MAUSAM, **65**, 3 (July 2014), 441-460

Weather in India

MONSOON SEASON (JUNE - SEPTEMBER 2013)†

1. Introduction

The seasonal rainfall (during June to September 2013) over the country as a whole was 106% of its Long Period Average (LPA) and thus categorized as a normal monsoon. However the rainfall over Arunachal Pradesh, Assam & Meghalaya and Nagaland-Manipur-Mizoram-Tripura consistently was deficient. Bihar, Jharkhand and Haryana received deficient rainfall during major part of the season for the months July-September. The first three months of the season, registered normal to above normal rainfall, and September experienced deficient rainfall. In all 18 low pressure areas formed during the monsoon season, this year, out of which two intensified into depressions as against the normal frequency of 4-6 monsoon Typical break situation did not develop during the months of July and August, but 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. The Madden

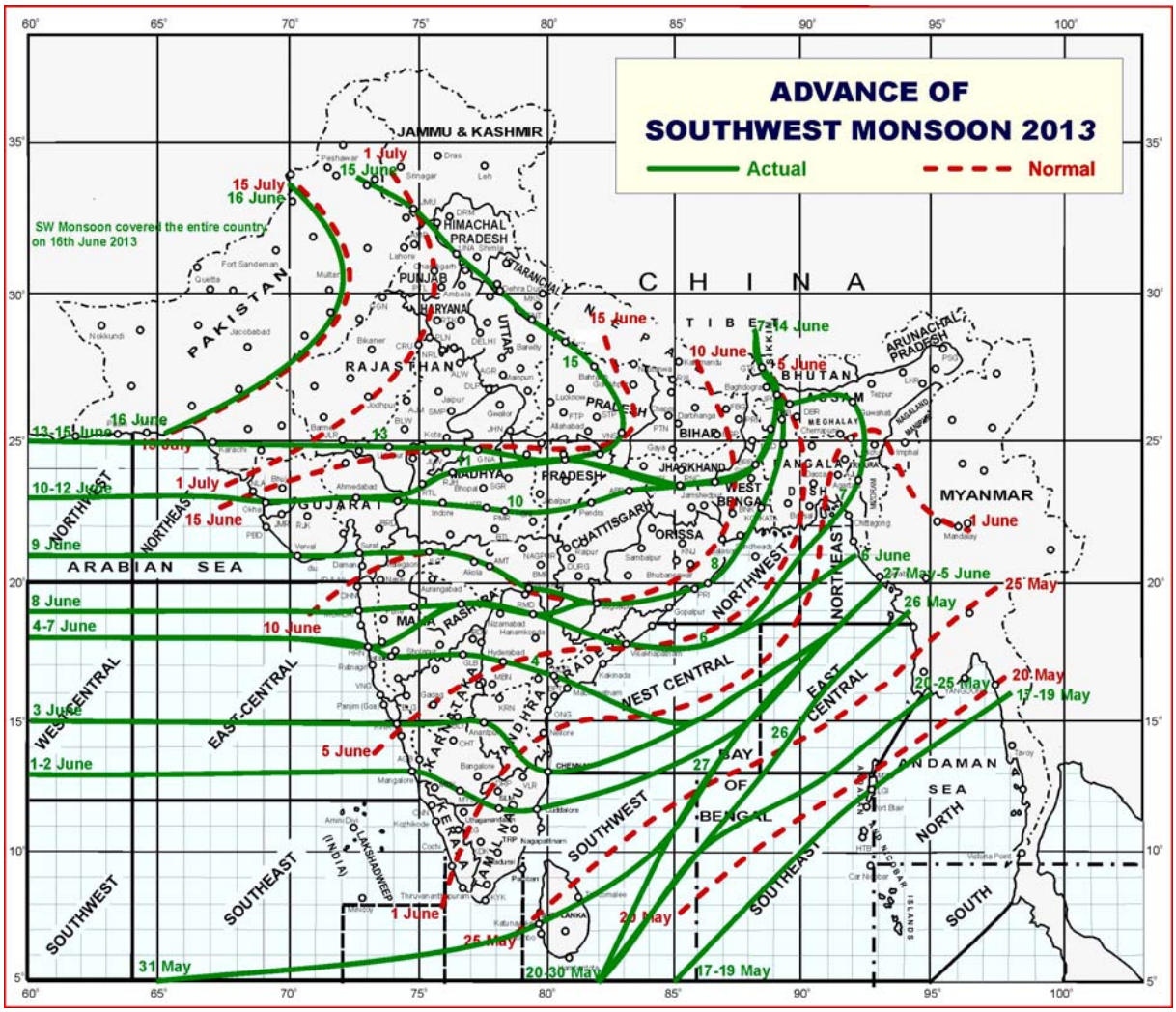

Fig. 1. Isochrones of advance of SW Monsoon 2013

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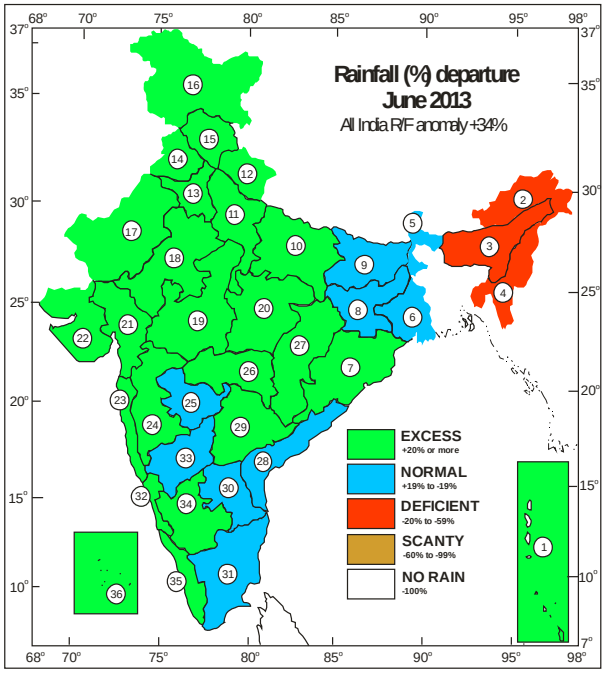


Fig. 2. Rainfall for the month of June 2013 as percentage departure from normal. 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	77	**7**	27	**13**	35	**19**	150	**25**	12	**31**	19
2	-42	**8**	-8	**14**	171	**20**	133	**26**	118	**32**	20
3	-46	**9**	9	**15**	152	**21**	29	**27**	45	**33**	-5
4	-55	**10**	188	**16**	76	**22**	85	**28**	-3	**34**	25
5	-17	**11**	166	**17**	26	**23**	53	**29**	37	**35**	60
6	1	**12**	191	**18**	45	**24**	46	**30**	-4	**36**	29

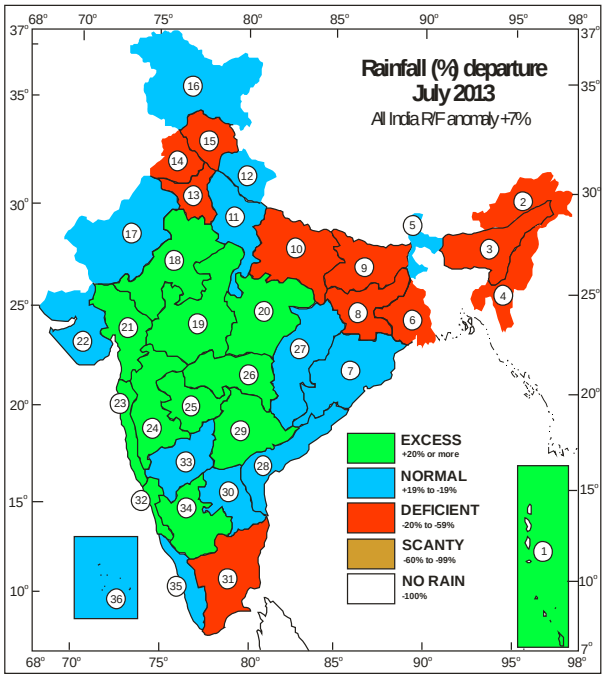


Fig. 3. Rainfall for the month of July 2013 as percentage departure from normal. 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	39	**7**	13	**13**	-42	**19**	66	**25**	57	**31**	-37
2	-39	**8**	-37	**14**	-37	**20**	31	**26**	72	**32**	32
3	-34	**9**	-47	**15**	-28	**21**	35	**27**	13	**33**	19
4	-38	**10**	-23	**16**	-9	**22**	11	**28**	-2	**34**	42
5	-4	**11**	-9	**17**	2	**23**	40	**29**	62	**35**	14
6	-20	**12**	-3	**18**	41	**24**	29	**30**	-12	**36**	3

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 rainfall activity over the country.

2. Various aspects of southwest monsoon – 2013

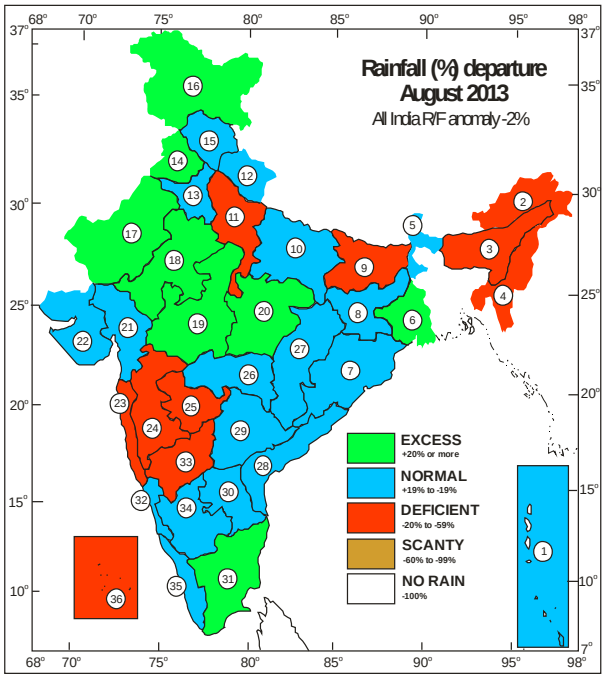
2.1. *Onset and advance*

Fig. 1 shows the isochrones of advance of monsoon over the country.

With the formation of Cyclonic Storm Viyaru (10th - 16th May) over southeast Bay of Bengal, low level cross equatorial monsoon flow strengthened over south Andaman Sea and adjoining south Bay of Bengal and aided the advance of southwest monsoon over Andaman Sea and some parts of southeast Bay of Bengal on 17th May, 3 days earlier than the normal date of 20th May.

The southwest monsoon also advanced into 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 on 1st June. Hence, the monsoon set in over Kerala on 1st June, on its normal date.

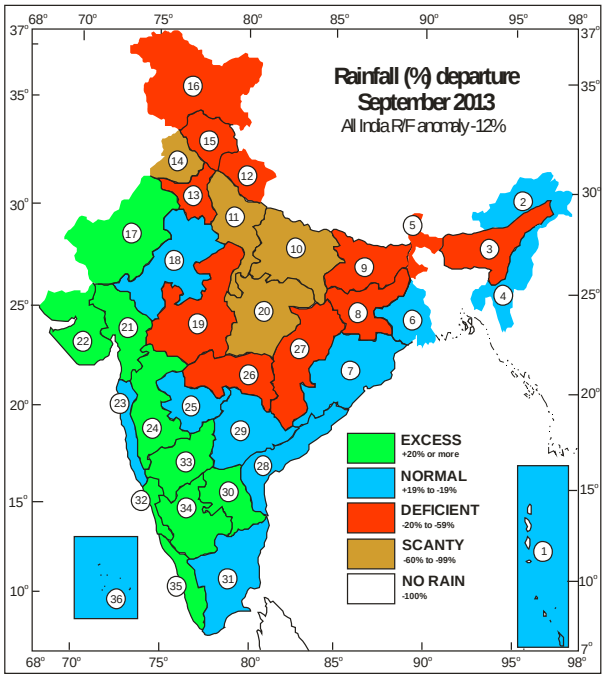
Convectively active phase of the Madden - Julian Oscillation (MJO) and the associated systematic northward propagation of the east-west shear zone at the mid-tropospheric levels contributed positively to the rainfall during the onset and advance phase of southwest monsoon this year.



EXCESS - 08 NORMAL - 18 DEFICIENT - 10 SCANTY - 00 NO RAIN - 00

Fig. 4. Rainfall for the month of August 2013 as percentage departure from normal. 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	-17	**7**	-30	**13**	-7	**19**	40	**25**	-27	**31**	27
2	-36	**8**	-12	**14**	27	**20**	30	**26**	7	**32**	-12
3	-29	**9**	-27	**15**	-13	**21**	-14	**27**	-10	**33**	-39
4	-23	**10**	-16	**16**	65	**22**	-19	**28**	-19	**34**	-6
5	-16	**11**	-3	**17**	55	**23**	-32	**29**	-3	**35**	-12
6	28	**12**	-16	**18**	22	**24**	-22	**30**	-13	**36**	-29



EXCESS - 09 NORMAL - 12 DEFICIENT - 11 SCANTY - 04 NO RAIN - 00

Fig. 5. Rainfall for the month of September 2013 as percentage departure from normal. 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	10	**7**	-12	**13**	-47	**19**	-42	**25**	-6	**31**	-2
2	-15	**8**	-29	**14**	-73	**20**	-61	**26**	-22	**32**	23
3	-31	**9**	-36	**15**	-52	**21**	106	**27**	-36	**33**	38
4	-17	**10**	-60	**16**	-37	**22**	313	**28**	-13	**34**	36
5	-25	**11**	-66	**17**	42	**23**	2	**29**	2	**35**	30
6	-9	**12**	-46	**18**	-12	**24**	38	**30**	37	**36**	10

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 9th June and central, eastern parts and western Himalayan region by 15th June. This was aided by the formation and west-northwestward movement of a low pressure area along the east-west trough during 12th - 15th June. The presence of the low pressure area over east Rajasthan and neighbourhood caused significant moisture influx over the entire northwest India on 16th. The low level vorticity, convergence and abundance of moisture, when superposed by the upper level divergence ahead of a trough in the mid & upper tropospheric westerlies made the environment conducive for large scale convection, thereby causing the monsoon rains to set in over the entire northwest India on 16th June, about a month earlier than its normal date of 15th July.

2.2. *Monthly rainfall distribution*

Figs. 2-5 show month wise distribution of rainfall.

The monthly monsoon rainfall for the country as a whole during June (134% of LPA) and July (107 % of LPA) were above the respective LPA. However, the rainfall during August (98% of LPA), and September (88% of LPA) was below the LPA.

2.3. *Seasonal rainfall distribution*

Meteorological sub-divisionwise seasonal rainfall distribution in terms of percentage departures from normal is given in Fig. 6. The seasonal rainfall was excess in 14, normal in 16 and deficient in the remaining 6 met. Sub-divisions. No sub-division reported scanty rainfall.

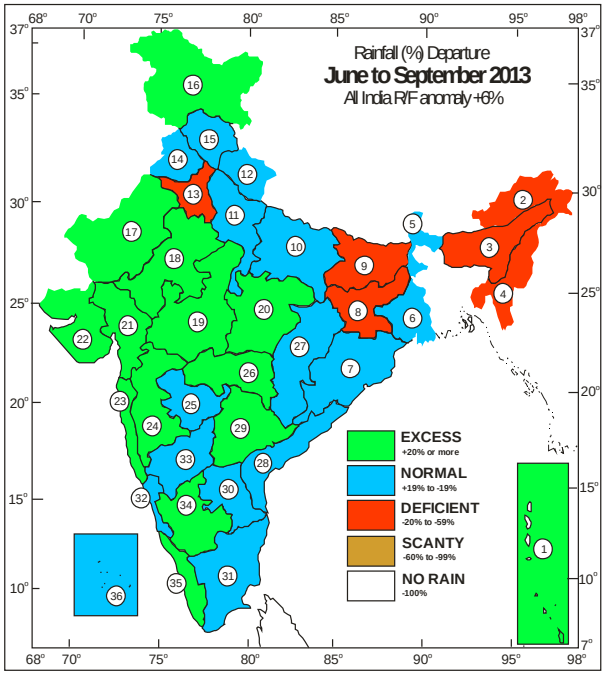


Fig. 6. Rainfall for the season as a whole (June - September) 2013 as percentage departure from normal. 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	28	**7**	-3	**13**	-22	**19**	46	**25**	9	**31**	1
2	-34	**8**	-23	**14**	-2	**20**	26	**26**	42	**32**	17
3	-35	**9**	-30	**15**	-6	**21**	31	**27**	2	**33**	6
4	-34	**10**	-4	**16**	22	**22**	64	**28**	-10	**34**	25
5	-14	**11**	-1	**17**	29	**23**	20	**29**	26	**35**	26
6	0	**12**	12	**18**	26	**24**	21	**30**	6	**36**	6

2.4. *Withdrawal of southwest monsoon*

Fig. 7 shows the isochrones of withdrawal of southwest monsoon.

The weather over the western parts of Rajasthan remained mainly dry for more than a fortnight's period (from 27th August). A change over in the lower tropospheric circulation pattern over the region from cyclonic to anti cyclonic during 8th - 9th September indicated the beginning of the withdrawal of southwest monsoon from the region. As such the withdrawal of southwest monsoon commenced from 9th September and the withdrawal line passed through Ganganagar, Bikaner and Barmer during 9th - 18th 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 19th and the withdrawal line passed through Kalpa, Hissar, Jodhpur and Naliya.

However, an almost complete revival in the monsoon activity occurred from the 3rd week of September which stalled the further withdrawal of southwest monsoon for almost a month.

The revival of monsoon took place with the successive formation of three low pressure areas (19-22 & 27-29 September and 28 September (Evening) - 5 October) and their westward movement across the central parts of the country which caused the east-west trough to remain active contributing to above normal rainfall during this period. This was followed by the formation of a Very Severe Cyclonic Storm (Phailin) during 8 - 14 October over the Bay of Bengal. After crossing Odisha - north Andhra coast on 12th, it moved in a north northeasterly direction and rapidly weakened.

Simultaneous with the dissipation of the Very Severe Cyclonic Storm, the Madden-Julian Oscillation also entered into a weak phase. Consequently, the ITCZ over the Indian region made a rapid retreat southwards at the end of the week. Almost all the semi-permanent features which persisted upto the first week of October gradually became unimportant towards the end of second week of the month. Dry northerly / northwesterly winds dominated the circulation pattern over northwest and central India, thereby confining the rainfall activity primarily to the southern Peninsula, during the later part of the second week of October.

On 17th, the southwest Monsoon withdrew from remaining parts of Himachal Pradesh, Haryana, Chandigarh & Delhi, Rajasthan; entire Uttarakhand, west Uttar Pradesh; most parts of west Madhya Pradesh, Gujarat State and north Arabian Sea and some parts of east Uttar Pradesh. On 19th, it further withdrew from remaining parts of Uttar Pradesh, Madhya Pradesh, Gujarat, north Arabian Sea, entire Bihar, Jharkhand, Chhattisgarh, Vidarbha, Marathwada; most parts of Odisha, Madhya Maharashtra and Konkan and some parts of Gangetic West Bengal, Telangana, north interior Karnataka and central Arabian Sea. Subsequently on 21st, the southwest Monsoon withdrew from remaining parts of the country, Bay of Bengal and Arabian Sea. Simultaneously, the northeast Monsoon rains commenced over Tamil Nadu, Kerala and adjoining areas of Andhra Pradesh and Karnataka.

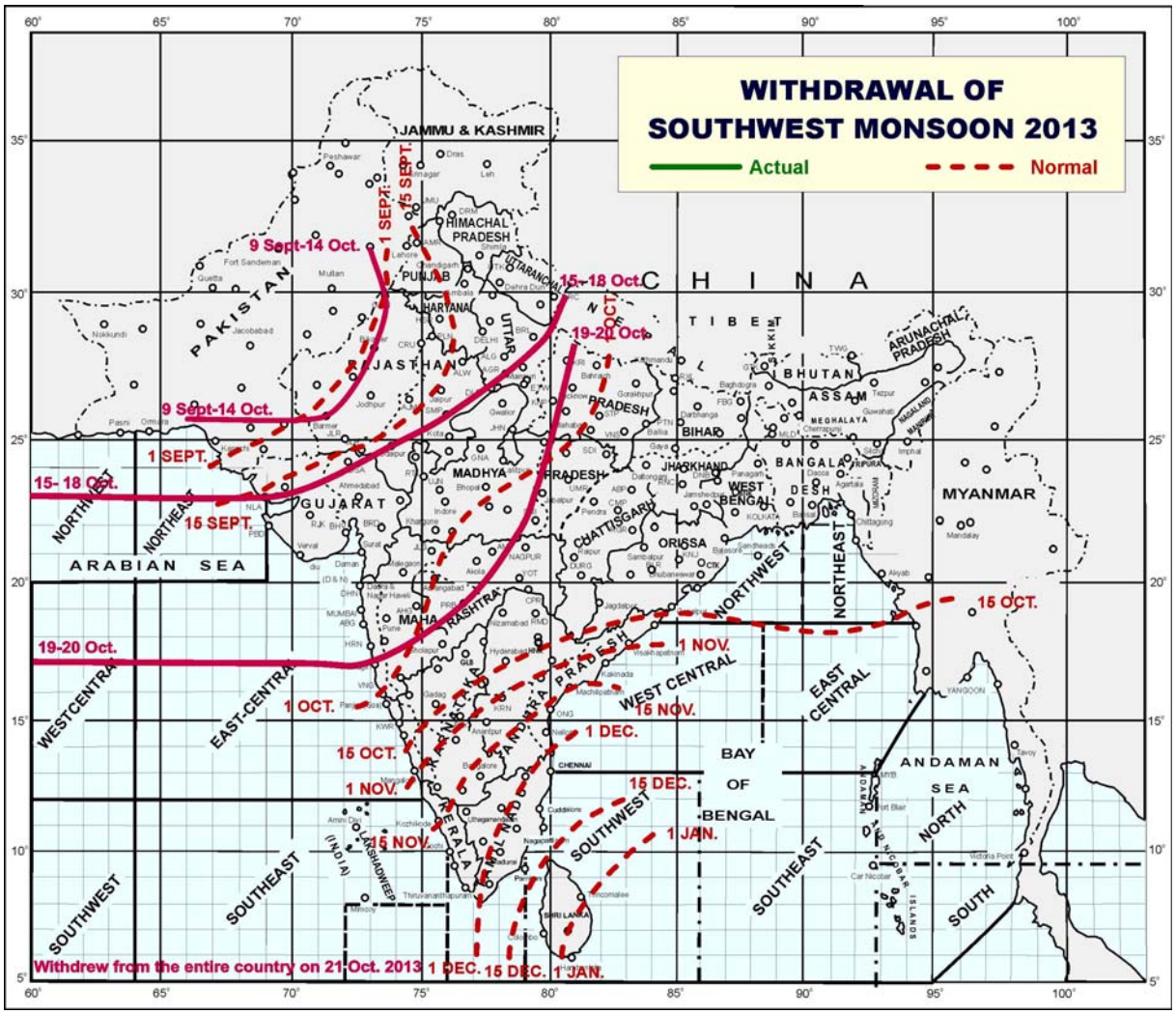


Fig. 7. Isochrones of withdrawal of SW Monsoon 2013

The trend of delay in the initiation of withdrawal due to the presence of moisture and cyclonic circulations favouring rainfall activity over the region which had continued since 2006 was terminated this year. However, the revival in the third week of September stalled the further withdrawal of southwest monsoon for almost a month as in some past years such as 1953, 1955, 1956 & 1959.

3. Chief synoptic features of southwest monsoon 2013

The synoptic disturbances which affected the Indian Monsoon region during June, July, August & September are given in Tables 1 to 4 respectively.

In all, there had been 2 Depressions and 16 low pressure areas / well marked low pressure areas during the season. Most of them originated as upper air cyclonic circulations. One depression formed over Bay of Bengal and the other, a land depression, formed over Gangetic West Bengal and adjoining areas. Eleven of the low pressure area formed over the Bay of Bengal, four over the land and 1 over the Arabian Sea. Month wise breakup of the systems is 3 in June, 5 in July, 6 in August and 4 in September.

Off-shore trough along different parts of the west coast persisted from 2 June - 6 October except during 3-5 August, 8-16 August, 19 August - 3 September, 7-13 September, 15 September, 23-28 September and 1-5

TABLE 1

Details of low pressure systems for the month of June 2013

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Well marked low pressure area*						
1.	Well marked Low pressure area	4 eve - 5	West central Arabian Sea	Northwest	Northwest Arabian Sea off Oman coast	It formed under the influence of cyclonic circulation embedded in the shear zone. Became unimportant on 6. Associated cyclonic circulation became less marked on 7
2.	Well marked Low pressure area	12 - 17	Northwest Bay of Bengal and neighbourhood	West northwest	Northeast Rajasthan and adjoining Haryana	Under the influence of cyclonic circulation extending upto 5.8 kms a.s.l. a low pressure formed on 12. It lay as a well marked low over south coastal Odisha and neighbourhood on 13 and as a low over Chhattisgarh and neighbourhood on 14; over southeast Madhya Pradesh and neighbourhood on 15 and west Madhya Pradesh and adjoining east Rajasthan on 16. It merged with the monsoon trough on 18. However associated cyclonic circulation extended upto mid & upper tropospheric levels and lay over east Uttar Pradesh and adjoining Bihar. It tilted southwestwards with height upto 16
3.	Well marked Low pressure area	22 Jun - 4 Jul	Do	Do	West Madhya Pradesh and adjoining east Rajasthan	Under the influence of cyclonic circulation between 3.1 & 5.8 kms a.s.l. over east central Bay of Bengal and neighbourhood a low pressure formed on 22. It lay as a well marked low on 25 June and on 3 July & 4 July. It merged with the monsoon trough on 5 July. However associated cyclonic circulation between 1.5 kms & 3.6 kms a.s.l. it lay over south Rajasthan and adjoining Gujarat on 5 & 6 tilting southwestwards with height
(B**)** *Upper air cyclonic circulations*						
1.	Upto mid tropospheric levels	4 - 10	East Uttar Pradesh and neighbourhood	East	Bihar and neighbourhood	It lay embedded in the trough at mean sea level on 9 & 10 and became less marked on 11
2.	Do	7 - 14	Off Konkan coast	Northnorthwest	Saurashtra & Kutch and neighbourhood	It was seen embedded in the off-shore trough during 7-10. It became less marked on 15
3.	Upto 3.1 kms a.s.l.	29 Jun - 1 Jul	Gangetic West Bengal and neighbourhood	Stationary	*In situ*	It lay embedded in the monsoon trough and merged with the cyclonic circulation associated with the low pressure area on 2 July
(**C**) *East-West troughs*						
1.	Lower levels/mean sea level	1	West Rajasthan to east central Bay of Bengal across east Rajasthan, centre of low pressure area over north Chhattisgarh and adjoining east Madhya Pradesh, Odisha and north Bay of Bengal	Oscillatory	East central Bay of Bengal across east Rajasthan, west Madhya Pradesh, the centre of low and north coastal Andhra Pradesh	It was first seen as a wind discontinuity during 16 May to 26 May with an embedded cyclonic circulation over Odisha and neighbourhood and as a trough at mean sea level from 27 May. It established as a monsoon trough on 16

TABLE 1 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**D**)	*East-West shear zone*					
1.	East-west shear zone (between mid & upper troposphere)	1 - 15	Along Lat. 13° N	Oscillatory	Along Lat. 20° N	Became less marked on 16
2.	Do (between 4.5 & 7.6 kms a.s.l.)	27 Mng	Along 22° N	Stationary	*In situ*	Less marked on 27 evening
(**E**)	*Western disturbances and other eastward moving systems*					
(*i*)	*Western disturbances*					
1.	As an upper air cyclonic circulation (up to 4.5 kms a.s.l.)	2 - 5	North Pakistan and neighbourhood	Northeast	Northern parts of Jammu & Kashmir	Moved away on 6
(*ii*)	*Troughs in westerlies*					
1.	Mid and Upper Tropospheric levels. (up to 5.8 kms a.s.l)	11	Along Long. 72° E to the north Lat. 35° N	Stationary	*In situ*	Moved away on 12
2.	Do	16 - 18	Along Long. 72° E to the north Lat. 30° N	East	Along Long. 75° E to the north Lat. 30° N	Moved away on 19

October. It was quite feeble on a few days including 5-6 June, 20-21 June, 16-18 July, 17 August, 14 September and 29 September.

4. Extra Indian features

4.1. *Cross equatorial flow*

4.1.1. *Over the Arabian Sea*

The Cross Equatorial flow along the equatorial belt (equator to 5° N / 5° S) over Arabian Sea was stronger than normal by about 6 kts during the first week and about 12 kts in second week of June. It was also stronger than normal by about 2 kts in third and fourth week of June and by about 4 kts in first & fourth week of July and in first & second week of September and it was also stronger by 8 kts in third week of September. It was weaker than normal by about 6 kts in second, third and fourth week of August and by about 2 kts in fourth week of September. Except these, the cross equatorial flow along the equatorial belt was close to normal during the entire monsoon period June-September 2013.

The surface winds over Arabian Sea to the north of 5° N were stronger than normal by about 6 kts during first & second week of June and in second week of September. It was also stronger than normal by about 10 kts in third & fourth week of June, in first, third and fourth week of September. It was weaker than normal by about 6 kts in first & second week of July and in second, third & fourth week of August. It was almost normal for the remaining period of the season.

4.1.2. *Over the Bay of Bengal*

The Cross Equatorial flow along the equatorial belt (equator to 5° N / 5° S) over Bay of Bengal was stronger

TABLE 2

Details of low pressure systems for the month of July 2013

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Depression*						
1.	Depression	30 - 1 Aug	Northwest Bay of Bengal (180 kms eastsoutheast of Balasore) within a half a degree of Lat. 21° N / Long. 88.5° E	Northwest and then westwards	East Madhya Pradesh and adjoining Chhattisgarh	A low pressure area formed over northeast Bay of Bengal and adjoining Bangla Desh and coastal areas of West Bengal on 29.It moved northwest and crossed Odisha coast between Balasore and Digha around 1230 hrs IST of 30 July and lay close to Balasore at 1730 hrs IST. Moving westward, it weakened into well marked low pressure area and lay over southeast Madhya Pradesh and neighbourhood on 1 Aug. It lay as a low pressure area over west Madhya Pradesh and neighbourhood on 2 Mng. and over west Madhya Pradesh and adjoining east Rajasthan on 2 evening. However, associated cyclonic circulation extended upto upper tropospheric levels upto 4 and merged with heat low on 5August
(**B**) *Well marked Low / Low pressure areas*						
1.	Low pressure area	10 - 13	Coastal Odisha and adjoining northwest Bay of Bengal	Northwest	Central parts of Rajasthan and neighbourhood	Under the influence of the cyclonic circulation between 3.1 & 5.8 kms a.s.l. over coastal areas of Odisha-north Andhra Pradesh and adjoining west central and northwest Bay of Bengal, a low pressure area formed on 10. It persisted and became well marked over the same region on 11 evening. It merged with the seasonal low pressure area on 14. Associated cyclonic circulation extended upto 7.6 kms a.s.l with a southwards tilt with height on 13. It lay over east Rajasthan and adjoining Haryana on 14 & 15 and over Haryana and adjoining areas of Punjab and north Rajasthan on 16 and merged with the seasonal low on 17
2.	Low pressure area	15 - 17	Northwest Bay of Bengal and adjoining areas of Gangetic West Bengal and north Odisha	West	East Madhya Pradesh and adjoining Chhattisgarh	Under the influence of a cyclonic circulation between 3.6 & 5.8 kms a.s.l. a low pressure area formed on 15. It merged with the monsoon trough on 18. The associated cyclonic circulation extending upto mid tropospheric levels persisted over same region on 18 and over northeast Madhya Pradesh and adjoining south Uttar Pradesh on 19 & 20. It merged with the cyclonic circulation over north Chhattisgarh and neighbourhood on 21
3.	Well marked Low	19 - 25	Northwest Bay of Bengal and neighbourhood	Northwest	North Madhya Pradesh and adjoining south Uttar Pradesh	It formed under the influence of a cyclonic circulation over northern parts of Odisha and adjoining areas of Gangetic West Bengal and Jharkhand. It was well marked on 22. It merged with the monsoon trough on 26. Associated cyclonic circulation extended between mid & upper troposphere upto 30 and became less marked on 31

TABLE 2 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
4.	Well marked Low	25 - 29	Northwest Bay of Bengal and adjoining coastal areas of West Bengal	North and then west	Southern parts of central Uttar Pradesh and adjoining north Madhya Pradesh	It formed under the influence of a cyclonic circulation over coastal Odisha and adjoining northwest Bay of Bengal. It was well marked on 26 & 27. It merged with the monsoon trough on 30. Associated cyclonic circulation extended upto 2.1 kms a.s.l. lay over northwest Madhya Pradesh and neighbourhood and became less marked on 31
(**C**)	*Upper air cyclonic circulations*					
1.	Upto 3.6 kms a.s.l.	9 - 11	Punjab and neighbourhood	East	Haryana and neighbourhood	Less marked on 12
2.	Upto 4.5 kms a.s.l.	14 - 16	East Madhya Pradesh and neighbourhood	Stationary	*In situ*	Merged with the cyclonic circulation associated with the low pressure area on 17
3.	Upto 3.1 kms a.s.l.	21 - 22	North Chhattisgarh and neighbourhood	Do	Do	Merged with the seasonal low on 23
4.	Upto 0.9 km a.s.l.	17 - 18	West Uttar Pradesh and neighbourhood	Do	Do	Less marked on 19
5.	lower & mid tropospheric levels	20 - 23	Punjab and adjoining Haryana	East	Haryana and adjoining north Rajasthan	Less marked on 24
6.	Upto mid tropospheric levels	24 - 30	Coastal Odisha and adjoining northwest Bay of Bengal	West	Northwest Madhya Pradesh and neighbourhood	Less marked on 31
7.	Upto 1.5 kms a.s.l.	25 - 26	North Rajasthan and adjoining areas of Haryana and Punjab	Do	-	Merged with the heat low on 27
(**D**)	*East–West shear zone*					
1.	At 5.8 kms a.s.l.	5	Along Lat. 20° N	Stationary	*In situ*	Less marked on 6
2.	Between 3.1 & 7.6 kms a.s.l.	12 - 13	Do	North	Along Lat. 22° N	Less marked on 14
(**E**)	*Western disturbances and other eastward moving systems*					
(*i*)	*Western disturbances*					
1.	As an upper air cyclonic circulation (upto 3.6 kms a.s.l.)	7 - 8	North Pakistan and adjoining Jammu & Kashmir	Northeast	Jammu & Kashmir and neighbourhood	Moved away on 9
2.	Do (upto 4.5 kms a.s.l.)	15	Jammu & Kashmir and neighbourhood	Do	Eastern parts of Jammu & Kashmir	A trough was seen aloft. Moved away on 16
3.	Do	16 - 17	North Pakistan and neighbourhood	Do	North Pakistan and adjoining Jammu & Kashmir	Moved away on 18
(*ii*)	*Troughs in westerlies*					
1.	Mid & upper troposphere (with an axis at 5.8 kms a.s.l.)	1 - 6	Long. 62° E to the north of Lat. 35° N	East	Long. 72° E to the north of Lat. 35° N	Moved away on 7

TABLE 3

Details of low pressure systems for the month of August 2013

S. No.	Systems	Duration	Place of first location	Direction of movement	Final Location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Depression*					
1.	Land Depression	20 - 23	Lat. 22° N / Long. 87.0° E Gangetic West Bengal and adjoining northwest Bay of Bengal, north Odisha and Jharkhand	Northwest	East Madhya Pradesh (50 kms southeast of Jabalpur)	Under the influence of a cyclonic circulation extending upto mid tropospheric levels tilting southwards with height, a low pressure area formed over north Bay of Bengal and adjoining Gangetic West Bengal and Bangla Desh coast on 18. It became well marked over northwest Bay of Bengal and adjoining coastal areas of West Bengal and Odisha on 19. It concentrated into Depression on 20. It weakened into well marked low over central parts of Madhya Pradesh and adjoining Vidarbha on 23 and as a Lopar over central parts of Madhya Pradesh, the same evening. It became less marked on 25. However, the associated cyclonic circulation extending upto mid tropospheric levels persisted upto 25 and became less marked on 26
(**B**)	*Low pressure areas*					
1.	Low pressure area	5 - 7 Eve	West central and adjoining northwest Bay of Bengal off north Andhra Pradesh- south Odisha coast	Northwest	North Jharkhand and adjoining Bihar and east Uttar Pradesh	It formed under the influence of a cyclonic circulation between 1.5 and 4.5 kms a.s.l. over northwest Bay of Bengal and neighbourhood tilting southwards with height on 4.The low pressure area merged with the monsoon trough on 8. However the associated cyclonic circulation extended upto mid tropospheric levels over Bihar and neighbourhood on 8
2.	Low pressure area	9 - 11	Northeast Madhya Pradesh and neighbourhood	West	West Uttar Pradesh and adjoining areas of east Rajasthan	The associated cyclonic circulation referred above moved westwards and under its influence a low pressure area formed on 9. It merged with the monsoon trough on 12. The associated cyclonic circulation extended upto mid tropospheric levels upto 19 and became less marked on 20
3.	Do	16	West central and adjoining northwest Bay of Bengal off north Andhra Pradesh south Odisha coast	Stationary	*In situ*	Merged with the monsoon trough on 17. It formed under the influence of a cyclonic circulation extending upto 5.8 kms a.s.l. tilting southwestwards with height
4.	Do	18	South Uttar Pradesh and adjoining north Madhya Pradesh	Do	Do	Merged with the monsoon trough on 19. It formed under the influence of a cyclonic circulation extending upto mid tropospheric levels over north Chhattisgarh and neighbourhood on 16
5.	Do	27 - 31	North Bay of Bengal and neighbourhood	Northwest	East Uttar Pradesh and adjoining Bihar	Under the influence of a cyclonic circulation extending upto mid tropospheric levels over northwest Bay of Bengal and neighbourhood on 25, a low pressure area formed over north Bay of Bengal and neighbourhood on 27. It became less marked on 1 September. However the associated cyclonic circulation extended upto 0.9 m a.s.l. persisted with a trough aloft from 1 September - 3 September and lay as a north-south trough in the lower level westerlies from Sub- Himalayan West Bengal & Sikkim to north Bay from 4- 7 September and became less marked on 8 Sept. An embedded cycir in Mid tropospheric levels in the trough lay over west central Bay of Bengal off Andhra Pradesh on 6

TABLE 3 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**B**)	*Upper air cyclonic circulations*					
1.	Upto 1.5 kms a.s.l.	5	South Uttar Pradesh and adjoining north Madhya Pradesh	Stationary	*In situ*	It lay embedded in the monsoon trough and became less marked on 6
2.	Upto lower tropospheric levels	5 - 7	Assam & Meghalaya and neighbourhood	Do	Do	Less marked on 8
3.	Do	8 - 9	Haryana and neighbourhood	East	Haryana and adjoining west Uttar Pradesh	Less marked on 10
4.	Upto 3.1 kms a.s.l.	11 - 14	Northwest Bay of Bengal off Odisha - West Bengal coast	Northwest	Chhattisgarh and neighbourhood	Merged with the Monsoon trough on 15
5.	Between 1.5 & 4.5 kms a.s.l.	14 - 15	Assam & Meghalaya and neighbourhood	Stationary	*In situ*	Less marked on 16
6.	Upto 4.5 kms a.s.l.	21	Haryana and neighbourhood	Do	Do	Merged with monsoon trough on 22
7.	Upto 3.6 kms a.s.l.	23	Assam & Meghalaya and adjoining Arunachal Pradesh	Do	Do	Less marked on 24
8.	Upto Mid Tropospheric levels	24 - 28 Mng	Jharkhand and neighbourhood	West	East Uttar Pradesh and neighbourhood	Merged with cyclonic circulation associated with low pressure area over Jharkhand and neighbourhood on 28 evening
9.	Upto 2.1 kms a.s.l.	30 Aug - 1 Sep	Sri Lanka and neighbourhood	Do	Comorin area and neighbourhood	Moved away westwards on 2 September. It was seen as a north- south wind Discontinuity with a cyclonic circulation aloft over Sri Lanka and neighbourhood on 28 & 29 August
(**C**)	*East west shear zone*					
1.	At 5.8 kms a.s.l.	4	Along Lat. 10° N	Stationary	*In situ*	Less marked on 5
(**D**)	*Western disturbances and other eastward moving systems*					
(*i*)	*As upper air cyclonic circulations*					
1.	Upto mid tropospheric levels	6 - 7	Jammu & Kashmir and adjoining north Pakistan	Northeast	Jammu & Kashmir and neighbourhood	Moved away northeastwards on 8
2.	Upto 4.5 kms a.s.l.	18	North Pakistan and adjoining Jammu & Kashmir	Stationary	*In situ*	Moved away northeastwards on 19
(*ii*)	*Trough in westerlies*					
1.	Mid & upper troposphere (with an axis at 5.8 kms a.s.l.)	3	Long. 68° E to the north of Lat. 35° N	Stationary	Long. 68° E to the north of Lat. 35° N	Moved away on 4. It was seen first as an upper air cyclonic circulation extending upto mid tropospheric levels over north Pakistan and adjoining Jammu & Kashmir on 1 & 2
2.	Mid & upper troposphere (with an axis at 7.6 kms a.s.l.)	13 - 16	Long. 68° E to the north of Lat. 30° N	East	Long.72° E to the north of Lat. 30° N	Moved away northeastwards on 17
3.	Mid & upper troposphere (with an axis at 5.8 kms a.s.l.)	16 - 17	Long. 62° E to the north of Lat. 30° N	Do	Long. 70° E to the north of Lat. 30° N	Became less marked on 18
4.	Do	19 - 22	Long. 65° E to the north of Lat. 25° N	Northeast	Long. 72° E to the north of Lat. 30° N	Moved away northeastwards on 23
5.	Do	23 - 25	Long. 62° E to the north of Lat. 35° N	Do	Long. 75° E to the north of Lat. 30° N	Moved away northeastwards on 26
6.	Mid & upper troposphere (with an axis at 7.6 kms a.s.l.)	31 Aug - 2 Sep	Long. 65° E to the north of Lat. 30° N	Do	Long. 72° E to the north of Lat. 35° N	Moved away northeastwards on 3

TABLE 4

Details of low pressure systems for the month of September 2013

S. No.	Systems	Duration	Place of first location	Direction of movement	Final Location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Low pressure areas*					
1.	Low pressure area	8 - 11	West central Bay of Bengal off Andhra Pradesh coast	Quasi-stationary	West central Bay of Bengal and adjoining coastal Andhra Pradesh	It was first observed as a cyclonic circulation over west central Bay of Bengal off Andhra Pradesh coast. It became less marked on 12. The associated cyclonic circulation extended upto mid tropospheric levels tilting southwestwards with height
2.	Do	19 - 22	Northwest Bay of Bengal off Odisha - West Bengal coasts	West	Central parts of south Madhya Pradesh and neighbourhood	A cyclonic circulation extended upto lower tropospheric levels and lay over Nagaland-Manipur-Mizoram-Tripura and neighbourhood from 9-13 and over north Bay of Bengal and neighbourhood from 14-18. Under the influence of the cyclonic circulation a low pressure area formed on 19th. A trough from the cyclonic circulation extended upto east central Arabian Sea with an embedded cyclonic circulation on 19th over Marathwada and neighbourhood and became less marked on 20. The low pressure area became less marked on 23. The associated cyclonic circulation extended upto mid & upper tropospheric levels over Gujarat Region upto 26 and emerged as a low pressure area on 27 [see I (3)]
3.	Do	27 - 29	Kutch and neighbourhood	Northwest and then northeast	South Rajasthan and neighbourhood	It formed under the influence of a cyclonic circulation It became less marked on 30. However, associated cyclonic circulation was seen over southeast Rajasthan and neighbourhood from 30th September - 2 October and over east central Arabian Sea off Maharashtra and Gujarat coast from 3rd -5th October and became less marked on 6th October
4.	Do	28 Sep (E) – 5 Oct	Northwest Bay of Bengal and adjoining coastal areas of West Bengal and Odisha	Northwest	Central parts of north Madhya Pradesh and neighbourhood	It formed under the influence of a cyclonic circulation embedded in the trough [see (IV (4)] over northeast Bay of Bengal and neighbourhood from 26th -28th September. It became less marked on 6. Associated cyclonic circulation extended up to mid tropospheric levels over Madhya Pradesh and adjoining areas from 6-11 and became less marked on 12th
(**B**)	*Upper air cyclonic circulations*					
1.	Upto 2.1 kms a.s.l.	3	Lakshadweep and neighbourhood	Stationary	*In situ*	Became less marked on 4
2.	Upto 1.5 kms a.s.l	9 - 11	West Uttar Pradesh and neighbourhood	East	East Uttar Pradesh and neighbourhood	Less marked on 12
3.	Do	11 - 12	Jharkhand and neighbourhood	Stationary	*In situ*	Became less marked on 13
4.	Upto mid tropospheric levels	12 - 14	West central Bay of Bengal off Andhra Pradesh coasts	Quasi-stationary	West central Bay of Bengal and neighbourhood	Became less marked on 15. It tilted southwestwards with height on 12 & 13

TABLE 4 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	Upto 3.1 kms a.s.l.	16	Haryana and neighbourhood	Stationary	*In situ*	Became less marked on 17
6.	Upto mid tropospheric levels	30 Sep - 5 Oct	Southeast Rajasthan and neighbourhood	South	Central Arabian Sea off Maharashtra coast	At first it was seen as associated cyclonic circulation with the system I(3). It became less marked on 6
(**C**)	*East west trough*					
1.	At lower levels	16 - 19	North Bay of Bengal and neighbourhood to east central Arabian Sea across Odisha, Chhattisgarh and Maharashtra	Stationary	*In situ*	It was first seen as an east-west shear zone extending between 3.1 & 5.8 kms a.s.l. along Lat. 15° E on 9.It became less marked on 20. An embedded cyclonic circulation extended upto 3.6 kms a.s.l. over Maharashtra State from 16-19 and became less marked on 20
2.	Mid & Upper tropospheric levels	23 - 24	Along Lat. 21° E	North	Along Lat. 22° E	Less marked on 25
(**D**)	*North-south trough/Wind discontinuity*					
1.	Lower level westerlies	4 - 7	Sub-Himalayan West Bay of Bengal & Sikkim to north Bay of Bengal	South	Sub-Himalayan West Bay of Bengal & Sikkim to west central Bay of Bengal	An embedded cyclonic circulation extending upto 4.5 kms a.s.l. lay over west central Bay of Bengal off Andhra coast on 6 & 7.The trough and cyclonic circulation became less marked on 8
2.	Lower tropospheric levels	2	Rayalaseema to south Tamil Nadu	Stationary	*In situ*	Became less marked on 3
3.	Do	10	From system [I(1)] to Gangetic West Bengal across Odisha	Do	Do	Became less marked on 11
4.	Lower levels	25 - 26	Bihar to northwest Bay of Bengal across Gangetic West Bengal	Quasi-stationary	Bihar to east central Bay of Bengal across Jharkhand and Gangetic West Bengal	Became less marked on 27. An embedded cyclonic circulation extended upto 4.5 kms a.s.l.
(**E**)	*Western disturbances and other eastward moving systems*					
(*i*)	*As upper air circulation*					
1.	As an upper air cyclonic circulation (Upto Mid tropospheric levels)	9	North Pakistan and adjoining Jammu & Kashmir	Northeast	Northern parts of Jammu & Kashmir	Moved away on 10
(*ii*)	*Troughs in westerlies*					
1.	Mid and upper troposphere (with its axis at 7.6 kms a.s.l.)	12 - 13	Long. 62° E, to the north of Lat. 35° N	Northeast	Long. 64° E, to the north of Lat. 30° N	It lay as an upper air cyclonic circulation extending upto 4.5 kms a.s.l. over Jammu & Kashmir during 14 - 17 and moved away northeastwards on 18
2.	Do (with its axis at 5.8 kms a.s.l.)	18	Long. 74° E, to the north of Lat. 30° N	Stationary	*In situ*	Moved away northeastwards on 19
3.	Do (with its axis at 5.8 kms a.s.l.)	19	Long. 70° E, to the north of Lat. 30° N	Do	Do	It lay as an upper air cyclonic circulation extending upto 5.8 kms a.s.l. over Jammu & Kashmir during 20 - 22 and moved away northeastwards in the evening of 22
4.	Do	23 - 24	Long. 67° E, to the north of Lat. 30° N	Northeast	Long. 70° E, to the north of Lat. 30° N	It lay as an upper air cyclonic circulation extending upto 5.8 kms a.s.l. over Jammu & Kashmir on 25 and moved away northeastwards on 26
5.	Do	26 - 28	Long. 52° E, to the north of Lat. 30° N	East	Long. 70° E, to the north of Lat. 30° N	It lay as an upper air cyclonic circulation extending upto 5.8 kms a.s.l. over Jammu & Kashmir and neighbourhood on 29 and moved away northeastwards on 30

TABLE 5

Rainfall figures (mm) for each month and season as a whole (June - September 2013)

S. No.	Sub-division	June			July			August			September			Monsoon		
		Act	Normal	%Dep	Act	Normal	%Dep	Act	Normal	%Dep	Act	Normal	%Dep	Act	Normal	%Dep
1	A & N Islands	777.0	438.6	77	564.8	407.7	39	336.7	403.8	-17	473.6	432.4	10	2152.1	1682.5	28
2	Arunachal Pradesh	290.0	500.4	-42	329.6	536.1	-39	230.2	359.9	-36	316.1	371.6	-15	1165.9	1768.0	-34
3	Assam & Meghalaya	285.6	502.3	-43	366.4	553.9	-34	291.2	410.3	-29	225.3	326.3	-31	1168.4	1792.8	-35
4	Naga., Mani, Mizo and Tri.	206.6	412.1	-50	255.9	415.0	-38	291.3	380.1	-23	241.4	289.7	-17	995.2	1496.9	-34
5	S. H. W. B. & Sikkim	404.9	485.2	-17	588.4	615.8	-4	416.3	495.2	-16	308.0	410.0	-25	1717.6	2006.2	-14
6	Gangetic West Bengal	247.9	244.4	1	266.1	331.7	-20	398.8	312.3	28	255.0	279.5	-9	1167.7	1167.9	0
7	Orissa	272.6	214.1	27	380.0	337.0	13	254.9	362.1	-30	208.1	236.7	-12	1115.6	1149.9	-3
8	Jharkhand	181.5	197.5	-8	211.1	334.6	-37	278.1	315.8	-12	173.8	244.0	-29	844.5	1091.9	-23
9	Bihar	183.3	168.5	9	182.0	343.5	-47	213.6	291.6	-27	143.3	224.0	-36	722.2	1027.6	-30
10	East Uttar Pradesh	310.1	107.8	188	230.0	298.0	-23	246.3	294.5	-16	78.2	197.3	-60	864.6	897.6	-4
11	West Uttar Pradesh	189.0	71.1	166	236.0	258.2	-9	282.6	291.6	-3	51.1	148.5	-66	758.6	769.4	-1
12	Uttarakhand	488.9	167.8	191	413.4	428.1	-3	359.4	426.3	-16	111.3	206.9	-46	1373.0	1229.1	12
13	Haryana, Chandigarh & Delhi	61.9	45.9	35	96.8	165.8	-42	161.8	173.6	-7	42.8	81.0	-47	363.3	466.3	-22
14	Punjab	120.3	44.4	171	117.9	186.0	-37	217.1	170.4	27	24.4	91.1	-73	479.7	491.9	-2
15	Himachal Pradesh	240.7	95.4	152	219.7	306.9	-28	245.9	283.0	-13	67.9	140.0	-52	774.2	825.3	-6
16	Jammu & Kashmir	112.7	64.1	76	175.3	192.4	-9	306.2	186.0	65	57.7	92.1	-37	651.9	534.6	22
17	West Rajasthan	37.6	29.9	26	104.5	102.7	2	138.2	89.3	55	58.7	41.3	42	339.0	263.2	29
18	East Rajasthan	90.4	62.5	45	318.3	225.2	41	278.4	228.4	22	87.9	99.7	-12	775.0	615.8	26
19	West Madhya Pradesh	263.7	105.4	150	485.1	291.6	66	432.6	308.7	40	98.9	170.4	-42	1280.4	876.1	46
20	East Madhya Pradesh	311.9	133.7	133	456.2	347.8	31	480.8	369.7	30	78.0	200.0	-61	1326.9	1051.2	26
21	Gujarat Region	168.2	129.9	29	454.2	336.7	35	238.1	277.7	-14	323.3	156.7	106	1183.8	901.0	31
22	Saurashtra & Kutch	159.1	85.9	85	208.9	188.2	11	100.4	124.6	-19	308.9	74.8	313	777.3	473.5	64
23	Konkan & Goa	1073.0	700.0	53	1555.1	1110.0	40	517.2	759.6	-32	353.1	344.7	2	3498.4	2914.3	20
24	Madhya Maharashtra	212.4	145.6	46	311.8	242.2	29	147.0	189.1	-22	210.3	152.4	38	881.5	729.3	21
25	Marathwada	160.9	143.3	12	293.4	187.2	57	136.9	188.2	-27	154.1	164.2	-6	745.3	682.9	9
26	Vidarbha	366.7	168.0	118	535.5	311.9	72	326.1	305.7	7	131.7	169.0	-22	1360.0	954.6	42
27	Chattisgarh	265.6	182.8	45	425.4	376.2	13	335.8	373.3	-10	138.3	215.0	-36	1165.1	1147.3	2
28	Coastal Andhra Pradesh	101.0	103.9	-3	157.9	160.4	-2	127.3	157.7	-19	138.0	159.1	-13	524.2	581.1	-10
29	Telangana	185.6	135.9	37	386.2	238.2	62	212.3	218.8	-3	165.1	162.3	2	949.2	755.2	26
30	Rayalaseema	65.2	67.7	-4	82.8	94.2	-12	90.0	103.3	-13	182.4	133.1	37	420.4	398.3	6
31	Tamil Nadu & Puducherry	54.6	46.0	19	42.7	68.0	-37	110.7	87.4	27	113.5	115.8	-2	321.5	317.2	1
32	Coastal Karnataka	1044.5	867.7	20	1536.4	1159.7	32	668.0	755.5	-12	370.5	300.9	23	3619.4	3083.8	17
33	North Interior Karnataka	99.4	104.6	-5	160.7	135.0	19	73.9	120.4	-39	201.0	146.0	38	534.9	506.0	6
34	South interior Karnataka	176.2	141.5	25	307.4	216.1	42	151.7	161.4	-6	191.8	141.0	36	827.1	660.0	25
35	Kerala	1042.7	649.8	60	830.2	726.1	14	369.7	419.5	-12	318.6	244.2	30	2561.2	2039.6	26
36	Lakshadweep	426.2	330.2	29	296.4	287.7	3	154.4	217.5	-29	180.0	163.1	10	1057.0	998.5	6

than normal by about 4 kts in first, second & third week of June, in first & third week of July, in first to fourth week of August and in second week of September. It was also stronger than normal by 8 kts in fourth week of June, in fourth week of August and in third week of September. It was weaker than normal by about 2 kts in first & fourth week of September.

The surface winds over the Bay of Bengal to the north of 5° N was stronger than normal by about 5 kts in third & fourth week of June, in fourth week of July, in first week of August and in first week of September. It was also stronger than normal by about 10 kts in second week of July, in third week of August and in third to fourth week of September. It was almost normal for the remaining period of the season June - September 2013.

4.2. *Systems in West Pacific Ocean/South China sea*

There were in all 18 low pressure systems (reaching the intensity of Tropical depression and above) in the northwest Pacific Ocean / South China Sea during June-September 2013.

4.3. *Systems in southern hemisphere*

4.3.1. *Tropical storms/depressions*

No low pressure system (TD, TS or Typhoon) was reported in Southern Hemisphere during June - September 2013.

4.3.2. *Mid-latitude troughs*

The number of troughs in upper air westerlies affecting the Indian region which penetrated south of 30° N is 1 each in June and July 2 in August and 3 in September at 300 hPa level and 2 each in June & July, 4 in August and 3 in September at 500 hPa level.

4.3.3. *Troughs in mid & upper tropospheric westerly over the south Indian Ocean*

There were 26 troughs in upper air westerlies which moved across the Indian Ocean from west to east, to the north of Lat. 30° S, in the Southern Hemisphere, during June to September 2013. The month wise break-up is 6 in June, 9 in July, 4 in August and 7 in September.

4.3.4. *Mascarene HIGH*

The mean position of Mascarene high during June to September 2013 was 33.5° S / 63.5° E. The intensity of Mascarene high was above normal by 1.625 hPa during the monsoon period June to September 2013. It was above normal by 2.7, 2.0, 2.0 and -0.2 hPa during the months of June, July, August and September 2013 respectively.
(*Source :* ACMAD, NOAA)

5. Semi-permanent systems

5.1. *Heat LOW*

The Heat low got established in its normal position over Pakistan and neighbourhood around 30th May. It was mostly seen east to northeast of its normal position during June, in the near normal position during July & August and west of its normal position in the month of September. The Heat Low started filling up from 28th August and was insignificant during the month of September except for the last week when, it slightly became more marked. It became less marked in the first week of October.

5.2. *Axis of the monsoon trough*

This year, a trough at mean sea level was seen extending from Haryana/east Uttar Pradesh to north Bay of Bengal from 27th May - 5th June and from west Rajasthan to north Bay of Bengal from 6th - 15th June. With the southwest monsoon covering the entire country, this trough got established as the monsoon trough on 16th July. During 18th - 19th and 28th - 29th June, the eastern end shifted to north and extended upto northeast India. Then the western end lay close to the foothills of the Himalayas during 20th - 21st June and 30th June - 1st July. During July and August, it generally remained in its near normal position and extended upto lower tropospheric levels. A branch of it extended upto Nagaland during 5th - 9th July. From 20th August, the western end lay to the north of its normal position. The eastern end was also seen extending upto northeast India on a few days from 25th August.

The monsoon trough remained active quite often, especially during July and August, with the successive formation and movement of low pressure areas along the trough zone. Its characteristic southward tilt with height was absent on most of the days during the season. It became less marked on 4th September. There was no typical break situation during the peak monsoon months of July and August.

5.3. *Tibetan Anticyclone/High*

The Tibetan Anticyclone (TA) got established in its near normal position at 300 & 200 hPa on 25th June. It was noticed all through the remaining period of the season. It was seen in its near normal position during June, July & August and south to southeast of its normal position in the month of September.

5.4. *Sub-Tropical Westerly Jet (STWJ)*

Sub-Tropical Westerly Jet (STWJ) started shifting northwards from the first week of June. Patiala reported 76 knots wind (at 293 hPa) at 0000 UTC of 9th June. Subsequently, the STWJ shifted to the north of the Himalayas. However, it made occasional re-appearances along the latitude of Srinagar during July and August. In the first week of September, it once again shifted southwards as evidenced by the 63 knots westerly wind reported over Srinagar at 233 hPa on 2nd September (1200 UTC).

5.5. *Tropical Easterly Jet (TEJ)*

TEJ got established over the southern tip of Peninsular India by 17th May with Kochi and Chennai reporting easterlies of 70 kts around 120 hPa. A wide latitudinal spread of the easterly jet speed winds was noticed during July and August while during June and September; the stations over the Peninsular India only reported jet wind speed. The highest wind speed of 143 kts was reported at Port Blair on 14th July.

Jet speed winds were also reported over Visakhapatnam, Bhubaneswar, Nagpur, Bhopal, Raipur, Ahmedabad and Kolkata on several days during the season.

6. Other features

6.1. *Monthly wind anomalies during southwest monsoon 2013*

The month wise circulation anomaly features at lower, middle & upper tropospheric levels 850, 500 & 200 hPa during the southwest Monsoon season are discussed below.

6.1.1. *June wind anomaly features*

In the monthly anomaly winds, two anomalous cyclonic circulations were observed at 850 hPa level, one over WC Bay of Bengal off Orissa coast and extending upto 500 hPa level and second over SE Arabian Sea.

At 700 hPa level, anomalous Cyclonic circulation was observed over EC Arabian Sea off Maharashtra coast and extending upto 500 hPa level. Two anomalous anti cyclonic circulations were observed at 500 hPa level, one over SE Arabian Sea off Karnataka coast and second over SW Bay of Bengal off Tamil Nadu coast. Ridge line at 200 hPa runs along 25° N to 30° N.

In the week ending 5th June, three anomalous cyclonic circulations were observed at 850 hPa level, one over Jharkhand and neighbourhood and extending upto 500 hPa, second over NE Bay of Bengal and neighbourhood and third over SW Bay of Bengal off Tamil Nadu coast and extending upto 500 hPa level.

In the week ending 12th June, four anomalous cyclonic circulations were observed at 850 hPa level, one over East Uttar Pradesh and neighbourhood, second over EC Arabian Sea off Maharashtra coast and extending upto 500 hPa level, third over South West Bay of Bengal off Orissa coast and extending upto 500 hPa and fourth over Telangana and neighbourhood. Ridge line runs along 30° N at 500 hPa level.

In the week ending 19th June, two anomalous cyclonic circulations were observed at 850 hPa level, one over East Central Arabian Sea off Gujarat coast and extending upto 500 hPa level and second over North East Bay of Bengal and neighbourhood.

In the week ending 26th June, anomalous cyclonic circulations were observed at 850 hPa level over West Central Bay of Bengal off Orissa coast and extending upto 500 hPa level. Ridge line runs along 25° N at 200 hPa level.

In the week ending 3rd July, two anomalous cyclonic circulations were observed at 850 hPa level, one over East Madhya Pradesh and neighbourhood and extending upto 500 hPa level and second over East Central Arabian sea off Maharashtra coast. The anomalous anti cyclonic circulation was observed at 850 hPa level over South West Bay of Bengal off Tamil Nadu coast Ridge line runs along 24° N at 200 hPa level.

6.1.2. *July wind anomaly features*

In the monthly winds, four anomalous cyclonic circulations were observed at 850 hPa level, one over West Central Bay of Bengal off Orissa coast and extending upto 200 hPa level, second over Chhattisgarh and neighbourhood, third over East central Arabian Sea off Maharashtra coast and extending upto 500 hPa level and fourth over Assam and Meghalaya.

At 700 hPa level, anomalous anticyclonic circulation was observed over Arunachal Pradesh and neighbourhood and extending upto 200 hPa level. Ridge line runs at 200 hPa along 30° N.

In the week ending 10th July, two anomalous cyclonic circulations were observed at 850 hPa level, one over East Rajasthan and neighbourhood and extending upto 700 hPa level and second over South West Bay of Bengal off Andhra Pradesh coast and extending upto 300 hPa level. Two anomalous anticyclonic circulations were observed at 700 hPa level, one over South East Arabian sea and extending upto 500 hPa and second over North West Bay of Bengal and extending upto 200 hPa level.

In the week ending 17th July, two anomalous cyclonic circulations were observed at 850 hPa level, one over South West Bay of Bengal off Andhra coast and extending upto 200 hPa level and second over North Andaman Sea and neighbourhood. The ridge line runs along 31° N at 200 hPa.

In the week ending 24th July, three anomalous cyclonic circulations were observed at 850 hPa level, one over West Central Bay of Bengal off Andhra Pradesh coast and extending upto 200 hPa level, second over North Andaman Sea and neighbourhood and third over West Rajasthan and neighbourhood. The anomalous anticyclonic circulation was observed at 700 hPa over East Uttar Pradesh and neighbourhood. Ridge line runs along 24° N at 200 hPa.

In the week ending 31st July, three anomalous cyclonic circulations were observed at 850 hPa level, one over East Central Arabian sea off Maharashtra coast, second over Vidarbha and neighbourhood and third over West Central Bay of Bengal off Orissa coast and extending upto 200 hPa level. Ridge line runs along 23° N to 32° N at 200 hPa levels.

6.1.3. *August wind anomaly features*

In the monthly winds, two anomalous cyclonic circulations were observed at 850 hPa level, one over Chhattisgarh and neighbourhood and second over Arunachal Pradesh and neighbourhood and extending upto 700 hPa levels. Two anomalous anticyclonic circulations were observed at 850 hPa, one over East Rajasthan and neighbourhood and extending upto 200 hPa level and second over North West Bay of Bengal and extending upto 200 hPa level. Ridge line runs along 32° N at 200 hPa level.

In the week ending 7th August, three anomalous cyclonic circulations were observed at 850 hPa level, one over Madhya Maharashtra and neighbourhood and extending upto700 hPa level, second over Coastal Andhra Pradesh and neighbourhood and extending upto 700 hPa and third over Assam and Meghalaya and neighbourhood and extending upto 700 hPa. The anomalous cyclonic circulation was observed at 500 hPa level over South East Arabian sea off Karnataka coast.

In the week ending 14th August, two anomalous cyclonic circulations were observed at 850 hPa level, one over East Rajasthan & neighbourhood and second over Assam and Meghalaya and neighbourhood. Two anomalous anticyclonic circulations were observed at 850 hPa, one over Gujarat & neighbourhood and second over Orissa & neighbourhood and extending upto 200 hPa level respectively.

In the week ending 21st August, four anomalous cyclonic circulations were observed at 850 hPa level, one over South West Bay of Bengal off Andhra Pradesh coast and extending upto 500 hPa level, second over Chhattisgarh & neighbourhood and extending upto 500 hPa, third over Haryana and neighbourhood and extending upto 700 hPa and fourth over Nagaland-Manipur-Mizoram-Tripura and neighbourhood and extending upto 500 hPa level. Ridge line runs along 13° N at 200 hPa level.

In the week ending 28th August, two anomalous cyclonic circulations were observed at 850 hPa level, one over Chhattisgarh and neighbourhood and extending upto 700 hPa level and second over Arunachal Pradesh and neighbourhood and extending upto 500 hPa level. Ridge line runs along 23° N at 200 hPa level.

6.1.4. *September wind anomaly features*

In the monthly winds, four anomalous cyclonic circulation at 850 hPa, one over East Central Arabian sea off Gujarat coast and extending upto 500 hPa level, second over Marathwada and neighbourhood, third over West Central Bay of Bengal off Andhra Pradesh coast and fourth over North West Bay of Bengal and extending upto 500 hPa level. At 850 hPa level, anomalous anticyclonic circulation was observed over East Uttar Pradesh and neighbourhood. Ridge line runs along 20° N at 200 hPa level.

In the week ending 4th September, an anomalous cyclonic circulation was observed at 850 hPa level over West Madhya Pradesh and neighbourhood. Two anomalous anticyclonic circulations were observed at 850 hPa and extending upto 200 hPa level, one over Maharashtra and neighbourhood and second over Orissa coast.

In the week ending 11th September, two anomalous cyclonic circulations were observed at 850 hPa level, one over South East Arabian sea off Karnataka coast and extending upto 200 hPa and second over coastal south West Bay of Bengal off Tamil Nadu coast and extending upto 200 hPa level. Two anomalous anticyclonic circulations were observed at 850 hPa and extending upto 200 hPa level, one over West Madhya Pradesh and neighbourhood and other over North West Bay of Bengal.

In the week ending 18th September, an anomalous cyclonic circulation was observed at 850 hPa level over East Central Arabian sea off Karnataka coast and extending upto 500 hPa level.

In the week ending 25th September, anomalous cyclonic circulations was observed at 850 hPa level over North Maharashtra and neighbourhood and extending upto 500 hPa level. Two ridge lines were runs at 200 hPa, one along 15° N and other over 24° N to 30° N.

In the week ending 2nd October, two anomalous cyclonic circulations were observed at 850 hPa level, one over West Rajasthan and neighbourhood and extending upto 500 hPa and second over North West Bay of Bengal and extending upto 200 hPa. Two ridge lines runs along 23° N to 27° N and 8° N to 13° N at 200 hPa level respectively.

7. Significant temperature during the season

Heat wave conditions prevailed over some parts of northwest and central India during first week of the month. The highest maximum temperature of 48.1° C was recorded in Ganganagar (Rajasthan) on 8th June 2013.

8. Disastrous weather events and damage during monsoon months

8.1. *June*

According to media reports, heavy rains, floods and landslides took a toll of 1100 persons (1000 in Uttarakhand, 44 in Uttar Pradesh, 24 in Himachal Pradesh, 23 in Kerala, 2 in Chhattisgarh and 1 in Assam).

Apart from the loss of life, extremely heavy rains caused catastrophic damage across Uttarakhand state. Near about 150 buildings were damaged and around lakh of people were stranded during second fortnight of the month. Around 600 villages, covering a population of 5 lakhs, in 23 districts of Uttar Pradesh were affected with flood. Floods and heavy rain damaged properties worth crores of rupees in 374 villages across the Kerala state. Seven districts of Assam were affected by floods hitting nearly 60,000 people and damaging farm fields with standing crops. In Chhattisgarh 8000 people, mostly tribal's in dozens of villages were affected in floods.

8.2. *July*

According to media reports, heavy rains and floods related incidents took a toll of 512 persons (200 each in Uttar Pradesh and Bihar, 50 in Maharashtra, 22 in Andhra Pradesh, 10 in Karnataka, 7 in Odisha, 6 each in Jharkhand and Madhya Pradesh, 4 in Kerala and 1 in Haryana).

Over 1.6 million people in 600 villages of 15 districts were affected by floods and crops in over 1.5 lakhs hectare were affected.

Nearly 7,000 hectare of agricultural land with standing crops across 11 districts and over 30,000 cattle's and poultry along with transport and communication systems were affected by the devastating floods in Assam & Meghalaya. Thousands of cattle were dead in rain and floods and cotton soya and paddy under more than 2 million hectares were damaged in Vidarbha. Thousands

of people were affected and Standing crops in five lakh hectares were destroyed in Bihar. In Andhra Pradesh more than 300 villages and about 100,000 hectares of farmland remained under water with soya, cotton crops and banana and betel leaf plantations badly damaged. Thousands of houses were also fully damaged. Twenty one bridges, barrages and roads were submerged. Many houses were collapsed. In 39 villages of Karnataka standing crops in over thousands of hectares were destroyed. Houses around 111 were also partially damaged.

8.3. *August*

Heavy rains, floods and landslides took a toll of 59 lives (30 in Madhya Pradesh, 18 in Kerala 15 in Maharashtra, 7 in Andhra Pradesh, 4 in Gujarat, 2 in Odisha and 1 in Karnataka).

About 19,764 houses were damaged and the crop over 60,466 hectares submerged in 8 districts. As many as 463 minor irrigation tanks were either damaged or breached in Andhra Pradesh. The floods caused extensive damage to both agriculture and civic amenities in Maharashtra. Crops on an estimated 6-700,000 ha of agricultural land in Vidarbha were damaged by the rains causing extensive damage to kharif crops. Many bridges and roads were damaged, cutting off contact with several areas. About 3,800 houses were completely destroyed by the rain.

Heavy rainfall led to flooding in 24 districts of Madhya Pradesh. As many as 24,000 homes had been destroyed. Heavy rain damaged standing crops and property and several low-lying areas were flooded in Karnataka.

8.4. *September*

According to media reports, heavy rains and floods took a toll of 13 persons in Gujarat.

About 13000 people in 11 villages affected in Arunachal Pradesh. Several paddy fields and irrigation channels in the state were inundated due to the floods. All the major rivers in Gujarat were in spate and affected many villages. Road and Rail traffic were also disrupted.

9. Severe floods experienced during southwest Monsoon - 2013

During the southwest monsoon season 2013, many states, *viz*., Arunachal Pradesh, Assam & Meghalaya, West Bengal, Bihar, Odisha, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Haryana, Madhya Pradesh, Gujarat State, Maharashtra, Jharkhand, Chhattisgarh, Andhra Pradesh, Karnataka and Kerala experienced flood/flash flood situations during various periods of the season. Incessant heavy rainfall associated with the low pressure systems as well as dis-organized convective activity in the form of scattered thunder showers were the major causes of flood.

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Appendix

Definitions of some terms

Rainfall

Excess	- Percentage departure from normal rainfall is + 20% or more.
Normal	- Percentage departure from normal rainfall is between – 19 % to + 19 %.
Deficient	- Percentage departure from normal rainfall is between – 20 % to – 59 %.
Scanty	- Percentage departure from normal rainfall is between – 60 % to – 99 %.
Heavy rain	- Rainfall amount from 6.5 cm to 12.4 cm.
Very heavy rain	- Rainfall amount more than 12.5 cm to 24.4 cm.
Extremely heavy rainfall	- Rainfall amount more than 24.5 cm.

Maximum/day temperatures

According to the revised criteria, since 1st March 2002, Heat Wave is declared only when the maximum temperature of a station reaches at least 40 °C for plains and at least 30 °C for Hilly regions.

Severe heat wave conditions - Departure of maximum temperature from normal is +6 °C or more for the regions were the normal maximum temperature is more than 40 °C and +7 °C or more for regions were the normal maximum temperature is 40 °C or less.

Heat wave conditions - Departure of maximum temperature from normal is + 4 °C to + 5 °C or more for the regions where the normal maximum temperature is more than 40 °C and departure of maximum temperature from normal is + 5 °C to + 6 °C for regions where the normal maximum temperature is 40 °C or less.