MAUSAM, **66**, 3 (July 2015), 657-674

Weather in India

MONSOON SEASON (JUNE - SEPTEMBER 2014)†

1. Introduction

The seasonal rainfall (during June to September 2014) over the country as a whole was 88% of its Long Period Average (LPA) and thus categorized as a below normal monsoon characterized by large spatial and temporal variability. Weak atmospheric circulation pattern and corresponding sluggish advance of southwest monsoon led to large rainfall deficiency in June. It recorded the fifth lowest rainfall (58%) since 1901. During the subsequent months, only on three occasions *viz*., second half of July, first week of August and September recorded above *normal* rainfall. Lack of rainfall at a crucial period of sowing during the advance phase of the monsoon and excess of it on certain occasions led to various weather calamities within the season. The *very heavy* to *extremely heavy* rainfall event experienced by the northern most met. sub-division, *viz*., Jammu & Kashmir during 3-6 September, 2014, as a result of a constructive interaction between a western disturbance and a monsoon low is one among them. In all 13 low pressure areas formed during the monsoon season this year, out of which one intensified into Cyclonic Storm (CS) 'Nanauk', another two into Deep Depression and a land Depression each as against the normal frequency of 4-6 monsoon Depressions. The season also witnessed strong intra seasonal variation in the rainfall activity with a prolonged break monsoon spell in the middle of August caused by unfavourable phase of Madden Julian Oscillation (MJO).

2. Various aspects of Southwest Monsoon - 2014

2.1. *Onset and advance*

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

During 17 and 18 May, an easterly wave trough embedded in the Northern hemispheric equatorial convergence zone developed into a cyclonic circulation over south Andaman Sea and neighbourhood. Associated with this, low level cross equatorial monsoon flow strengthened and aided the advance of Southwest Monsoon (SWM) over most parts of Andaman Sea and some parts of southeast Bay of Bengal on 18th May, 2 days prior to the normal date of 20th May.

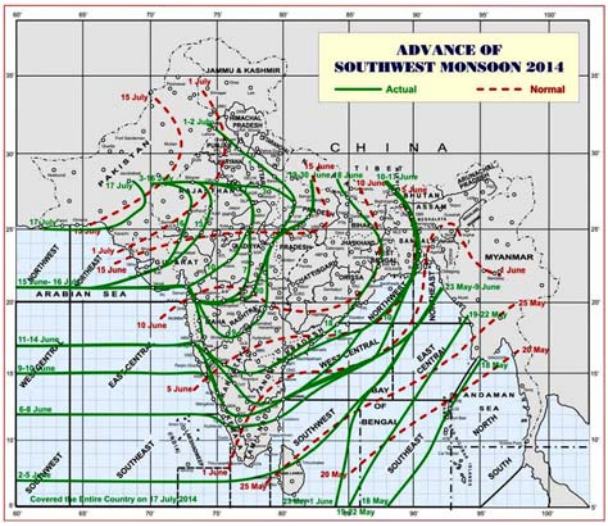


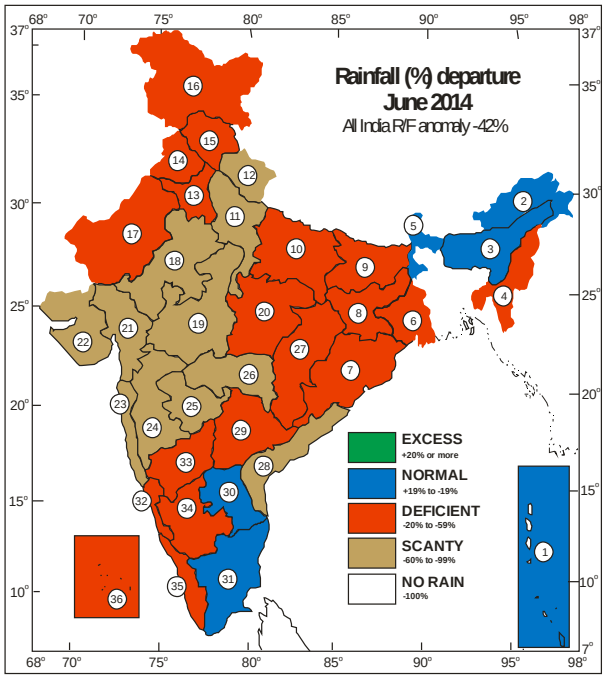
Fig. 1. Isochrones of advance of monsoon 2014

The SWM advanced into most parts of south Arabian Sea and Kerala, remaining parts of Maldives-Comorin areas, some parts of Tamil Nadu, most parts of southwest Bay of Bengal and some parts of west central Bay of Bengal, 5 days later than its normal date of onset over Kerala (1st June). The pace of advance of southwest monsoon this year had been much slower as compared to last year.

The Arabian Sea branch of the monsoon current was aided by the formation of a Cyclonic Storm (Nanauk) over the Arabian Sea. The eastward propagation of MJO over maritime continent led to the development of convection over north Bay of Bengal and the subsequent formation of season's first low pressure area over coastal areas of Bangladesh and neighborhood on 19th June. This helped the advance of Bay of Bengal branch of the SW monsoon over northeastern states.

After a hiatus of 10 days, monsoon started reviving. Subsequently, a favourable interaction of the SWM current with the mid-latitude westerlies aided the advance into the western Himalayan region and adjoining plains of northwest India. It advanced into entire Uttarakhand, Himachal Pradesh and Jammu & Kashmir, some more parts of Uttar Pradesh and some parts of Haryana (including Chandigarh) and Punjab on 1st July.

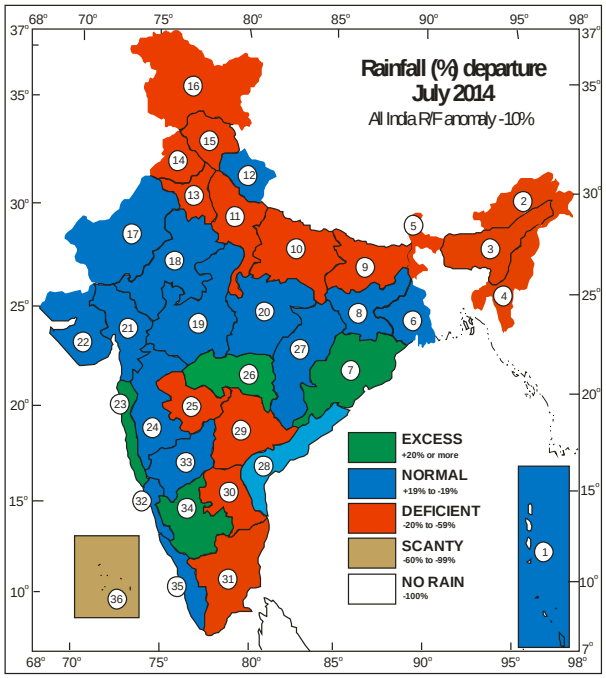
†*Compiled by* : Medha Khole, Sunitha Devi S. and A. P. Kundale, Meteorological Office, Pune – 411 005, India



EXCESS - 00 NORMAL - 06 DEFICIENT - 19 SCANTY - 11 NO RAIN - 00

Fig. 2. Rainfall for the month of June 2014 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	-5	**7**	-57	**13**	-44	**19**	-71	**25**	-79	**31**	4
2	-17	**8**	-29	**14**	-54	**20**	-31	**26**	-62	**32**	-43
3	-17	**9**	-32	**15**	-43	**21**	-91	**27**	-44	**33**	-52
4	-35	**10**	-56	**16**	-45	**22**	-74	**28**	-66	**34**	-25
5	12	**11**	-69	**17**	-54	**23**	-63	**29**	-59	**35**	-30
6	-25	**12**	-63	**18**	-62	**24**	-70	**30**	-3	**36**	-26



EXCESS - 03 NORMAL - 17 DEFICIENT - 15 SCANTY - 01 NO RAIN - 00

Fig. 3. Rainfall for the month of July 2014 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	15	**7**	47	**13**	-56	**19**	16	**25**	-44	**31**	-26
2	-27	**8**	-4	**14**	-59	**20**	-19	**26**	8	**32**	1
3	-33	**9**	-23	**15**	-30	**21**	2	**27**	12	**33**	1
4	-29	**10**	-25	**16**	-48	**22**	-12	**28**	-12	**34**	26
5	-38	**11**	-41	**17**	-8	**23**	22	**29**	-40	**35**	-26
6	-9	**12**	8	**18**	-13	**24**	15	**30**	-32	**36**	-60

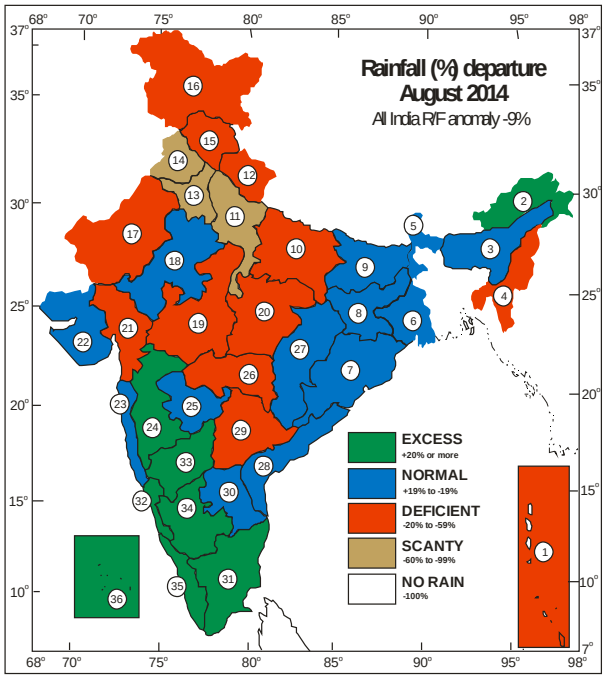
Subsequent to the formation and west northwestward movement of a low pressure area (11th - 16th July), an off shore trough at mean sea level extending from Gujarat coast to Kerala coast (10th - 16th July) and the cyclonic circulation extending between 3.1 & 5.8 km a.s.l. over northeast Arabian Sea (14th - 16th July), during the second week of July, the monsoon activity revived gradually over central India and west coast thereby causing further advance of southwest monsoon over remaining parts of central India and most parts of northwest India on 16th July and into remaining parts of north Arabian Sea, Saurashtra & Kutch, Gujarat Region and west Rajasthan, and thus the entire country on 17th July, 2014.

2.2. *Monthly rainfall distribution*

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

The large rainfall deficiency in June owing to the weak monsoon circulation regime and consequent sluggish advance occurred over most of the meteorological sub-divisions which received *deficient/ scanty* rainfall. The only 6 sub-divisions which received *normal* rainfall are Sub-Himalayan West Bengal & Sikkim, Assam & Meghalaya, Arunachal Pradesh, Rayalaseema, Tamil Nadu and Andaman & Nicobar Islands, which usually report deficiency in a normal type of monsoon wind pattern.

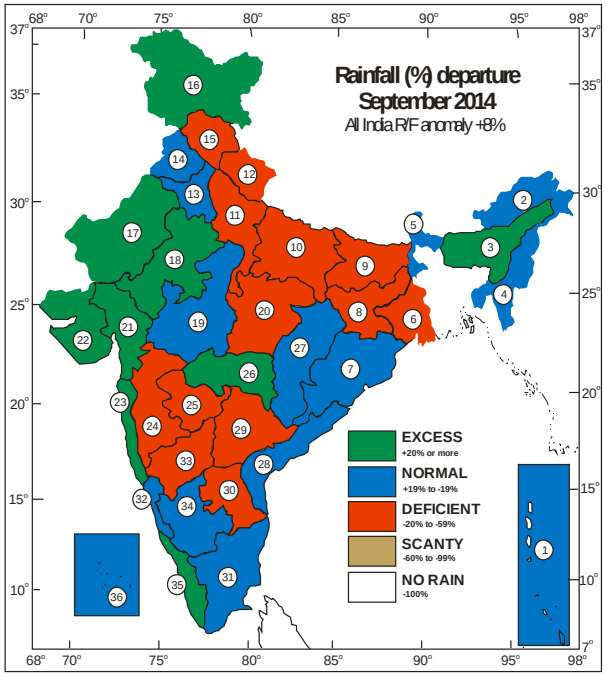
The rainfall activity as compared to June was on a slightly higher side for July. With the formation and west northwestward movement of a low pressure area during 11th - 16th July, the monsoon activity revived over central India and west coast in the 3rd & 4th weeks of July. The formation of the Land Depression over northeastern parts of Odisha and adjoining areas of Gangetic West Bengal



EXCESS - 08 NORMAL - 14 DEFICIENT - 11 SCANTY - 03 NO RAIN - 00

Fig. 4. Rainfall for the month of August 2014 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	20	**7**	7	**13**	-80	**19**	-32	**25**	-5	**31**	35
2	67	**8**	-8	**14**	-75	**20**	-37	**26**	-37	**32**	46
3	16	**9**	5	**15**	-41	**21**	-44	**27**	-12	**33**	70
4	-2	**10**	-53	**16**	-28	**22**	19	**28**	-9	**34**	58
5	14	**11**	-72	**17**	-22	**23**	-8	**29**	-21	**35**	75
6	-5	**12**	-38	**18**	14	**24**	27	**30**	3	**36**	114



EXCESS - 09 NORMAL - 14 DEFICIENT - 13 SCANTY - 00 NO RAIN - 00

Fig. 5. Rainfall for the month of September 2014 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	-5	**7**	19	**13**	-17	**19**	13	**25**	-49	**31**	-15
2	-8	**8**	-27	**14**	16	**20**	-30	**26**	33	**32**	16
3	29	**9**	-28	**15**	-38	**21**	71	**27**	18	**33**	-38
4	4	**10**	-46	**16**	294	**22**	58	**28**	-19	**34**	15
5	-9	**11**	-43	**17**	105	**23**	27	**29**	-22	**35**	22
6	-20	**12**	-48	**18**	37	**24**	-21	**30**	-45	**36**	-19

and its westward movement caused *active* to *vigorous* monsoon conditions over central and adjoining parts of peninsular India. All India weekly rainfall anomalies were positive in the third week of July.

A deep depression formed over northwest Bay of Bengal and adjoining coastal areas of West Bengal during 3rd-7th August causing *active* to *vigorous* monsoon conditions over the Indo-Gangetic Plains. Remnant cyclonic circulation of the Depression enhanced rainfall activity over northwest India. As a result, cumulative rainfall departure was positive during the first two weeks of August. Subsequent weakening of the monsoon and transition to break like conditions led to *deficien*t rainfall during the later half of August.

Presence of a couple of well marked low pressure areas and southward shift of the monsoon trough led to *vigorous* monsoon activity over north, east, central and adjoining peninsular India during the first half of September. The rainfall activity decreased due to the weakening of the monsoon flow once again during the later half of September.

2.3. *Seasonal rainfall distribution*

Meteorological sub-divisionwise seasonal rainfall distribution in terms of percentage departures from normal is given in Fig. 6. It may be noted that no sub-division reported *scanty* rainfall by the end of the season. However, the region comprising the plains of northwest India remained largely *deficient*, especially Uttar Pradesh and Haryana, Chandigarh & Delhi. This is due to the accumulated rainfall deficiency all through the season.

2.4. *Withdrawal of southwest monsoon*

Fig. 7 shows the isochrones of withdrawal of SW Monsoon.

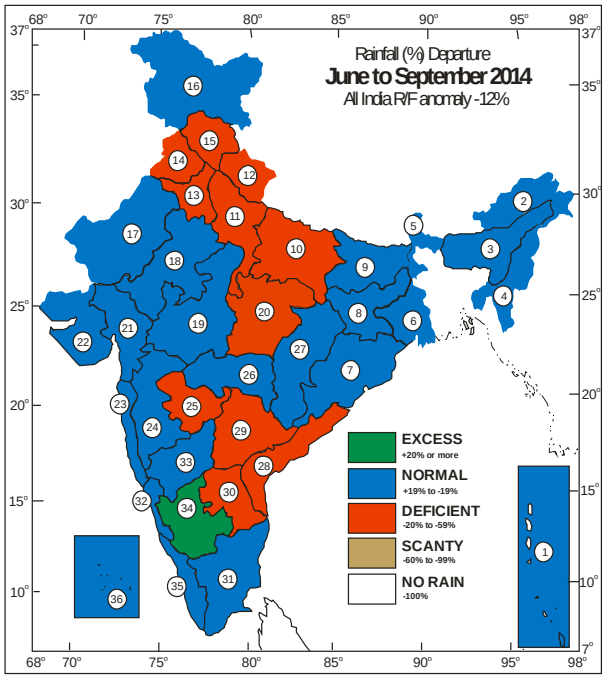


Fig. 6. Rainfall for the season as a whole (June - September) 2014 as percentage departure from normal. 36 sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	-4	**7**	9	**13**	-57	**19**	-12	**25**	-42	**31**	-1
2	-1	**8**	-15	**14**	-50	**20**	-29	**26**	-14	**32**	1
3	-6	**9**	-17	**15**	-37	**21**	-14	**27**	-4	**33**	-5
4	-17	**10**	-42	**16**	18	**22**	-4	**28**	-23	**34**	20
5	-7	**11**	-56	**17**	0	**23**	-6	**29**	-34	**35**	6
6	-14	**12**	-27	**18**	0	**24**	-6	**30**	-22	**36**	-4

The weather over the western parts of Rajasthan remained mainly dry from 17th September. A change in the lower tropospheric circulation pattern over the region from cyclonic to anti cyclonic during 16th - 17th September also made conditions favourable for the withdrawal of SWM from the region. Subsequently, withdrawal of monsoon from northwestern parts of the country commenced on 23rd September with a delay of more than 3 weeks as the normal date of withdrawal from this region is 1st September. On the same day it withdrew from some parts of west Rajasthan and Kutch. On 26th September, the SWM withdrew from some parts of Punjab, Haryana and Gujarat Region, some more parts of Kutch area and remaining parts of west Rajasthan. On 28th September, it further withdrew from remaining parts of Punjab, Haryana, Chandigarh & Delhi and east Rajasthan; some parts of Jammu & Kashmir, Himachal Pradesh, east Uttar Pradesh, Madhya Pradesh and Saurashtra; most parts of

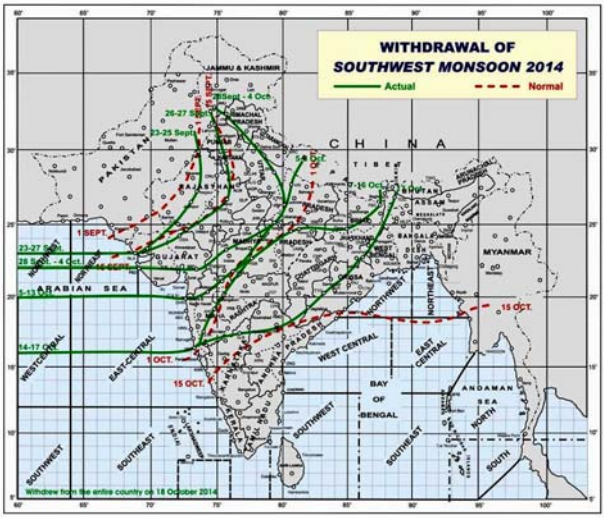


Fig. 7. Isochrones of withdrawal of monsoon 2014

west Uttar Pradesh and some more parts of Gujarat Region, Kutch and north Arabian Sea. There was no further withdrawal till 5th October. On 5th October, the SWM further withdrew from remaining parts of Jammu & Kashmir, Himachal Pradesh, west Uttar Pradesh, Gujarat state, north Arabian Sea, entire Uttarakhand, some parts of north Madhya Maharashtra and north Konkan and some more parts of east Uttar Pradesh and Madhya Pradesh. Further withdrawal had been stalled due to the formation and landfall of the Very Severe Cyclonic Storm 'HUD HUD'. The SWM further withdrew on 14th October from some more parts of west Madhya Pradesh, most parts of Madhya Maharashtra, Konkan and some parts of Marathwada and central Arabian Sea. On 18th October the SWM further 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 on 18th October.

The trend of delay in the initiation of withdrawal due to the presence of moisture and cyclonic circulations favouring rainfall activity over the northwest India continued except in 2013, as seen from the table below.

Year	*Date of withdrawal of SW Monsoon from extreme west Rajasthan*
2010	27th September
2011	23rd September
2012	24th September
2013	9th September
2014	23rd September

TABLE 1

Details of the weather systems during June 2014

S. No.	System	Duration	Place of initial location	Direction of movement	Place of Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Cyclonic Storm*						
1.	Cyclonic storm (Nanauk)	10 - 14	Arabian Sea, near Lat. 15.5° N/ Long. 68.5° E	Northwest and then north and northeast	Near Lat. 20.5° N/ Long. 62.0° E	Dissipated over northeast and adjoining east central Arabian Sea. Details are given in the article on Storms & Depressions over the north Indian Ocean-2014
(**B**) *Low pressure area*						
1.	Low pressure area	19 - 22	Coastal areas of Bangla Desh and neighbourhood	West	Bangla Desh and adjoining West Bengal	It formed under the influence of a cyclonic circulation extending upto mid tropospheric levels over northwest Bay of Bengal and neighbourhood. It became less marked on 23. However, the associated cyclonic circulation extending up to 0.9 km a.s.l. persisted over the region with a trough aloft upto 26 and became less marked on 27
(**C**) *Western disturbances /Eastward moving systems*						
(*i*) *Upper air cyclonic circulation*						
1.	Upto 3.1 kms a.s.l.	7 - 8	Jammu & Kashmir and neighbourhood	Northeast	Eastern parts of Jammu & Kashmir	Became less marked on 9
2.	Upto mid tropospheric levels	16 - 21	Northeast Afghanistan and adjoining Pakistan	Do	Jammu & Kashmir and neighbourhood	Moved away on 22
3.	Upto Mid & upper tropospheric levels	21 - 25	North Afghanistan and neighbourhood	East-northeast	Along Long. 78.0° E to the north of Lat. 30° N	It lay as a cyclonic circulation extending upto mid tropospheric levels over north Afghanistan and neighbourhood on 21. It lay as a trough with its axis at 5.8 kms along Long. 72.0° E to north of Lat. 30° N on 23 and moved away east northeastwards on 26
4.	Upto 3.1 kms a.s.l.	26 - 27	North Pakistan and adjoining Jammu & Kashmir	Do	Jammu & Kashmir and neighbourhood	Moved away on 28
(**D**) *Other upper air cyclonic circulations*						
1.	Upto 0.9 km a.s.l.	1	Odisha and neighbourhood	Stationary	*In situ*	Less marked on 2
2.	Upto lower tropospheric levels	4 - 7	Assam & Meghalaya and neighbourhood	West	Sub-Himalayan West Bengal & Sikkim and neighbourhood	Less marked on 8
3.	Do	8 - 9	Northeast Madhya Pradesh and neighbourhood	East	East Uttar Pradesh and neighbourhood	Less marked on 10
4.	Upto 0.9 km a.s.l.	10	Assam & Meghalaya and neighbourhood	Stationary	*In situ*	Less marked on 11
5.	Upto lower tropospheric levels	11 - 16	Sub-Himalayan West Bengal & Sikkim and neighbourhood	East	Nagaland-Manipur-Mizoram-Tripura	Less marked on 17
6.	Upto 0.9 km a.s.l.	12	East Uttar Pradesh and neighbourhood	Stationary	*In situ*	Less marked on 13
7.	Upto 1.5 kms a.s.l.	15	East Uttar Pradesh and adjoining Bihar	Do	Do	Less marked on 16
8.	Upto 3.1 kms a.s.l.	15	West Rajasthan and adjoining central Pakistan	Do	Do	Less marked on 16

TABLE 1 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
9.	Upto 0.9 km a.s.l.	18	Jharkhand and neighbourhood	Stationary	*In situ*	It lay embedded in the east-west trough and merged in it on 19
10.	Upto 1.5 kms a.s.l.	23	West Uttar Pradesh and neighbourhood	Do	Do	Less marked on 24
11.	Between lower & upper tropospheric levels	25 June - 8 July	Northeast Bay of Bengal and neighbourhood	West	East Uttar Pradesh and neighbourhood	It tilted southwards with height. Under its influence a low pressure area formed on 1 July. It persisted upto 8 and merged with the trough at mean sea level on 9
12.	Upto mid tropospheric levels	28 - 29	West Uttar Pradesh and neighbourhood	Quasi-stationary	Haryana and adjoining west Uttar Pradesh	It merged with the trough extended from Punjab to east central Bay of Bengal across Haryana, Uttar Pradesh, Jharkhand, Gangetic West Bengal and north Bay of Bengal on 30
13.	Do	27 - 29	Bihar and adjoining Jharkhand	-	Bihar and neighbourhood	It merged with the trough extended from Punjab to east central Bay of Bengal across Haryana, Uttar Pradesh, Jharkhand, Gangetic West Bengal and north Bay of Bengal on 30
14.	Between 3.1 & 5.8 kms a.s.l.	27 – 29	Lakshadweep area and neighbourhood	-	East central Arabian Sea off Karnataka coast	It merged with the shear zone along Lat. 12° N on 30
(**E**)	*East-west trough*					
1.	Up to 0.9 km a.s.l.	10	West Uttar Pradesh to Assam across east Uttar Pradesh, Jharkhand and Gangetic West Bengal	Stationary	*In situ*	Became less marked on 11
2.	At mean sea level	18 - 23	Punjab to northeast Bay of Bengal across Haryana, Uttar Pradesh, Jharkhand and Gangetic West Bengal	Oscillatory	West Uttar Pradesh to Mizoram across east Uttar Pradesh, Jharkhand, Gangetic West Bengal, Bangla Desh and Meghalaya	It lay as a trough at 0.9 km a.s.l. on 17. Less marked on 24
3.	At mean sea level	24 June - 16 July	Eastern parts of Bihar to east central Bay of Bengal across Gangetic West Bengal and north Bay of Bengal	Do	North Rajasthan to east central Bay of Bengal across northwest Madhya Pradesh, centre of low pressure area, north Chhattisgarh and Odisha	It established as a Monsoon trough on 17
(**F**)	*North South trough*					
1.	At mean Sea level	1	Lakshadweep area off Kerala coast	Stationary	*In situ*	Became less marked on 2
2.	Do	10	East central Arabian Sea to Lakshadweep area	Do	Do	Became less marked on 11
3.	At 1.5 kms a.s.l.	5	Southwest Madhya Pradesh to north interior Karnataka across Marathwada	West	Southwest Madhya Pradesh to north interior Karnataka across Madhya Maharashtra	Became less marked on 6
(**G**)	*East-West shear zone*					
1.	Mid tropospheric levels	3 - 10(M)	Along Lat.10° N	North	Along Lat. 14° N	Became less marked on 10 evening
2.	Do	30 June	Along Lat.12° N	Stationary	*In situ*	Became less marked on 1 July

TABLE 2

Details of the weather systems during July 2014

S. No.	System	Duration	Place of initial location	Direction of movement	Place of Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Deep Depression/Depression*						
1.	Depression	21 - 23	Northeastern parts of Odisha and adjoining areas of Gangetic West Bengal.(50 kms east of Baripada) near Lat. 22.0° N/ Long. 87.0° E	West	West Madhya Pradesh and neighbourhood near Lat.22.5° N/ Long. 77.5° E	Details are given in the article on Storms & Depressions over the north Indian Ocean-2014
(**B**) *Well marked Low/Low Pressure area*						
1.	Low pressure area	1 – 7 (M)	North Bay of Bengal and adjoining coastal areas of Bangla Desh and Gangetic West Bengal	Northwest & west	East Uttar Pradesh and neighbourhood	It formed under the influence of a cyclonic circulation extending between 1.5 & 7.6 kms a.s.l. over coastal areas of Bangla Desh and neighbourhood. It became less marked on 7th evening. However, the associated cyclonic circulation extending up to upper tropospheric levels persisted upto 8 and merged with the trough at mean sea level on 9
2.	Low pressure area	11 - 18	Northwest Bay of Bengal off west Bengal and Odisha coasts	Northwest	Southwest Uttar Pradesh and neighbourhood	It formed under the influence of a cyclonic circulation over northwest Bay of Bengal and adjoining west central Bay of Bengal tilting southwestwards with height on 11. It became less marked on 19. Associated cyclonic circulation extended upto mid tropospheric levels over central parts of Uttar Pradesh on 19 and over east Uttar Pradesh and adjoining Bihar on 20. It merged with the axis of monsoon trough on 21
3.	Well marked Low	27 - 31	Northwest Bay of Bengal and neighbourhood	West	Interior parts of Odisha and neighbourhood	Under the influence of a cyclonic circulation extending upto mid tropospheric levels over north Bay of Bengal and neighbourhood during 24-26, a low pressure area formed on 27. It became less marked on 1 Aug. However, associated cyclonic circulation extending upto mid tropospheric levels persisted upto 2 August and merged with the monsoon trough on 3 August
(**C**) *Western Disturbances/Eastward moving systems*						
(*i*) *Upper air cyclonic circulation/ trough in westerlies*						
1.	Upto mid tropospheric levels	1 - 5	Jammu & Kashmir and neighbourhood	Northeast	Eastern parts of Jammu & Kashmir	Became less marked on 6. A trough was seen aloft during 2-5
2.	Do	6 - 8	Along Long.68° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	East	Along Long. 72° E to the north of Lat. 30° N	Moved away northeastwards on 9
3.	Do	10 - 13	Jammu & Kashmir and neighbourhood	Northeast	Eastern parts of Jammu & Kashmir	Moved away eastnortheastwards on 14
4.	Do	15 - 18	Along Long.68° E to the north of Lat. 35° N (axis at 5.8 kms a.s.l.)	East	Along Long. 75° E to the north of Lat. 30° N	The feeble trough moved away northeastwards on 19

TABLE 2 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	Upto mid tropospheric levels	19 - 21	Along Long.72° E to the north of Lat. 28° N (axis at 5.8 kms a.s.l.)	Northeast	Along Long. 75° E to the north of Lat. 28° N	Moved away northeastwards on 22
6.	Between 3.1 & 5.8 kms a.s.l.	24 - 27	Jammu & Kashmir and neighbourhood	Do	Eastern parts of Jammu & Kashmir	Moved away northeastwards on 28
(**D**)	*Other upper air cyclonic circulations*					
1.	Mid & upper tropospheric levels	1	Lakshadweep areas and neighbourhood	Stationary	*In situ*	Less marked on 2
2.	Upto lower tropospheric levels	2 - 3	Punjab and neighbourhood	Do	Do	Merged with the trough at mean sea level on 8
3.	Upto mid tropospheric levels	3 - 5	West Uttar Pradesh and neighbourhood	Do	Do	Less marked on 6
4.	Do	5	Punjab and neighbourhood	Do	Do	Less marked on 6
5.	Lower & mid tropospheric levels	6	Northern parts of Tamil Nadu and neighbourhood	Do	Do	Merged with the shear zone on 17
6.	Upto 1.5 kms a.s.l.	9 - 12	Sub-Himalayan West Bengal & Sikkim and neighbourhood	West	Central Uttar Pradesh and neighbourhood	It initially lay as a trough between 1.5 & 3.1 kms a.s.l. extended from Sub-Himalayan West Bengal & Sikkim to west central Bay of Bengal on 8. Merged with the heat trough on 13
7.	Upto mid tropospheric levels	9 - 11	South Rajasthan and neighbourhood	Stationary	*In situ*	Less marked on 12
8.	Lower & mid tropospheric levels	14 - 18	Northeast Arabian Sea and neighbourhood	East	Gujarat and neighbourhood	Less marked on 19
9.	Mid & upper tropospheric levels	15 - 16	Northwest Bay of Bengal and neighbourhood	Stationary	*In situ*	Less marked on 17
10.	Upto lower tropospheric levels	17 - 18	Bihar and adjoining Jharkhand	East	Jharkhand and neighbourhood	It lay embedded in the monsoon trough and merged with monsoon trough on 19
11.	Upto 0.9 km a.s.l.	18	Assam & Meghalaya and neighbourhood	Stationary	*In situ*	Less marked on 19
12.	Upto 0.9 km a.s.l.	22	Do	Do	Do	Less marked on 23
13.	Lower & mid tropospheric levels	29 Jul-2 Aug	West Madhya Pradesh and neighbourhood	West	Northeast Rajasthan and neighbourhood	It merged with the monsoon trough on 3 August
(**E**)	*Troughs in westerlies*					
1.	At 5.8 kms a.s.l.	6 - 8	Along Long.68° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	East	Along Long. 72° E to the north of Lat. 30° N	Moved away northeastwards on 9
2.	Do	15 - 18	Along Long.68° E to the north of Lat. 35° N (axis at 5.8 kms a.s.l.)	Do	Along Long. 75° E to the north of Lat. 30° N	The feeble trough moved away northeastwards on 19
(**F**)	*East-West shear zone*					
1.	Between Mid & Upper levels	7 - 8	Along Lat. 13° N	North	Along Lat. 14° N	Became less marked on 9

TABLE 3

Details of the weather systems during August 2014

S. No.	System	Duration	Place of initial location	Direction of movement	Place of Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Deep Depression/Depression*						
1.	Deep Depression	3(1200 UTC) - 7(0000 UTC)	Northwest Bay of Bengal and adjoining coastal areas of West Bengal. (88 kms southeast of Diamond Harbour) near Lat. 21.5° N/ Long. 88.5° E	West northwest	Northwest Madhya Pradesh and neighbourhood (50 kms southeast of Gwalior) near Lat. 25.5° N/ Long. 78.5° E	Details are given in the article on Storms & Depressions over the north Indian Ocean - 2014
(**B**) *Well marked Low/Low Pressure area*						
1.	Low pressure area	9 - 11	North Bay of Bengal and neighbourhood	Northwest	Southern parts of Bihar and neighbourhood	It formed under the influence of a cyclonic circulation extending between 5.8 & 7.6 kms a.s.l. over north Bay of Bengal and neighbourhood. It merged with the monsoon trough on 12. However, the associated cyclonic circulation extending up to mid tropospheric levels persisted upto 18 and became less marked on 19
2.	Low pressure area	23 (0000 UTC) - 24	East central Arabian Sea and adjoining coastal areas of Karnataka and Maharashtra	Stationary	*In situ*	It formed under the influence of a cyclonic circulation over Lakshadweep - Comorin area. It became less marked on 25. Associated cyclonic circulation persisted on 25 and became less marked on 26
3.	Well marked Low	27 Aug - 6 Sep	West central and adjoining northwest Bay of Bengal off north Andhra Pradesh-south Odisha coasts	West	Punjab and adjoining Rajasthan and Haryana	It formed under the influence of a cyclonic circulation over west central Bay of Bengal and neighbourhood. It became less marked on 7 September. However, associated cyclonic circulation extending upto upper tropospheric levels persisted upto 7 and became less marked on 8 September
(**C**) *Western Disturbances /Eastward moving systems*						
(*i*) *Upper air cyclonic circulation/trough*						
1.	Between 3.1 & 5.8 kms a.s.l.	11 - 13	North Pakistan and neighbourhood	East-northeast	Jammu & Kashmir and neighbourhood	Moved away east northeastwards on 14
2.	Mid tropospheric levels	22 - 26	Afghanistan and neighbourhood	Do	Eastern parts of Jammu & Kashmir and neighbourhood	Moved away east northeastwards on 26 evening
3.	Do	25 - 26	North Pakistan and adjoining Jammu & Kashmir	Northeast	Jammu & Kashmir and neighbourhood	Moved away northeastwards on 27
4.	Do	26 - 31	Afghanistan and neighbourhood	Do	Do	Moved away northeastwards on 1 September
5.	Mid tropospheric levels	30 Aug - 3 Sep	Western parts of Afghanistan and adjoining Pakistan	Do	Do	Moved away northeastwards on 4 September
(**D**) *Other upper air cyclonic circulations*						
1.	Upto lower tropospheric levels	2	Gangetic West Bengal and neighbourhood	Stationary	*In situ*	Merged with the circulation associated with the low pressure area on 3
2.	Upto lower levels	1 - 4	Saurashtra & Kutch and neighbourhood	West	Kutch and adjoining south Pakistan	Moved away on 5
3.	Between 2.1 & 5.8 kms a.s.l.	7 - 9	Gujarat region and neighbourhood	Do	Kutch and neighbourhood	Became less important on 10
4.	Between 1.5 & 5.8 kms a.s.l.	12	Kutch and adjoining south Pakistan	Stationary	*In situ*	Became unimportant on 13

TABLE 3 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	Between 5.8 & 7.6 kms a.s.l.	16	North Bay of Bengal and neighbourhood	Stationary	*In situ*	Merged with the cyclonic circulation over northern parts of Gangetic West Bengal and neighbourhood on 17
6.	Between 3.1 & 5.8 kms a.s.l.	18 - 22	Southwest Bay of Bengal off north Tamil Nadu coast	West	Marathwada and neighbourhood	Became less marked on 23
7.	Upto 1.5 kms a.s.l.	22	South interior Karnataka and neighbourhood	Do	Do	Merged with the well marked low pressure area over east central Arabian Sea and adjoining coastal areas of Karnataka and Maharashtra on 23
8.	Between 1.5 & 3.6 kms a.s.l.	26 - 29	Gujarat region and neighbourhood	Do	South Pakistan and neighbourhood	Became unimportant on 30
9.	Upto 0.9 km a.s.l.	29	West Madhya Pradesh and adjoining east Rajasthan	Stationary	*In situ*	Merged with the monsoon trough on 30
10.	Upto 2.1 kms a.s.l.	31	Nagaland and neighbourhood	Do	Do	Became less marked on 1 September
(**E**)	*Troughs in westerlies*					
1.	Mid & upper tropospheric levels	3 - 6	Along Long. 65° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	East	Along Long. 77° E to the north of Lat. 30° N	Moved away northeastwards on 7
2.	Do	8 - 10	Along Long. 72° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	Do	Along Long.76° E to the north of Lat. 30° N	Moved away northeastwards on 11
3.	Upto mid tropospheric levels	14 - 15	Sub-Himalayan West Bengal & Sikkim to west central Bay of Bengal	Oscillatory	Sub-Himalayan West Bengal & Sikkim to north Bay of Bengal across Gangetic West Bengal	Became less marked on 16
4.	Do	15	Along Long. 70° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	Stationary	*In situ*	Moved away northeastwards on 16
5.	Mid & upper tropospheric levels	16 - 19	Along Long. 66° E to the north of Lat. 28° N (axis at 5.8 kms a.s.l.)	-	Along Long. 79° E to the north of Lat. 35° N	Moved away northeastwards on 20
6.	Lower tropospheric levels	18 - 19	West Bengal & Sikkim and neighbourhood to coastal Odisha	West	Sub-Himalayan West Bengal & Sikkim to north Chhattisgarh across Bihar and Jharkhand	Became less marked on 20
7.	Lower levels	20	East Madhya Pradesh to Kerala across interior parts of Maharashtra and Karnataka	Stationary	*In situ*	Became less marked on 21
8.	Lower & mid tropospheric levels	20 - 26	Sub-Himalayan West Bengal & Sikkim to north Bay of Bengal across Gangetic West Bengal	Do	Do	Became less marked on 27
(**F**)	*East-West shear zone*					
1.	Upper tropospheric levels	9 - 10	Along Lat. 12° N	South	Along Lat. 10° N across south Peninsula	Became less marked on 11
2.	Between 3.1 & 5.8 kms a.s.l.	19 - 21	Along Lat. 10° N across south Peninsula	Stationary	Along Lat. 10° N across south Peninsula	Became less marked on 22. A cyclonic circulation was seen embedded over Lakshadweep- Comorin area on 21
3.	Mid- tropospheric levels	24 - 26	Along Lat. 14° N across south Peninsula	North	Along Lat. 17° N	Became less marked on 27. A cyclonic circulation was seen embedded over west central Bay of Bengal and neighbourhood on 26

TABLE 4

Details of the weather systems during September 2014

S. No.	System	Duration	Place of initial location	Direction of movement	Place of Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Well marked Low/Low Pressure area*						
1.	Low pressure area	2 - 4	Saurashtra & Kutch and adjoining northeast Arabian Sea	North	Kutch and neighbourhood	It formed under the influence of a cyclonic circulation extending upto 3.1 kms a.s.l. over south Rajasthan and neighbourhood. It became less marked on 5. However, the associated cyclonic circulation extending up to mid tropospheric levels tilting southwards with height lay over Kutch and adjoining south Pakistan and became less marked on 6
2.	Well marked low pressure area	5 - 9	Northwest Bay of Bengal off west Bengal-Bangla Desh coasts	West	West Madhya Pradesh and adjoining east Rajasthan	It formed under the influence of a cyclonic circulation over northwest Bay of Bengal and neighbourhood on 5 and became well marked over northwest Bay of Bengal and adjoining Odisha- West Bengal coasts on 6. It became less marked on 10. Associated cyclonic circulation extending upto mid tropospheric levels persisted over the same region on 10. It lay over north Rajasthan and adjoining areas of Haryana and Punjab on 11 and over Haryana and neighbourhood on 12. It merged with the monsoon trough on 13
3.	Well marked low pressure area	16 - 24	Northwest Bay of Bengal and adjoining coastal areas of Odisha and west central Bay of Bengal	Northeast	North Bangla Desh and neighbourhood	Under the influence of a cyclonic circulation over coastal areas of Odisha and adjoining areas of northwest Bay of Bengal a low pressure area formed over northwest Bay of Bengal and adjoining coastal areas of Odisha and west central Bay of Bengal on 16. It became well marked over northwest and adjoining west central Bay of Bengal off Gangetic West Bengal - Odisha and north coastal Andhra Pradesh coasts on 20. It became less marked as a low pressure area on 25. However, associated cyclonic circulation extending upto upper tropospheric levels tilting southwards with height lay over the same region embedded in the north-south trough upto 27 and became less marked on 28
(**B**) *Western Disturbances /Eastward moving systems*						
(*i*) *Upper air cyclonic circulation/ trough*						
1.	Mid & Upper tropospheric levels	3 - 7	Along Long. 64° E to the north of Lat. 28° N (axis at 5.8 kms a.s.l.)	Northeast	Long. 78° E to the north of Lat. 30° N	Moved away northeastwards on 8
2.	Do	7 - 13	Along Long. 65° E to the north of Lat. 25° N (axis at 5.8 kms a.s.l.)	Do	Along Long. 78° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	Moved away northeastwards on 14
3.	Do	14 - 16	Along Long. 72° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	Do	Along Long. 80° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	Moved away northeastwards on 17

TABLE 4 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
4.	Mid & Upper tropospheric levels	18 - 21	Along Long. 62° E to the north of Lat. 28° N (axis at 5.8 kms a.s.l.)	Northeast	Along Long. 78° E to the north of Lat. 28° N (axis at 5.8 kms a.s.l.)	Moved away northeastwards in the evening of 21
5.	Between 3.1 & 5.8 kms a.s.l.	23 - 27 M	North Pakistan and neighbourhood	East Northeast	Eastern parts of Jammu & Kashmir	Moved away east-northeastwards on 27 evening
6.	Mid & Upper tropospheric levels	27 - 29	Along Long.62° E to the north of Lat. 35° N (axis at 5.8 kms a.s.l.)	Northeast	Along Long.80° E to the north of Lat. 30° N (axis at 5.8 kms a.s.l.)	Moved away northeastwards on 30
(**C**)	*Other upper air cyclonic circulations*					
1.	Upto mid tropospheric levels	7 - 9	East Assam & Meghalaya and neighbourhood	West	Assam & Meghalaya	Became less marked on 10
2.	Between lower & mid tropospheric levels	9 - 17	Gujarat and adjoining northeast Arabian Sea	Northwest	Saurashtra & Kutch and neighbourhood	Became less marked on 18
3.	Do	10 - 17	East Madhya Pradesh and adjoining Chhattisgarh	North	East Uttar Pradesh and neighbourhood	Became less marked on 18
4.	Upto mid tropospheric levels	12 - 16	Punjab and adjoining areas of Pakistan	Stationary	*In situ*	Became less marked on 17
5.	Do	13 - 15	Western parts of Assam & Meghalaya	East	Assam & Meghalaya and neighbourhood	Became less marked on 16
6.	Between 1.5 & 3.1 kms a.s.l.	16	Haryana and adjoining west Uttar Pradesh	Stationary	*In situ*	Became less marked on 17
7.	Between 3.1 & 4.5 kms a.s.l.	18 - 19	West Uttar Pradesh and adjoining Haryana	Do	Do	Became less marked on 20
8.	Upto 1.5 kms a.s.l.	18 - 19	Over Nagaland-Manipur-Mizoram-Tripura and adjoining Assam	Do	Do	Became less marked on 20
9.	Upto mid tropospheric levels	22 Sep - 4 Oct	Lakshadweep area and neighbourhood	West	Southwest Arabian Sea and neighbourhood	Became unimportant on 5 October
10.	Do	29 Sep - 2 Oct	Eastern parts of Assam & Meghalaya and adjoining Tripura	Quasi-Stationary	Tripura and neighbourhood	Became less marked on 3 Oct. Initially it lay as a trough extending between 1.5 & 3.1 kms a.s.l. from sub-Himalayan West Bengal & Sikkim to northeast Bay of Bengal on 28 September
11.	Between 1.5 & 4.5 kms a.s.l.	26	Gujarat and neighbourhood	Stationary	*In situ*	Became less marked on 27
12.	Upto lower tropospheric levels	30 Sep - 5 Oct	Punjab and neighbourhood	West	Northwest Rajasthan and neighbourhood	Became less marked on 6 October
13.	Do	30	Eastern parts of Bihar and adjoining sub-Himalayan West Bengal & Sikkim	Stationary	*In situ*	Became less marked on 1 October
(**D**)	*Other Troughs*					
1.	Upto mid tropospheric levels	25 - 26	North Bangla Desh and neighbourhood to west central Bay of Bengal	Quasi-Stationary	Sub- Himalayan west Bengal & Sikkim to west central Bay of Bengal	Became less marked on 27. A cyclonic circulation extending upto 3.1 kms a.s.l. lay embedded in the trough over north Bangla Desh and neighbourhood on 26. It persisted on 27 and became less marked on 28
2.	Upto 1.5 kms a.s.l.	25 - 26	Comorin area and neighbourhood to south interior Karnataka	Do	Comorin area and neighbourhood to Konkan coast	Less marked on 27

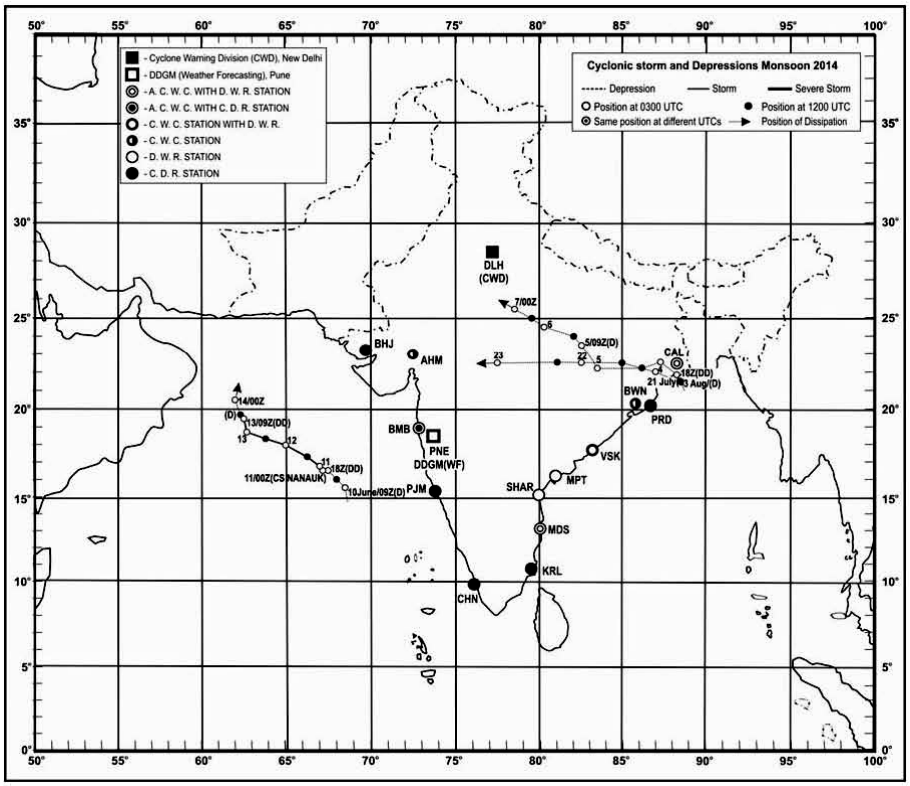


Fig. 8. Tracks of the intense low pressure systems during SW monsoon 2014

3. Chief synoptic features of southwest monsoon 2014

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

In all, three intense low pressure systems formed during the season, out of which one formed over Arabian Sea and intensified into Cyclonic Storm (Nanauk), one as deep depression over Bay of Bengal and one as a Land Depression. Tracks of these systems are shown in Fig. 8. Based on the recorded history of Cyclonic Storms and Depressions, about 6 monsoon depressions developed over the Indian region during the SWM season [June to September]. On an average, two depressions get formed during July and August and one each during June & September.

Off-shore trough along different parts of west coast persisted from 3 June - 15 September except during 9 - 10 June, 23 June - 2 July, 26 - 27 July, 15 August and 18 - 24 August. It was quite feeble from 3 - 5 June, 11 - 13 June, 18 June, 20 - 22 June, 24 - 25 July, 14 August, 27 - 31 August and 7 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 the Arabian Sea was stronger than normal by about 2 kts during the first and fourth week and about 5 kts in second week of June. It was stronger by about 4 kts in third and weaker than normal by 5 kts in first week of July. It was stronger by 7 kts in fourth week and weaker than normal by 3 kts in second week of August. It was stronger than normal by 4 kts, 6 kts, 8kts and 7 kts respectively in first, second, third and 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 2014.

The surface winds over the Arabian Sea to the north of 5° N were stronger than normal by about 2 kts during first, 3 kts in second & fourth and 8 kts in third week of June. It was also stronger than normal by about 3 kts in second and 6 kts in third week of July. It was also stronger

than normal by about 12 kts, 8 kts, 9 kts, 6 kts in the first, second, third and fourth weeks of September respectively. It was weaker than normal by about 4 kts in the first & by 2 kts in the fourth week of July and by 3 kts, 9 kts and 4 kts in the second, third & fourth weeks of August. It was normal in first week of August.

4.1.2. *Over the Bay of Bengal*

The cross equatorial flow along the equatorial belt (equator to 5° N / 5° S) over the Bay of Bengal was stronger than normal by about 2 kts in first, second & third week of June and by 4 kts in the fourth week of June. It was stronger than normal by 4 kts, 11 kts and 3 kts respectively in first, second and fourth week of July. It was also stronger than normal by 2 kts, 7 kts and 11 kts respectively in first, third and fourth week of August. It was stronger than normal by 5 kts, 4 kts, 7 kts and 5 kts respectively in first, second, third and fourth weeks of September. It was normal in third week of July and second week of August.

The surface winds over the Bay of Bengal to the north of 5° N were stronger than normal by 3 kts in first week of June, July, and August and in the fourth week of September, 7 kts in second of June and third week of September. It was also stronger by 4 kts and 5 kts respectively in the third and fourth weeks of June. It was also stronger by 12 kts in second and by 6 kts in third and fourth weeks of July. In September it was stronger than normal by 11 kts and 13 kts in the first and second weeks. It was near normal during rest of the period of August.

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

There were in all 12 low pressure systems (reaching the intensity of Tropical depression and above) in the northwest Pacific Ocean / South China Sea during June-September, 2014.

4.3. *Systems in southern hemisphere*

4.3.1. *Tropical storms/depressions*

No intense low pressure system was reported in Southern Hemisphere during June-September, 2014.

4.3.2. *Mid-latitude troughs*

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

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

There were 53 troughs in mid & upper tropospheric 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, 2014. The month wise break-up is 13 each in June and July, 2014 in August and 13 in September.

4.3.4. *Mascarene HIGH*

The mean position of Mascarene HIGH during June to September, 2014 was 30.7° S/63.7° E. The intensity of Mascarene HIGH was above normal by 1.9 hPa during the monsoon period June to September 2014. It was above normal by 1.3, 2.6, and 3.7 during the months of June, July and September, 2014 respectively. It was near normal in the month of August, 2014.

5. Semi-permanent systems

5.1. *Heat low*

This year, the continued presence of the mid-latitude circulation regime and passage of western disturbances caused weakening of the 'Heat Low' and delayed its setting. It established in its near normal position over west Pakistan and neighbourhood on 6th June. It was mostly seen in its near normal position during June, July & August and September. The Heat Low was less discernible during second fortnight of August. It became less marked in the first week of October.

5.2. *Axis of the monsoon trough*

In 2014, the higher than normal mean sea level pressure anomalies over the northwestern parts of India, presence of mid-latitude circulation regime and passage of western disturbances during end of May and first week of June delayed the establishment of an organized Heat Low during the initial part of the season. A trough at mean sea level was seen extending along Indo-Gangetic plain during 18th June - 23rd June. It became less marked on 24th June. It was present at mean sea level but as a shallow trough, since 26th June. With the southwest monsoon covering the entire country, this trough got established as the monsoon trough on 17th July. The axis of monsoon trough remained normal / south of its normal position during July and first half of September It extended up to mid tropospheric levels without its characteristic tilt. It mostly remained north of its normal position/close to foot

hills of the Himalayas during August. The seasonal 'heat low' was less demarcated since second half of August except for first half of September, when it became noticeable. Thereafter, it became less apparent and subsequently, the axis of monsoon trough also weakened thereby becoming less delineated since 22nd September.

With the shifting of the monsoon trough to the foot hills of Himalayas during the month of August, the circulation features and rainfall pattern resembled typical break like situation during 15th - 21st August.

5.3. *Tibetan Anticyclone/High*

The Tibetan Anticyclone got established in its near normal position at 200 hPa on 11th July. It was seen all through the remaining period of the season. Initially, It was seen to the west and then to the northeast of its normal position during July. It exhibited east-west oscillation about its normal position during first half of August and weakened in second half due to mid latitude westerly intrusion and was shifted to south to southeast of its normal position. It remained in its near normal position except during mid September when it was east of its normal position.

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

The STWJ started shifting northwards from the first week of June. Srinagar reported 60 knots wind (at 300 hPa) at 0000 UTC of 20th 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 third week of September, it once again shifted southwards as evidenced by the 69 knots westerly wind reported over Srinagar at 222 hPa on 21st September (0000 UTC).

5.5. *Tropical Easterly Jet (TEJ)*

The TEJ got established over the southern tip of Peninsular India by 29th May with Thiruvananthapuram reporting easterlies of 66 kts around 106 hPa. A wide latitudinal spread of the easterly jet speed winds was seen during July and August while during June and September; the stations over the Peninsular India only reported jet speed wind. The highest wind speed of 125 kts at 130 hPa was reported at Thiruvananthapuram on 14th August.

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 2014*

The month wise circulation anomaly features at lower, middle & upper tropospheric levels *viz*., 850, 700, 500 & 200 hPa during the southwest Monsoon season are discussed below.

6.1.1. *June wind anomaly features*

In the monthly anomaly winds, three anomalous cyclonic circulations were seen at 850 hPa, one over northwest (NW) Bay of Bengal off Gangetic West Bengal (GWB) coast, second over southeast (SE) Arabian Sea and third over southwest (SW) Bay of Bengal off Tamil Nadu coast extending upto 500 hPa.

At 700 hPa, two anomalous anticyclonic circulations were seen, one over Vidarbha and neighbourhood, extending upto 500 hPa and second over Arunachal Pradesh and neighbourhood extending upto 500 hPa.

In the week ending on 4th June, five anomalous cyclonic circulations were seen at 850 hPa, one over Chattisgarh and neighbourhood, second over Jharkhand and neighbourhood, third over East Uttar Pradesh (EUP) and neighbourhood, fourth over Nagaland-Manipur-Mizoram-Tripura (NMMT) & neighbourhood and fifth over Arunachal Pradesh and neighbourhood and extending upto 700 hPa level. A Ridge line at 200 hPa extended along 73° E.

In the week ending on 11th June, four anomalous cyclonic circulations were seen at 850 hPa level, one over EUP and neighbourhood, extending upto 500 hPa, second over Assam & Meghalaya and neighbourhood extending upto 500 hPa, third over east central Arabian Sea and extending upto 500 hPa and fourth over SW Bay of Bengal off Tamil Nadu coast and extending upto 300 hPa. An anomalous cyclonic circulation was seen at 700 hPa over west. Rajasthan and neighbourhood and extending upto 500 hPa. A Ridge line extended along 19° N at 500 hPa.

In the week ending 18th June, an anomalous cyclonic circulation was seen at 850 hPa over NMMT and neighbourhood and extending upto 500 hPa. At 700 hPa, three anomalous cyclonic circulations were seen, one over East Uttar Pradesh and neighbourhood and extending upto 500 hPa, second over west Rajasthan and neighbourhood and third over SW Bay of Bengal off Tamil Nadu coast and extending upto 200 hPa. An anomalous anticyclonic circulation was seen at 700 hPa over Chhattisgarh and neighbourhood, extending upto 500 hPa.

In the week ending on 25th June, anomalous cyclonic circulation was seen at 850 hPa over SW Bay of Bengal off Tamil Nadu coast extending upto 500 hPa. Two anomalous anticyclonic circulations were seen at 850 hPa, one over Gujarat and neighbourhood and second over Odisha and neighbourhood. A Ridge line at 200 hPa extended along 16° N.

In the week ending on 2nd July, two anomalous cyclonic circulations were seen at 850 hPa, one over GWB & neighbourhood and extending upto 700 hPa and second over west Uttar Pradesh (WUP) and neighbourhood. A Ridge line at 200 hPa extended along 23° N.

6.1.2. *July wind anomaly features*

In the monthly anomaly winds, four anomalous cyclonic circulations were seen at 850 hPa, one over westcentral (WC) Bay of Bengal off Odisha extending upto 300 hPa, second over SE Arabian Sea off Karnataka coast and extending upto 500 hPa, third over EUP & neighbourhood and extending upto 700 hPa and fourth over NMMT & neighbourhood and extending upto 300 hPa.

In the week ending on 9th July, four anomalous cyclonic circulations were seen at 850 hPa, one over Jharkhand & neighbourhood, second over WUP & neighbourhood, third over Arunachal Pradesh & neighbourhood and fourth over SW Bay of Bengal off Tamil Nadu coast extending upto 200 hPa. Three anomalous anticyclonic circulations were seen at 700 hPa, one over Gujarat & neighbourhood, second over Odisha & neighbourhood and third over SE Arabian Sea. A Ridge at 200 hPa, extended along 16° N.

In the week ending on 16th July, three anomalous cyclonic circulations were seen at 850 hPa, one over EC Arabian Sea off Maharashtra coast, second over WC Bay of Bengal off Odisha coast and extending upto 200 hPa and third over NMMT & neighbourhood and extending upto 700 hPa. Two anomalous anticyclonic circulations were seen at 500 hPa kevel, one over west Rajasthan & neighbourhood and second over Assam & Meghalaya and neighbourhood. A Ridge line, at 200 hPa extended along 23° N.

In the week ending on 23rd July, three anomalous cyclonic circulations were seen at 850 hPa, one over NMMT & neighbourhood, second over Odisha & neighbourhood and extending upto 700 hPa and third over WUP & neighbourhood extending upto 500 hPa. Two ridge lines extended one along 15° N and the other along 30° N at 200 hPa.

In the week ending on 30th July, four anomalous cyclonic circulations were seen at 850 hPa, one over EC Arabian Sea off Maharashtra coast, second over WC Bay of Bengal off Odisha coast extending upto 300 hPa, third over NMMT & neighbourhood and fourth over SW Bay of Bengal off Tamil Nadu coast. At 200 hPa, two ridge line extended, one along 12° N and second along 26° N.

6.1.3. *August wind anomaly features*

In the monthly anomaly winds, four anomalous cyclonic circulations were seen at 850 hPa, one over Arunachal Pradesh and neighbourhood, second over WC Bay of Bengal off Odisha coast, third over SW Bay of Bengal off Tamil Nadu coast and fourth over SE Arabian Sea. At 700 hPa, two anomalous anticyclonic circulations were seen one over Jharkhand & neighbourhood and second over Marathwada & neighbourhood. Ridge line extended along 17° N, 60° E to 29° N, 97° E.

In the week ending on 6th August, three anomalous cyclonic circulations were seen at 850 hPa, one over WUP & neighbourhood and extending upto 700 hPa, second over NW Bay of Bengal off WB coast and extending upto 200 hPa and third over Arunachal Pradesh & neighbourhood and extending upto 700 hPa. Two anticyclonic circulations were seen at 500 hPa, one over coastal Karnataka & neighbourhood and another over Assam- Meghalaya & neighbourhood.

In the week ending on 13th August, two anomalous cyclonic circulations were seen at 850 hPa, one over Sub-Himalayan West Bengal & Sikkim and neighbourhood and extending upto 500 hPa and another over SE Arabian Sea off Lakshadweep area. Two anomalous anticyclonic circulations were seen at 700 hPa, one over Haryana & neighbourhood and second over Telangana & neighbourhood extending upto 300 hPa. At 200 hPa, a ridge line extended along 24° N to 28° N.

In the week ending on 20th August, two anomalous cyclonic circulations were seen at 850 hPa, one over Jharkhand & neighbourhood and second over Gujarat & neighbourhood. Ridge line extended at 200 hPa between 21° N to 26° N.

In the week ending on 27th August, an anomalous cyclonic circulation was seen at 850 hPa over SE Arabian Sea off Lakshadweep area extending upto 700 hPa. Two anomalous anticyclonic circulations were seen at 850 hPa, one over West Rajasthan & neighbourhood and second over Jharkhand & neighbourhood and both extending upto 700 hPa. At 200 hPa, ridge line extended along 23° N.

In the week ending on 3rd September, two anomalous cyclonic circulations were seen at 850 hPa, one over

Madhya Maharashtra & neighbourhood and second over Odisha & neighbourhood extending upto 500 hPa. Ridge line extended along 20° N at 200 hPa.

6.1.4. *September wind anomaly features*

In the monthly anomaly winds, four anomalous cyclonic circulations were seen at 850 hPa, one over EC Arabian Sea off Maharashtra coast extending upto 700 hPa, second over WUP & neighbourhood, third over SE Arabian Sea off extreme South Kerala coast extending upto 700 hPa and fourth over NW Bay of Bengal off WB Coast extending upto 700 hPa. A Ridge line at 200 hPa, extended along 17° N.

In the week ending on 10th September, four anomalous cyclonic circulations were seen at 850 hPa, one over west Rajasthan & neighbourhood extending upto 500 hPa, second over Odisha coast, extending upto 500 hPa, third over Madhya Maharashtra & neighbourhood and fourth over Arunachal Pradesh & neighbourhood extending upto 500 hPa.

In the week ending on 17th September, an anomalous cyclonic circulation was seen at 850 hPa over west Rajasthan & neighbourhood extending upto 700 hPa. An anomalous anticyclonic circulation was seen over Telangana & neighbourhood at 850 hPa. At 700 hPa, an anomalous cyclonic circulation was seen over WC Bay of Bengal off Odisha coast. At 200 hPa, ridge line extended along 25° N.

In the week ending on 24th September, two anomalous cyclonic circulations were seen at 850 hPa, one over Assam-Meghalaya & neighbourhood and second over west Rajasthan & neighbourhood. At 500 hPa, two anomalous anticyclonic circulations were seen, one over SE Arabian Sea and another over SW Bay of Bengal. At 200 hPa, ridge line extended along 25° N.

In the week ending on 1st October, an anomalous cyclonic circulation was seen at 850 hPa over Assam & Meghalaya and neighbourhood. At 850 hPa, anomalous anticyclonic circulation was seen over Vidarbha & neighbourhood extending upto 300 hPa.

7. Significant temperatures during the season

Owing to the sluggish advance of monsoon, heat wave conditions prevailed over some parts of northwest, central and peninsular India during June and first half of July month. The highest maximum temperature of 49.2 °C was recorded in Ghazipur (east Uttar Pradesh) on 8th June, 2014.

8. Disastrous weather events and damage during Monsoon months

8.1. *June*

According to media reports, river Brahmaputra and Jiabharali at Jiabharali (NTX) in Assam were flowing above the danger level with rising trend. Lakhimpur, Darrang, Sonitpur and Udaigiri were the districts affected. Four districts of Assam were affected by floods, hitting nearly 25,000 people and damaging fully 3 and partially 40 houses, and farm fields with standing crops in around 3000 hectares. Several road embankments were eroded and approaches of bridges and culverts were washed away by the floods.

8.2. *July*

Continuous rains in Uttarakhand hills and state led rising of water level in Ganga and its tributaries. Heavy release of water from Banbasa barrage on Indo-Nepal border in Uttarakhand caused flooding of Ghagra, Sharda, Ramganga, and Dabri rivers. Heavy rains and flooding of rivers caused inundation of many low lying areas of Moradabad, Bijnor, Pilibhit, Kheri and Lakhimpur districts. Various flood-related incidents have also claimed at least 6 lives.

Heavy incessant rains caused flooding of river Baitarani in Odisha where 4 people died. Thousands of people were evacuated and as many villages were marooned with floodwater breaching river embankments at several places in Odisha. Nearly about 11,000 hectares of agricultural land across 30 villages were damaged. Two lakh people from Jajpur, Keonjhar, Kalahandi and Bhadrak districts were mostly affected.

8.3. *August*

Heavy rains, floods and landslides took a toll of 233 lives (89 in Uttar Pradesh, 45 in Odisha, 24 in Uttarakhand, 18 in Bihar, 16 in Karnataka, 13 in Kerala, 11 in Assam, 7 in Rajasthan, 4 in Tamil Nadu, 3 in Arunachal Pradesh, 2 in Himachal Pradesh and 1 in Andhra Pradesh)

Around 33 lakh people and 3.22 lakh hectares of crops across 23 districts of Odisha were affected. Torrential rain caused flooding of nearly 100 villages in Rajasthan and damaged 300 houses. It affected 12 lakh people across 16 districts of Assam and 70 percent of Kaziranga National park flooded. Heavy rainfall in catchment areas of Nepal caused flooding in eastern parts of Uttar Pradesh and Bihar, and affected 18 lakh people across 16 districts of Bihar and 4 lakh people in 9 districts

of Uttar Pradesh. It also damaged crops of worth 56.44 crores in 3 lakh hectares of agricultural land. It caused extensive damage to both agriculture and civic amenities. Flooding of rivers and inundation of low lying areas caused damage to houses and crops in Kerala.

8.4. *September*

According to media reports, heavy rains and floods took a toll of 397 people (284 in Jammu & Kashmir, 52 in Meghalaya, 36 in Assam, 22 in Punjab, 6 in Madhya Pradesh).

One of the worst flood in six decades caused extensive damage in Jammu & Kashmir. Incessant rain triggered landslide and floods. Around 2600 villages were affected and 20000 houses were partially or fully damaged. About 2500 livestock perished in this flood. Torrential rain in adjacent Garo hills districts led to flooding of low lying areas of Assam & Meghalaya. It affected 10 lakh people and damaged over 1 lakh hectares of crops and also around 80000 houses across both the state.

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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.

Monsoon activity

Active	-	Average rainfall of a sub-division is more than 1½ to 4 times the normal with minimum 5 cms along the west coast and 3 cms elsewhere in at least two stations in the sub-division.
Vigorous	-	Average rainfall of a sub-division is more than 4 times or more than the normal with minimum 7 cm along the west coast and 5 cm elsewhere in at least two stations in the sub-division.

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.