, some parts of central Arabian Sea, entire Kerala, some parts of Coastal & South Interior Karnataka and most parts of Tamil Nadu. Convectively active phase of the Madden - Julian Oscillation (MJO) and the associated systematic northward propagation of the east-west shear zone at the mid-tropospheric levels during the subsequent period helped faster advance of monsoon and increased rainfall activity over the country.

The pace of advance of southwest monsoon this year had been the fastest during the period 1941-2013. Since the onset took place over Kerala on 1st June, it rapidly covered the south peninsula and northeast India by 9<sup>th</sup> June and central, eastern parts and western Himalayan region by 15<sup>th</sup> June. This was also aided by the formation and west- northwestward movement of a low pressure area along the east-west trough during the same period. On 16<sup>th</sup> June, presence of this low pressure area over east Rajasthan & neighbourhood superposed with a trough in the mid & upper tropospheric westerlies provided conditions conducive for the large scale convection and wide spread monsoon rains over northwest India. This helped monsoon to advance over the entire country on 16<sup>th</sup> June, about a month earlier than its normal date of 15<sup>th</sup> July.

Fig.1 shows the isochrones of advance of monsoon 2013.

## 2. Chief Synoptic Features

Strong cross equatorial flow prevailed during June and July. It gradually weakened during the latter half of the season. The axis of monsoon trough remained in its near normal position and extended upto lower tropospheric levels without its characteristic southward tilt with height during most parts of the season. The seasonal 'heat low' weakened from the beginning of September. Subsequently, the axis of monsoon trough also weakened and thereby became less delineated at mean sea level since 4<sup>th</sup> September.

Though no typical break situation developed during the season, the rainfall pattern from the end of August to the first week of September resembled break like, as a consequence to the overall weakening of the monsoon circulation.

During the season, only 2 monsoon depressions were formed against a normal of 6 depressions per season. However, 16 monsoon low pressure areas were formed against a normal of 6 low pressure areas per season. The tracks of the 2 monsoon depressions are given in Fig.2. One depression formed over the Bay of Bengal in the month of July and another formed over land in August. During the last about 30 years, there were two years (1984 and 1996) when 18 low pressure areas had formed in the monsoon season. During each of both these years, 3 low pressure areas had intensified into depressions. Out of the sixteen low pressure areas formed during this season, 12 formed over the Bay of Bengal, 3 formed over land and one formed over the Arabian Sea. The month wise break up is 3 in June, 4 in July, 5 in August and 4 in September.

The first low pressure area (4<sup>th</sup>-5<sup>th</sup> June) formed over the Arabian Sea under the influence of cyclonic circulation embedded in the shear zone during the onset phase. Though it was short lived, the formation of this low pressure area stalled the advance of the Monsoon over the Arabian Sea for 3 days (5<sup>th</sup> -7<sup>th</sup> June). However, the second low pressure area which formed over the Bay of Bengal moved west-northwestwards during 12<sup>th</sup> – 17<sup>th</sup> June upto Rajasthan and Haryana and its interaction with a trough in the mid & upper tropospheric westerlies helped the monsoon to cover the entire country.

During July one low pressure area (10<sup>th</sup>-13<sup>th</sup> July) formed over land and 3 low pressure areas (15<sup>th</sup> – 17<sup>th</sup> July, 19<sup>th</sup>-25<sup>th</sup> July, 25<sup>th</sup>-29<sup>th</sup> July) formed over the Bay of Bengal. All these 4 low pressure areas and one depression (30<sup>th</sup>-31<sup>st</sup> July) that formed over the Bay of Bengal moved northwestward along the monsoon trough and helped to maintain the monsoon activity over the region.

The cyclogenesis during the second half of the season had a major contribution from the remnant vortices from the east. A land depression formed during 20<sup>th</sup>-22<sup>nd</sup> August over Gangetic West Bengal and adjoining northwest Bay of Bengal dissipated over east Madhya Pradesh. The five low pressure areas that formed in the month of August were mostly of short duration. Two dissipated *in-situ* and were of 1 day duration, two moved up to east Uttar Pradesh and adjoining areas and the low pressure area during 9<sup>th</sup>-11<sup>th</sup> August dissipated over west Uttar Pradesh and adjoining areas of east Rajasthan. Monsoon activity in general remained weak over areas outside central and east India.

During the first fortnight of the September, rainfall was mainly confined to east, northeast and south peninsula. With the formation of a low pressure area over northwest Bay of Bengal on 19<sup>th</sup> September and its westward movement across the central parts of the country, the monsoon activity revived. Even after the dissipation of the low pressure area on 23<sup>rd</sup>, the remnant of the system as an upper air cyclonic circulation remained quasi-stationary over Gujarat State. Under the influence of this cyclonic circulation, another low pressure area formed over Kutch & neighbourhood on 27<sup>th</sup> September and

became less marked on 30<sup>th</sup>. The last low pressure area of the season formed over northwest Bay of Bengal and adjoining coastal areas of West Bengal and Odisha on 28<sup>th</sup> evening and persisted there till the last day of the season.

### **3. Floods and Droughts**

Incessant rainfall associated with the monsoon low pressure systems and active monsoon conditions often caused flood situations over various states during different parts of the season. The interaction between the monsoon low and the trough in the westerlies during the advance phase of monsoon caused severe floods during 16<sup>th</sup>–17<sup>th</sup> June over Uttarakhand. Downstream convergence of the stronger than normal low level winds during the first half of the season led to several events of incessant heavy rains and floods over Kerala. Towards the end of the season, Gujarat and adjoining areas of south Rajasthan experienced extremely heavy rainfall and flood situation due to the revival of the monsoon activity associated with a cyclonic circulation that remained quasi-stationary for few days over Gujarat and neighboring areas. Apart from these, some other subdivisions/states which experienced flood situations were Assam & Meghalaya, West Bengal & Sikkim, Odisha, Jharkhand, Bihar, Uttar Pradesh, Haryana, Himachal Pradesh, Madhya Pradesh, Gujarat, Vidarbha, Chhattisgarh, Andhra Pradesh and Karnataka. The floods occurred in Assam & Meghalaya, Jharkhand and Bihar were primarily due to the flooding of the rivers because of the heavy rainfall in the upper reaches of catchment areas.

During most part of the season, many districts of Arunachal Pradesh, Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Jharkhand and Bihar experienced moderate to extreme drought conditions.

### **4. Withdrawal of southwest Monsoon**

The weather over the western parts of Rajasthan remained mainly dry for more than a fortnight (from 27<sup>th</sup> August). A change over in the lower tropospheric circulation pattern over the region from cyclonic to anti cyclonic during 8<sup>th</sup> - 9<sup>th</sup> September resulted in the withdrawal of southwest monsoon from the region. Hence the withdrawal of southwest monsoon commenced from 9<sup>th</sup> September and the withdrawal line passed through Ganganagar, Bikaner and Barmer during 9<sup>th</sup>-18<sup>th</sup> September. The Southwest Monsoon withdrew from entire Jammu & Kashmir, Himachal Pradesh and Punjab; some parts of Haryana; some more parts of Rajasthan and some parts of Kutch on 19<sup>th</sup> and the withdrawal line passed through Kalpa, Hissar, Jodhpur and Naliya. However, an almost complete revival in the monsoon activity occurred from the 3<sup>rd</sup> week of September. With the successive formation of two low pressure areas and their westward movement across

the central parts of the country caused the east-west trough to remain active contributing to above normal rainfall during this period. This development has stalled the further withdrawal of southwest monsoon.

Fig.3 shows the isochrones of withdrawal of monsoon 2013.

## 5. Rainfall Distribution

The actual season (June to September) rainfall over the country as a whole and four broad geographical regions during the 2013 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.

<b>Season (June to September) rainfall</b>			
Region	LPA (mm)	Actual Rainfall for 2013 SW Monsoon Season	
		Rainfall (mm)	Rainfall (% of LPA)
All India	886.9	936.7	106
Northwest India	615.0	671.8	109
Central India	974.2	1195.3	123
Northeast India	1437.8	1037.9	72
South Peninsula	715.7	825.6	115
<b>Monthly &amp; second half of the monsoon season rainfall over the country as a whole (All India)</b>			
Month	LPA (mm)	Actual Rainfall for 2013 SW Monsoon Season	
		Rainfall (mm)	Rainfall (% of LPA)
June	163.5	216.3	132
July	288.9	307.5	106
August	261.0	257.0	98
September	173.5	149.5	86
August + September	434.5	406.5	94

As seen in the table above, the season rainfall over the country as whole and that over three of the four geographical regions of the country (except over northeast India) were more than the respective LPAs. The season rainfall over northeast India was less than its LPA. Month wise, the rainfall over the country as a whole during the first two months (June and July) were above its LPA values. On the other hand, the monthly rainfall during the last two months (August and September) of the monsoon season was less than respective LPA values.

**Fig.4 shows the subdivision wise season (June to September) rainfall.**

The season rainfall from 1st June to 30 September 2013 was excess in 14 subdivisions, which constitutes 48% of the total area of the country, normal in 16

meteorological subdivisions (38% of the total area of the country) and deficient in 6 meteorological subdivisions (14% the total area of the country).

***Fig.5 shows the subdivision wise monthly rainfall.***

In June, except for 3 subdivisions from extreme northeast India (Arunachal Pradesh, Assam and Meghalaya, and Nagaland, Manipur Mizoram & Tripura), which received deficient rainfall, all the other subdivisions (33 out of 36) received excess (25 subdivisions) or normal (8 subdivisions) rainfall. In July, 10 subdivisions from northern, eastern and northeastern parts of the country and one in the extreme southeast (Tamil Nadu and Pondicherry) received deficient rainfall. Out of the 25 remaining subdivisions, 12 subdivisions received normal and 13 subdivisions, majority of which are from central India and along the west coast, received excess rainfall. In August, rainfall activity weakened compared to the first two months but was close to normal. During August, 8 subdivisions received excess rainfall, 18 subdivisions received normal rainfall and remaining 10 subdivisions received deficient rainfall. The excess subdivisions were Jammu & Kashmir, Punjab, west and east Rajasthan, west and east Madhya Pradesh, Gangetic West Bengal and Tamil Nadu. The deficient subdivisions were 3 of the 4 subdivisions of Maharashtra (except Vidarbha), north interior Karnataka, Lakshadweep, Orissa, Bihar, and 3 subdivisions from extreme northeast India.

In September, the rainfall activity reduced further and 17 subdivisions from north, east, northeast and central India received deficient or scanty rainfall. The 4 scanty subdivisions were Punjab, west and east Uttar Pradesh and east Madhya Pradesh. Out of the remaining 19 subdivisions, 9 subdivisions were excess and 10 subdivisions were normal. The excess subdivisions were, west Rajasthan, 2 subdivisions of Gujarat, Madhya Maharashtra, 3 subdivisions of Karnataka, Kerala and Rayalaseema.

From the monthly distribution, it can be clearly seen that during most part of the season, the 3 subdivisions from the extreme northeast received deficient rainfall. On the other hand, most of the subdivisions from the central India and neighboring northwest India and south Peninsula received excess rainfall during the first 3 months of the season. However no subdivisions experienced scanty rainfall during first 3 months of the season. Only in September that 4 subdivisions received scanty rainfall. Overall, there was noticeable disparity in the spatial distribution of the rainfall with below normal or deficient rainfall over east and northeast India and above normal or excess rainfall over most of the other regions.

**Figures 6 and 7 depict the all India weekly and cumulative weekly rainfall anomaly expressed as percentage departure from the LPA.**

The all India weekly rainfall anomalies during 8 of the 9 weeks of the first half of the monsoon season were positive. The only exception was the negative rainfall anomaly

during the week ending 10<sup>th</sup> July. On the other hand, during 6 out of the 8 weeks (except weeks ending 21<sup>st</sup> August and 21<sup>st</sup> Sept) of the second half of the season, the weekly rainfall anomalies were negative. Due to above normal all India rainfall during most of the weeks of the first half of the monsoon season, the all India cumulative weekly rainfall anomalies were positive throughout the season.

## **6. Verification of the Long Range Forecasts**

Based on an indigenously developed statistical model, it was predicted on 15<sup>th</sup> May 2013 that monsoon will set in over Kerala on 3<sup>rd</sup> June with a model error of  $\pm 4$  days. The forecast came correct as the actual monsoon onset over Kerala took place on the normal date of 1<sup>st</sup> June, 2 days earlier than the forecasted date. Thus, this is the ninth consecutive correct operational forecast for the date of monsoon onset over Kerala since issuing of operational forecast for the event was started in 2005.

This year, the first stage long range forecast for the season (June-September) rainfall for the country as a whole was issued on 26<sup>th</sup> April and its update was issued on 14<sup>th</sup> June. Both the forecast were same (98% of LPA) but with a model error of  $\pm 5\%$  of LPA for the first stage forecast and that of  $\pm 4\%$  of LPA for the updated forecast. However, the actual season rainfall for the country as a whole (106% of LPA) was more than the forecast by 8% of LPA, and therefore was above the upper forecast limit of 102% of LPA. The forecast for the second half of the monsoon season (August –September) for the country as a whole issued in August was 96% with a model error of 8% of LPA against the actual rainfall of 94% of LPA. Thus the forecast for the rainfall during the second half of the monsoon season over the country as a whole was within the forecast limit.

The forecasts for monthly rainfall over the country as a whole for the months of July, August issued in June were 101% & 96% respectively with a model error of  $\pm 9\%$ . The forecast for rainfall over the country as a whole for the September issued in August was 96% of LPA with a model error of  $\pm 13\%$ . The actual rainfall during July, August and September were 106%, 98% & 86% of respective LPA values. Thus the forecast during July, August and September were within the forecasts limits.

Considering the four broad geographical regions of India, the season rainfall was expected to be 94% of its LPA over northwest India, 98% of LPA over Central India, 98% of LPA over northeast India and 103% of LPA over South Peninsula all with a model error of  $\pm 8\%$ . The actual rainfalls over northwest India, central India, northeast India and south Peninsula were 109%, 123%, 72% and 115% of the LPA respectively. Thus forecast for the season rainfall over northwest India, central India and south Peninsula were all underestimates to the actual rainfall by 15% of LPA, 25% of LPA and 12% of LPA respectively. On the other hand, the forecast for the season rainfall over the northeast India was overestimate to the actual rainfall by 26% of LPA. Thus all the forecast for

seasonal rainfall over all the four geographical regions were outside the forecast limits. The Table below gives the summary of the verification of the long range forecasts issued for the 2013 Southwest monsoon.

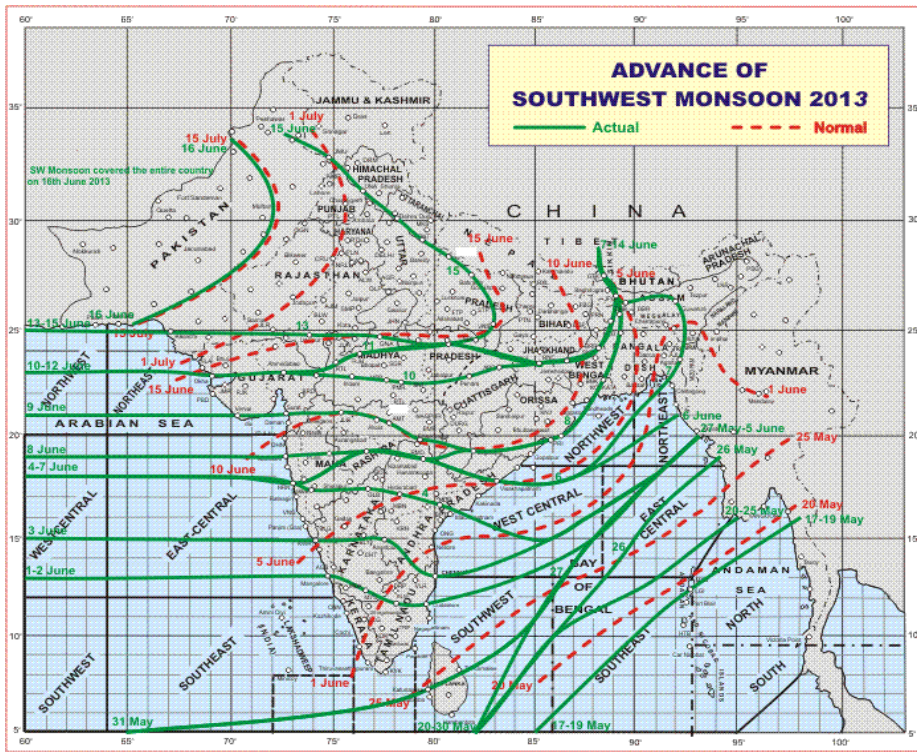
**Table: Details of long range forecasts and actual rainfall.**

Region	Period	Date of Issue	Forecast (% of LPA)	Actual Rainfall (% of LPA)
All India	June to September	26 <sup>th</sup> April	98 ± 5	106
All India	June to September	22 <sup>st</sup> June	98 ± 4	
Northwest India	June to September		94%± 8	109
Central India	June to September		98%± 8	123
Northeast India	June to September		98%± 8	72
South Peninsula	June to September		103%± 8	115
All India	July		101%± 9	106
All India	August		96%± 9	98
All India	August to September	2 <sup>nd</sup> August	96%± 8	94
All India	September	1 <sup>st</sup> September	96%± 13	86

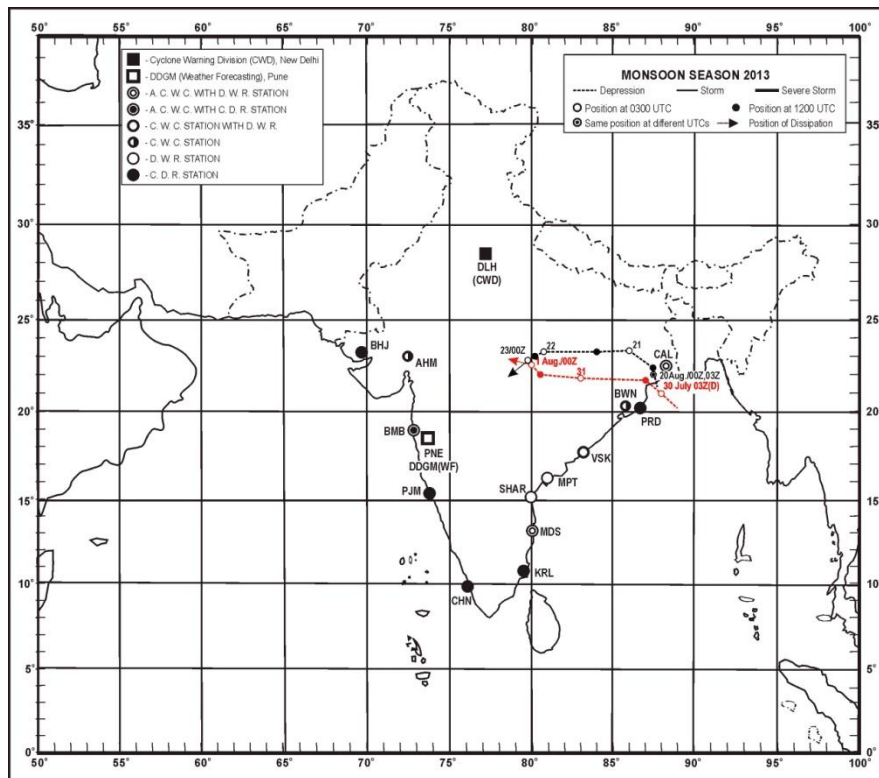
As seen in the table, the operational long range forecasts for season rainfall over the country as a whole and that over four broad geographical regions (northwest India, central India, northeast India and south Peninsula) were not accurate. On the other hand, the forecast rainfall over the country as a whole for all the three months (July, August and September) and that for the second half of the monsoon season were all accurate. The main reason for the underestimation of the season rainfall forecasts was the early advance of monsoon over the entire country and formation and passage of above normal activity of monsoon low pressure systems (cyclonic circulations, lows & depressions) across central India & north Peninsula. The formation and the passage of large number of monsoon low pressure systems also caused large disparity between the rainfall over east & northeast India and that over remaining regions of the country. The passage of monsoon low pressure systems along the monsoon trough some times upto northwest India and associated strengthening of low level winds caused strong moisture convergence and active monsoon conditions over the monsoon trough region and along the west coast. This resulted in the above normal rainfall over many parts of northwest India, central India & south Peninsula. On the other hand, presence of these systems over central India reduced the moisture supply to east and northeast India by way of diverting monsoon flow towards the systems resulting in conditions conducive for reduced rainfall activity over the region. During this monsoon season, the SST conditions over equatorial Pacific and Indian Ocean were more or less close to normal and thus had not much role on the observed rainfall distribution over the country.

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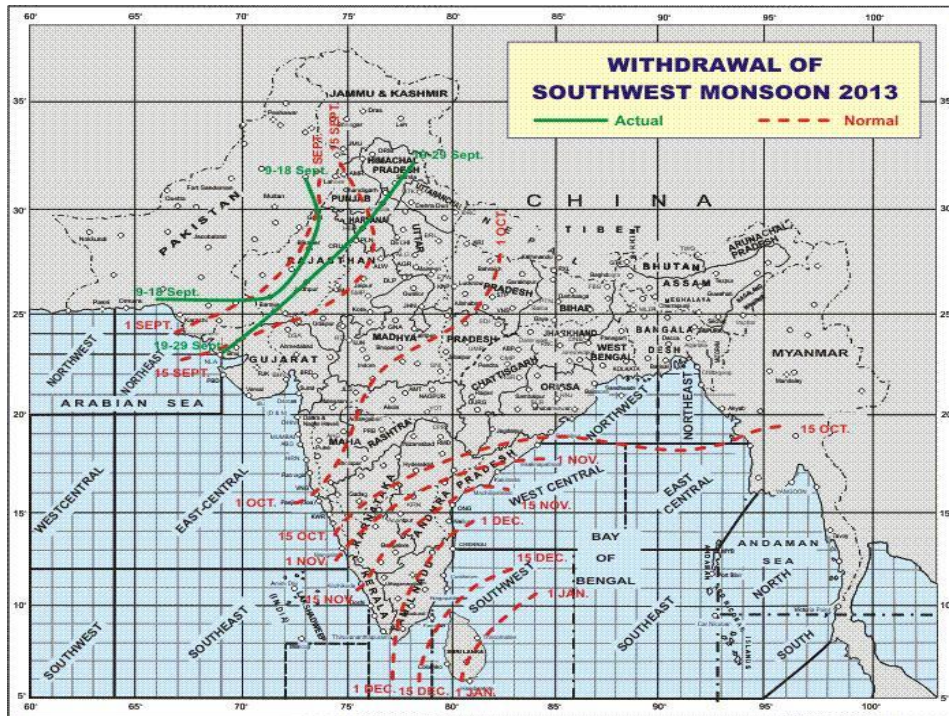




**Fig.1: Progress of Southwest Monsoon – 2013**

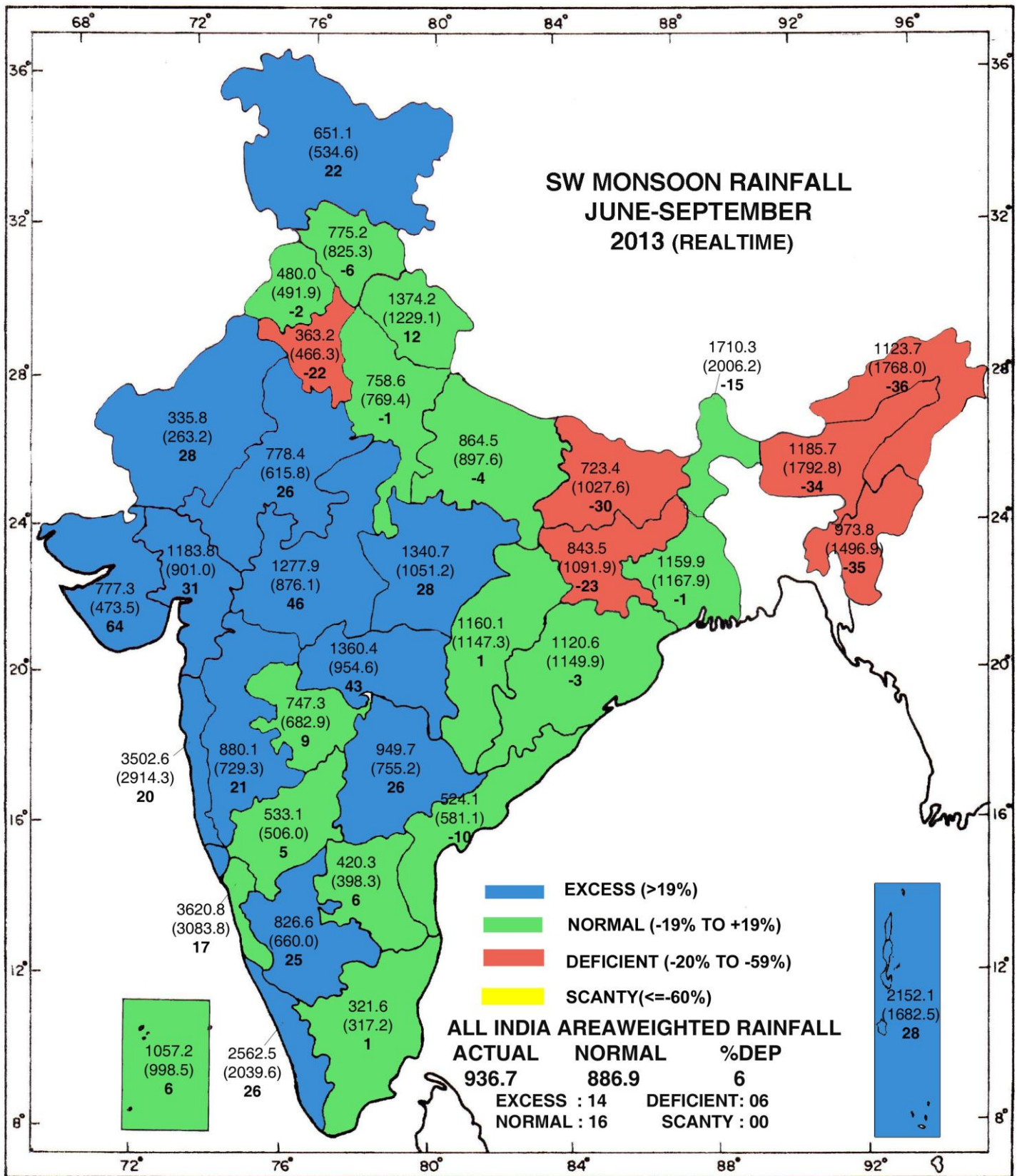


**Fig.2: Track of the monsoon depressions**

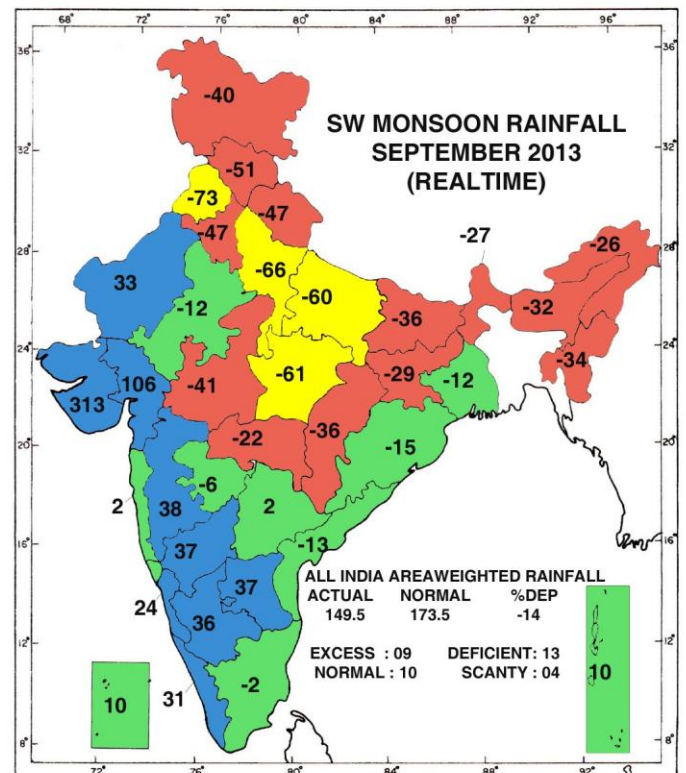
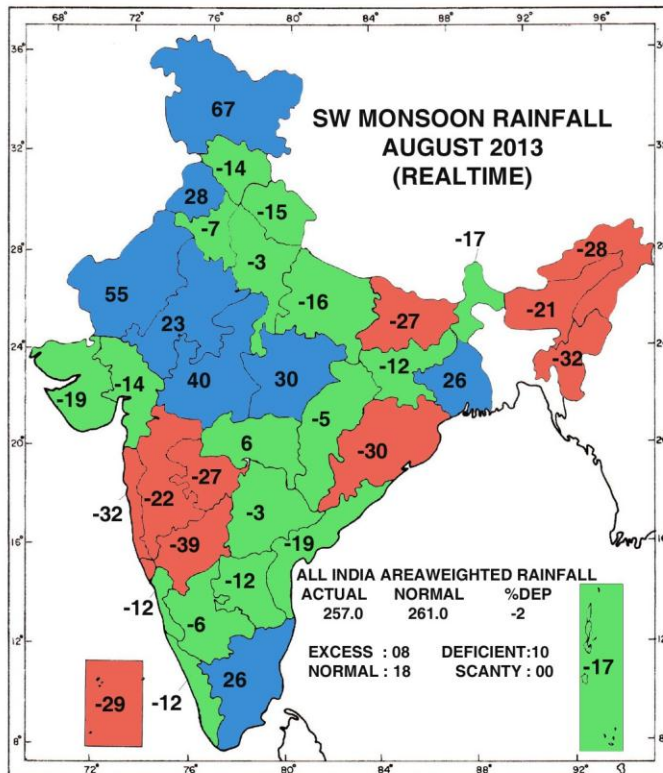
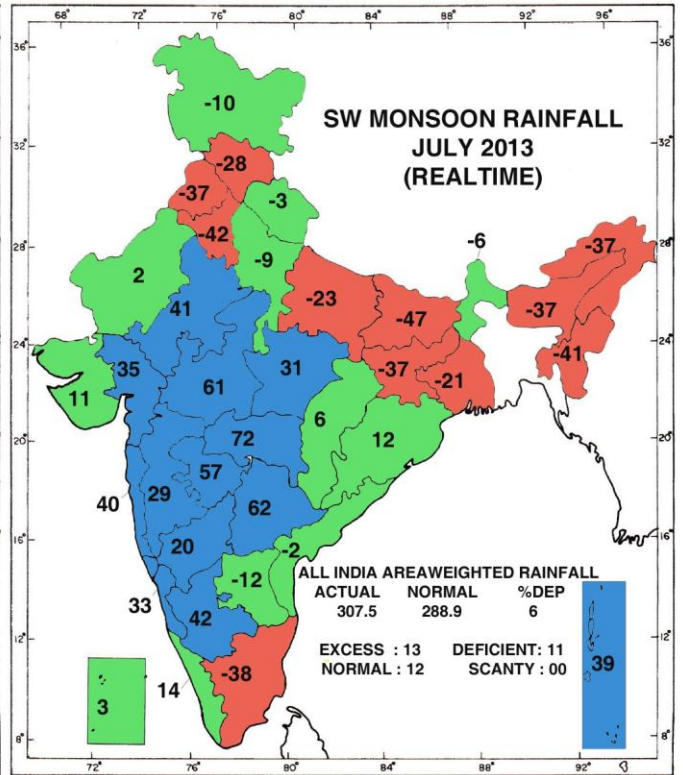
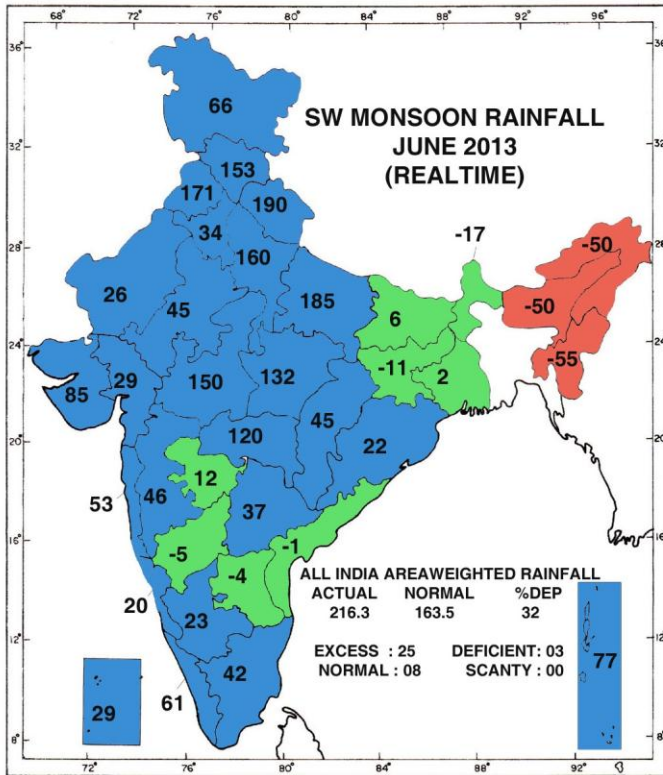


**Fig.3:** Isochrones of withdrawal of southwest monsoon - 2013.

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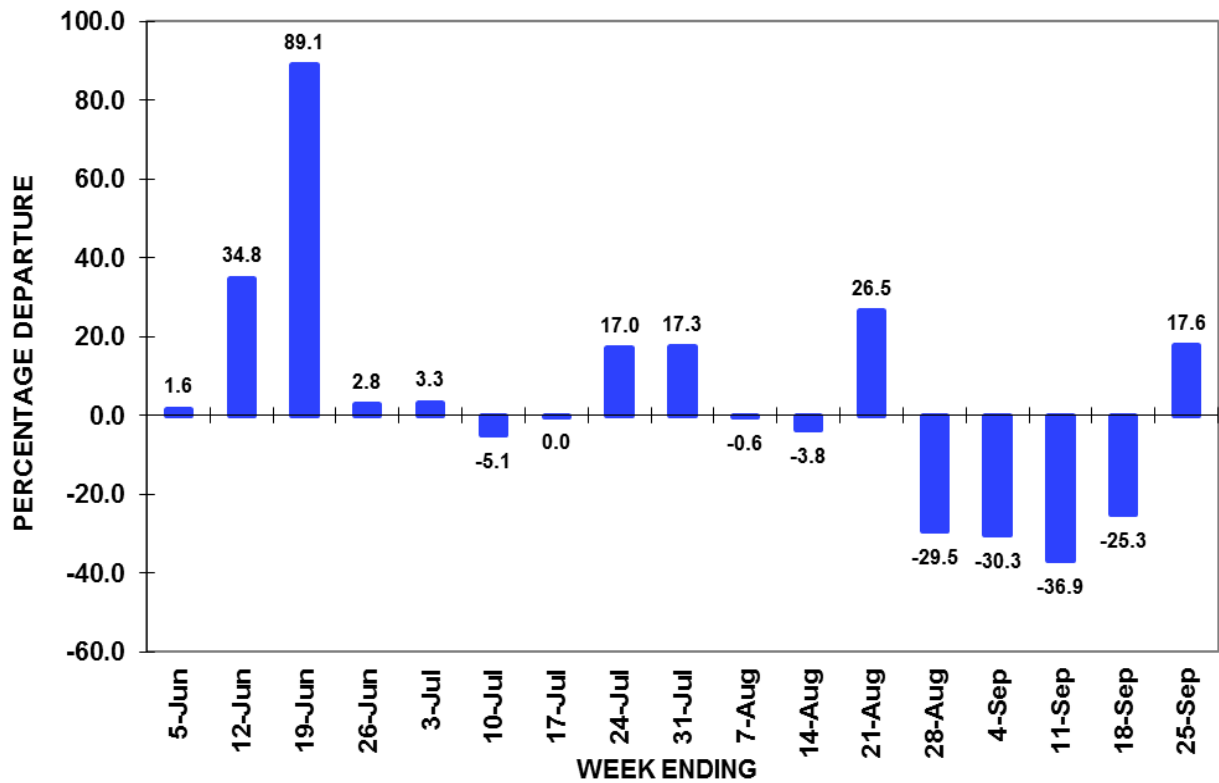


**Fig.4:** Sub-divisionwise rainfall distribution over India during southwest monsoon season (June to September) – 2013

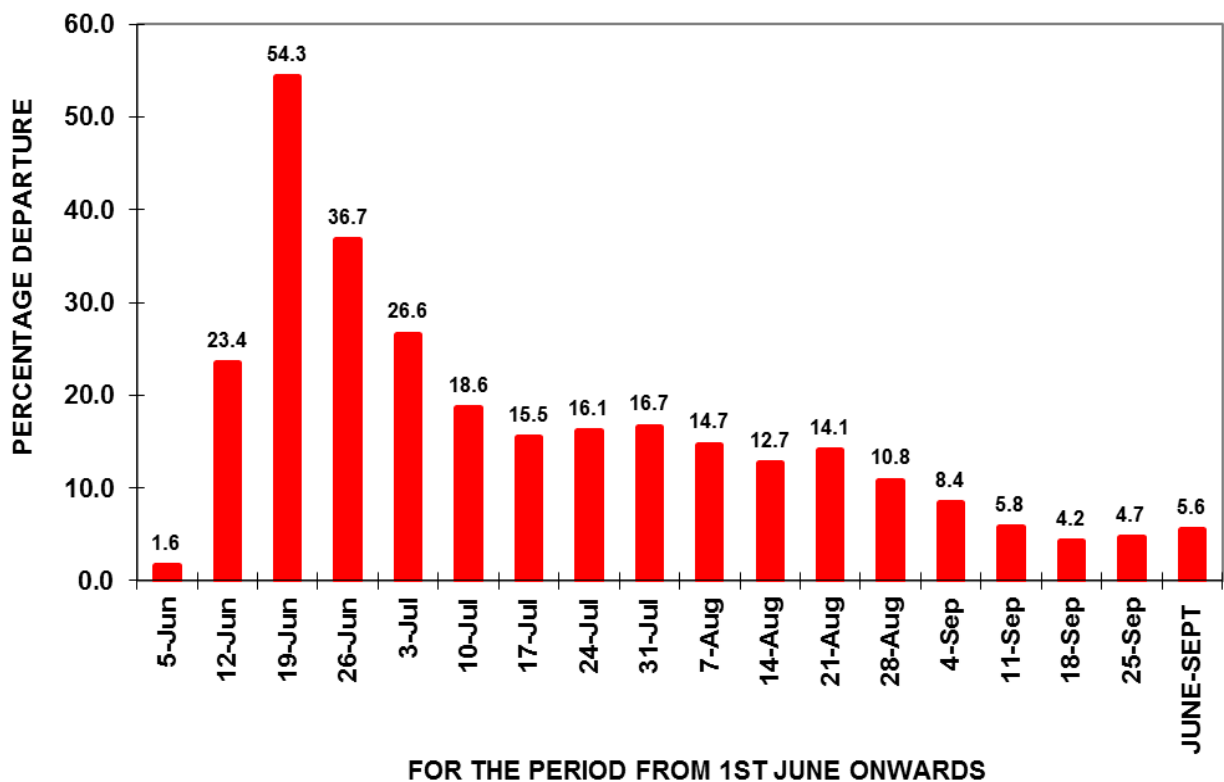


■ EXCESS (>19%) ; 
 ■ DEFICIENT (-20% TO -59%) ; 
 ■ NORMAL (-19% TO +19%)  
■ SCANTY(<=-60%)

**Fig.5: Sub-division wise monthly rainfall distribution over India during southwest monsoon season – 2013**



**Fig.6:** Week - by - Week Progress of the Monsoon Rainfall – 2013



**Fig.7:** Week - by - Week Progress of the Monsoon Rainfall - 2013 (Cumulative)