MAUSAM, **57**, 3 (July 2006), 527-566

Weather in India

MONSOON SEASON (June to September 2005)†

1. Introduction

The seasonal rainfall for the country as a whole was 99% of its long period average. Though being bountiful in terms of the cumulative rainfall, which was also well distributed spatially by the end of the season, it was not quite well distributed in time. Rainfall occurred in quantums with pronounced dry spells/break situations in between. There was prolonged weak/break conditions during August. Heavy rainfall events caused flood situations in several states like Maharashtra, Gujarat, Karnataka, Madhya Pradesh etc. A Mesoscale convective system embedded in the offshore trough, when combined with the active monsoon conditions and strong westerly current, caused a record rainfall of 94.4 cm at Mumbai (Santacruz) on 26-27 July and unaccountable devastations. 72% of the meteorological districts received *excess/normal** rainfall, whereas 26% received *deficient* and 2% *scanty* rainfall. Out of the 168 meteorological districts which suffered from drought conditions last year, as many as 113 districts received *normal* / *excess* rainfall during this season, but drought continued in 55 districts.

2. Characteristic features of southwest monsoon 2005

2.1. Slightly behind schedule onset over Kerala- on 5 June. No onset vortex could be detected other than the trough off the west coast. Much delayed onset over northeast India – on 16 June.

2.2. It covered the entire country on 30 June, 15 days prior to the normal date.

2.3. In all, one cyclonic storm and 4 depressions over the Arabian Sea and the Bay of Bengal and 1 land depression formed during the season.

2.4. Out of the 36 met. sub-divisions, 8 received *excess* and 25 received *normal* rainfall while the remaining 3 were *deficient*.

2.5. The seasonal rainfall over the country as a whole was 99% of its long period average and thus had been a *normal monsoon* year.

2.6. *Exceptionally heavy* rainfall incidents and severe floods demarcated the season.

2.7. A prolonged absence of rainfall and a change of circulation patterns resulted in withdrawal of southwest monsoon from the extreme west Rajasthan on 2 September, near about the normal date (1 September). It withdrew from the entire country on 11 October, with the subsequent commencement of northeast monsoon rains over the southern peninsula on 12 October.

3. Features of monsoon

3.1. *Advance of southwest monsoon*

The monsoon current reached south Andaman Sea and parts of southeast Bay on 26 May, with a delay of about 6 days. Only the Bay branch advanced and covered parts of the central Bay by 2 June (3-4 days delay).

The Arabian Sea branch started advancing on 5 June and the onset took place over Kerala on 5th June. But the steady advance was only till 8 June. The hiatus occurred during 9 to 15 June, might have been caused by the subsidence induced by an anticyclone over central India and the mid- latitude westerly intrusion. This westerly intrusion, along with the prevalence of anticyclone over central India, gave rise to *severe heat wave conditions* over many parts of the country, while moderating the temperature over northwest India. The sweeping in of northwesterly winds, by preventing the onset of sea breeze, also contributed to the heat wave conditions especially over Orissa and coastal Andhra Pradesh. During the period of hiatus, the heat low and the heat trough became less marked and the pressure gradient along the west coast slackened. After a week, *i.e.*, from 15 June onwards, the amplitude of mid latitude westerly trough decreased and the westerlies weakened. Anticyclone over central India also gradually weakened. Accordingly, the east-west shearline shifted to the north. Two cyclonic circulations developed, one over the north Bay and another off the west coast. West coast pressure

* Definition of terms in '*Italics*' are given in Appendix.

†*Compiled by* : N. Jayanthi, R. R. Lele and S. Sunitha Devi, Meteorological Office, Pune – 411 005, India

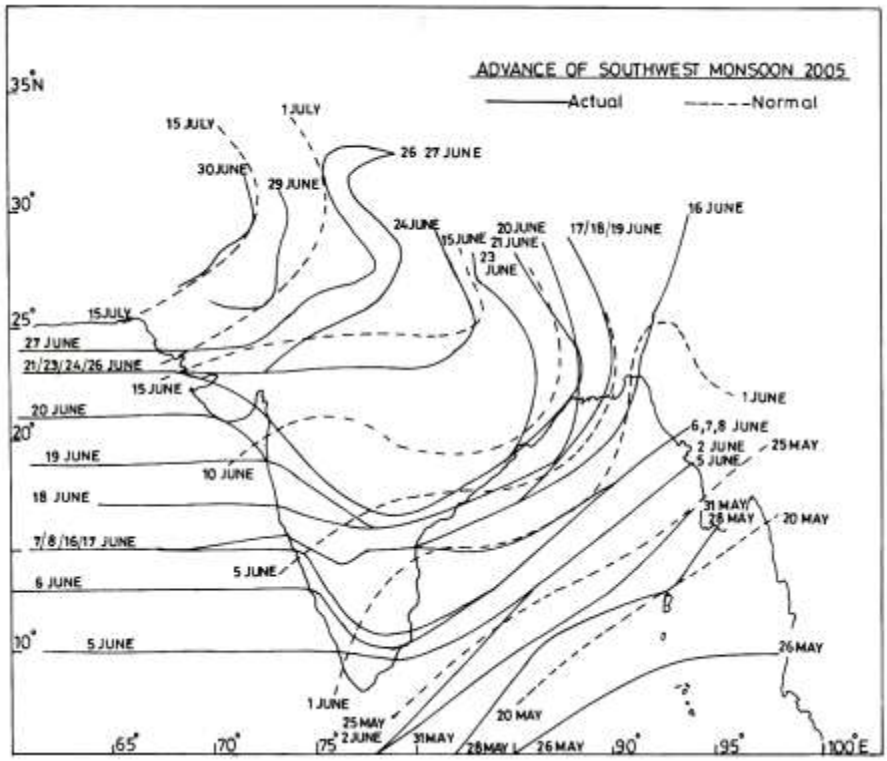


Fig. 1. Isochrones of advance of southwest monsoon 2005

gradient also started strengthening. All the above features resulted in an enhanced cross equatorial flow, increased rainfall activity and hence the subsequent advance over the country during 16-30 June was quite rapid. Monsoon covered the entire country on 30 June, 15 days prior to the normal date, inspite of its behind schedule onset and a hiatus of 7 days. During the period 1960-2005, there had been 8 such occasions (*viz*., 1960, 1961, 1975, 1980, 1994, 1996, 1998 & 2005) in which monsoon covered the entire country on or before 30 June. Fig. 1 gives the isochrones of advance and Table 1 gives the dates of covering different areas.

3.2. *Weekly rainfall distribution*

3.2.1. *Week by week rainfall*

Meteorological sub-divisionwise weekly rainfall departures (percentage departure from normal rainfall) during the southwest monsoon season comprising of 18 weeks (1 June to 30 September) are given in Fig. 2(a).

Rainfall activity was very much subdued during the first three weeks of June. It picked up from the 4th week of June and continued to be good till the end of July. But rainfall was *scanty* over Gujarat region and Saurashtra & Kutch during the period 7 to 27 July. There was considerable reduction in rainfall activity from 28 July till the first week of September. Prolonged break like conditions during the whole of August caused the deficiency. During the period, though northeast India received good rainfall, typical of break conditions, sub-divisions like Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura and Sub-Himalayan West Bengal & Sikkim were *deficient* during a few weeks. West Rajasthan remained mainly dry during 25 August to 7 September and many of the sub-divisions over northwest, north and central India received *scanty* rainfall during most of the weeks of August. Rainfall was good during September except over northeast India and southern most peninsular India, where it remained *deficient* or *scanty* for a few weeks.

3.2.2. *Weekly cumulative rainfall distribution*

Meteorological sub-divisionwise cumulative rainfall departures (percentage departure from normal) during the season from 1 June to 30 September, comprising of 18 weeks are given in Fig. 2(b).

Until the week ending on 22 June, the cumulative rainfall over all the sub-divisions other than those of the

TABLE 1

Advance of southwest monsoon 2005

Date	SW monsoon advanced over	Remarks
26 May	South Andaman Sea and parts of southeast Bay of Bengal	Delayed advance
28 May	Some parts of southwest Bay of Bengal, some more parts of southeast Bay of Bengal and entire Andaman Sea	A week's delay
31 May	East–central Bay and some more parts of south Bay	Do
2 June	Some more parts of southwest Bay, entire southeast Bay, parts of west–central Bay, some more parts of east–central Bay and parts of northeast Bay	3-4 days delay
5 June	Some parts of south Arabian Sea, southern parts of Kerala and Tamil Nadu and some more parts of southwest Bay	Onset took place over Kerala with a delay of 4 days
6 June	Entire south Arabian Sea, parts of central Arabian Sea, entire Kerala, extreme south Karnataka and some more parts of Tamil Nadu, southwest Bay, central and northeast Bay	Near normal date
7 June	Some more parts of central Arabian Sea, most parts of coastal Karnataka, some more parts of south interior Karnataka, Tamil Nadu and southwest Bay	Do
8 June	Some more parts of east central Arabian Sea, Goa, entire coastal Karnataka, most parts of south interior Karnataka, Tamil Nadu, parts of Rayalaseema and southern parts of coastal Andhra Pradesh, entire southwest Bay and some more parts of central Bay	3 – 4 days ahead of normal
16 June	Some more parts of west–central Bay, north Bay, entire east–central Bay, most parts of north Bay and parts of Nagaland-Manipur-Mizoram-Tripura, parts of Assam & Meghalaya and Arunachal Pradesh	Hiatus in the northern limit during 9 to 15. Advance took place with the advance of the Bay branch over extreme eastern parts
17 June	Some parts of west–central and north Bay, entire Nagaland-Manipur-Mizoram-Tripura, Arunachal Pradesh, Assam & Meghalaya and parts of Sub-Himalayan West Bengal & Sikkim	About 12 days delay
18 June	Some more parts of central Arabian Sea, parts of Konkan & Goa, south Madhya Maharashtra, north interior Karnataka, entire Rayalaseema, parts of Telangana, coastal Andhra Pradesh, some more parts of west-central and northwest Bay	Do
19 June	Most parts of central Arabian Sea, Konkan & Goa, some more parts of Madhya Maharashtra and of north interior Karnataka	About 2 weeks delay over the peninsular region
20 June	Entire central Arabian Sea, parts of north Arabian Sea, southern most parts of Saurashtra & Kutch, some more parts of northwest Bay, parts of Gangetic West Bengal, and entire Sub-Himalayan West Bengal & Sikkim	10-15 days delay
21 June	Some more parts of north Arabian Sea, Saurashtra & Kutch, some parts of Gujarat Region, some more parts of Madhya Maharashtra, north interior Karnataka, Telangana, coastal Andhra Pradesh, some parts of coastal Orissa, entire north Bay, some more parts of Gangetic West Bengal and some parts of Bihar	Do
23 June	Entire Gangetic West Bengal, some more parts of Orissa, Bihar and some parts of Jharkhand and east Uttar Pradesh	A week's delay
24 June	Some more parts of Gujarat State, entire Maharashtra State, Telangana, parts of Madhya Pradesh, entire Chattisgarh, Orissa, Jharkhand, Bihar and some more parts of east Uttar Pradesh	Near normal date
26 June	Some more parts of Gujarat state, some parts of southeast Rajasthan, most parts of west Madhya Pradesh, parts of west Uttar Pradesh, entire east Madhya Pradesh, east Uttar Pradesh, Uttaranchal and parts of Himachal Pradesh	4 days ahead
27 June	Most parts of Arabian Sea, Gujarat State, entire west Madhya Pradesh, west Uttar Pradesh, most parts of east Rajasthan, parts of Haryana, some parts of Punjab and some more parts of Himachal Pradesh	Do
29 June	Entire Arabian Sea, Gujarat State, east Rajasthan, parts of west Rajasthan, entire Haryana, Punjab, Himachal Pradesh and Jammu & Kashmir	A week ahead
30 June	Covered the entire country	Covered the entire country 15 days prior in spite of the hiatus

Week by week rainfall during SW Monsoon 2005

1 June – 30 September 2005

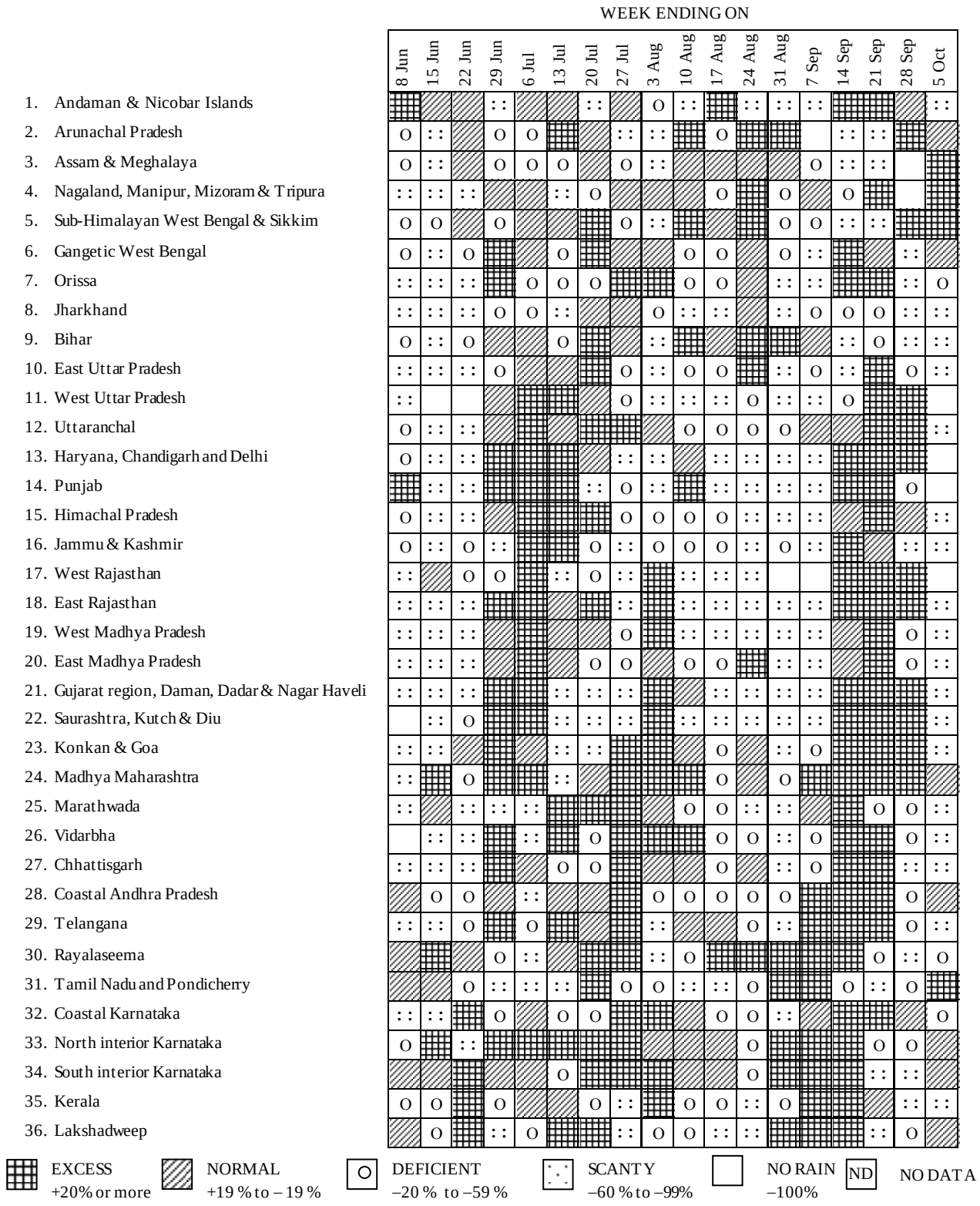


Fig. 2(a). Week by week rainfall during SW Monsoon 2005

Week by week cumulative rainfall

1 June – 30 September 2005

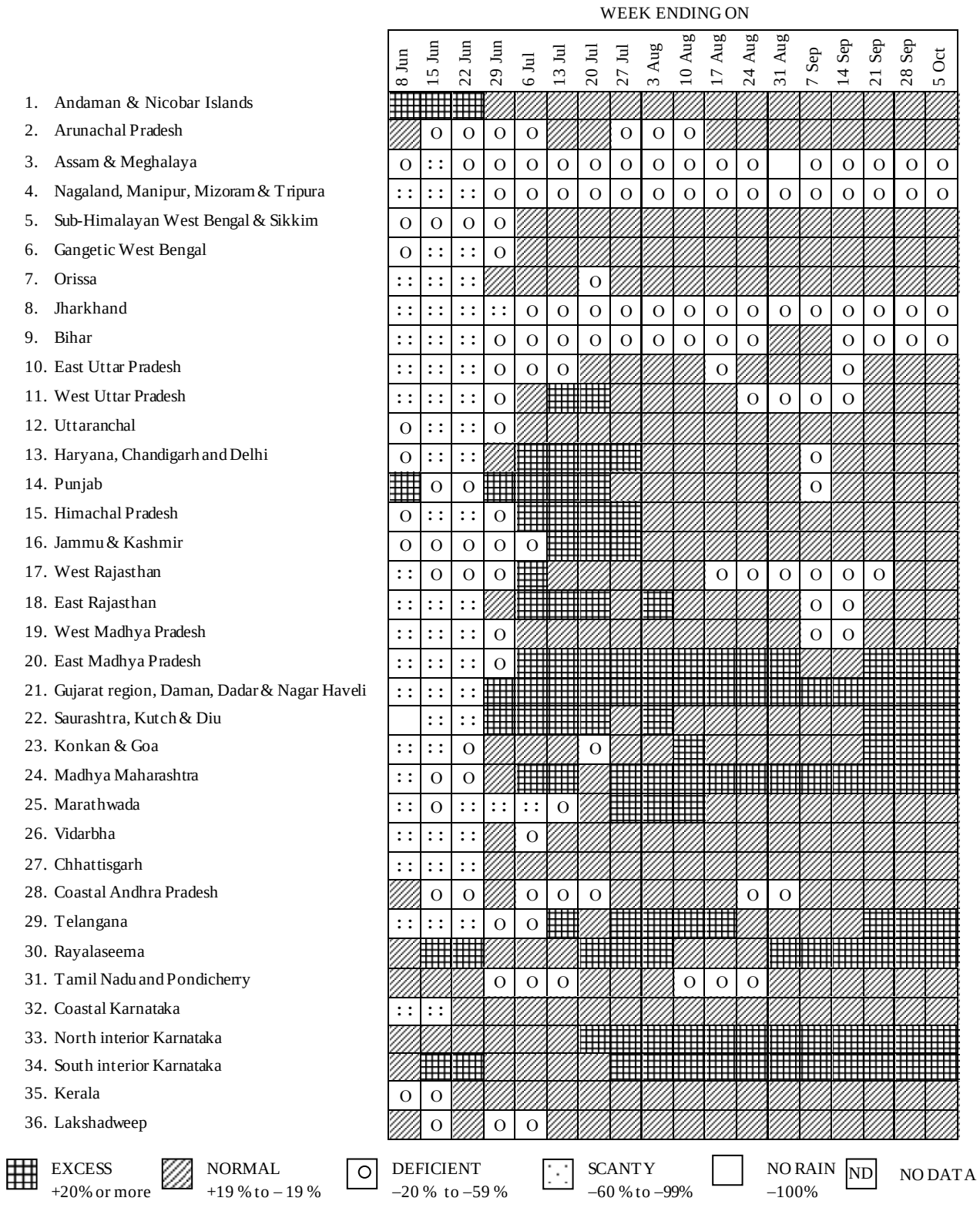


Fig. 2(b). Week by week cumulative rainfall during SW monsoon 2005 (1 June to 30 September 2005)

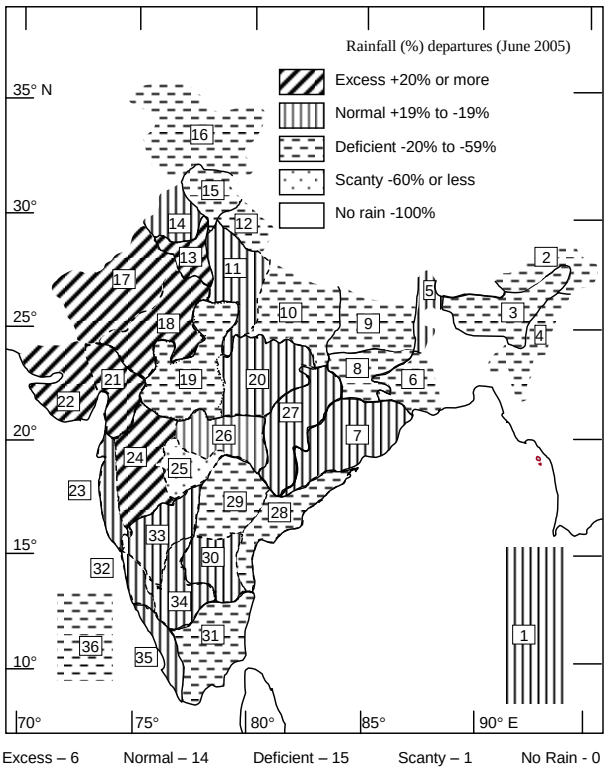


Fig. 3. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (June 2005). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–2	**7**	0	**13**	39	**19**	–24	**25**	–64	**31**	–34
2	–43	**8**	–42	**14**	14	**20**	4	**26**	–10	**32**	–10
3	–38	**9**	–51	**15**	–41	**21**	228	**27**	5	**33**	–2
4	–54	**10**	–36	**16**	–51	**22**	139	**28**	–22	**34**	14
5	–18	**11**	–11	**17**	24	**23**	7	**29**	–26	**35**	–6
6	–26	**12**	–43	**18**	20	**24**	49	**30**	–1	**36**	–24

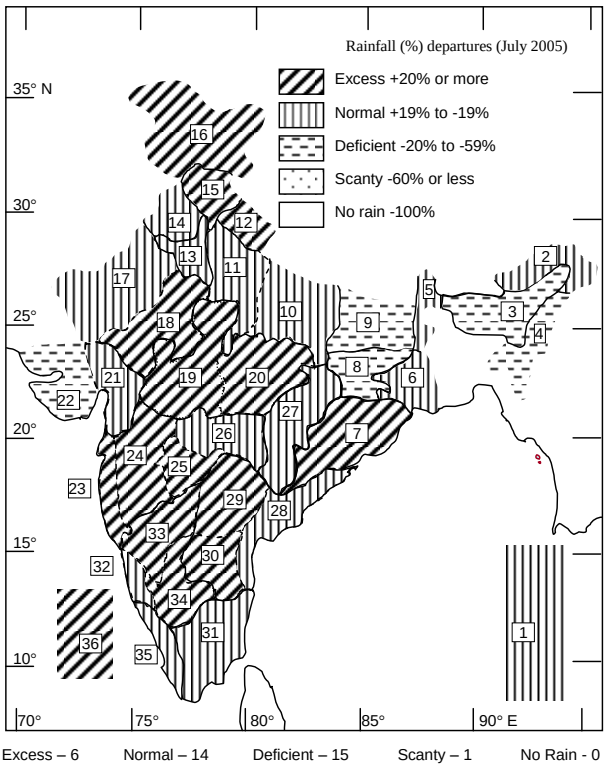


Fig. 4. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (July 2005). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–17	**7**	21	**13**	16	**19**	24	**25**	35	**31**	2
2	0	**8**	–25	**14**	6	**20**	76	**26**	19	**32**	–5
3	–22	**9**	–22	**15**	27	**21**	7	**27**	–11	**33**	78
4	–26	**10**	0	**16**	35	**22**	–27	**28**	–5	**34**	45
5	4	**11**	16	**17**	–14	**23**	23	**29**	64	**35**	16
6	9	**12**	27	**18**	21	**24**	35	**30**	45	**36**	35

southern peninsula and Islands remained to be either *scanty* or *deficient*. Later on, even with the *excess* rainfall during July, the 3 sub-divisions which turned out to be *deficient* by the end of the season, had remained so, almost continuously throughout the season. The met. sub-divisions *viz*., Nagaland-Manipur-Mizoram-Tripura and Jharkhand remained *deficient* throughout the season (on real time basis). Assam & Meghalaya became *normal* only once (for the week ending on 31 August) and Bihar twice (for the weeks ending on 31 August and 7 September) during the season.

3.3. *Monthly rainfall distribution*

Figs. 3 – 6 show monthwise distribution of monsoon rainfall. Sub-divisionwise rainfall figures and departures for each month and season as a whole, are given in Table 2.

3.4. *Seasonal rainfall distribution*

Meteorological sub-divisionwise seasonal rainfall distribution in terms of percentage departures from normal is given in Fig. 7 and in Table 2. The seasonal rainfall was *normal* in 25, *excess* in 8 and *deficient* in the remaining 3 met. sub-divisions.

3.5. *Districtwise distribution of monsoon rainfall*

Seventy two percent of the districts received *excess* / *normal* rainfall and the rest 28% received *deficient* /

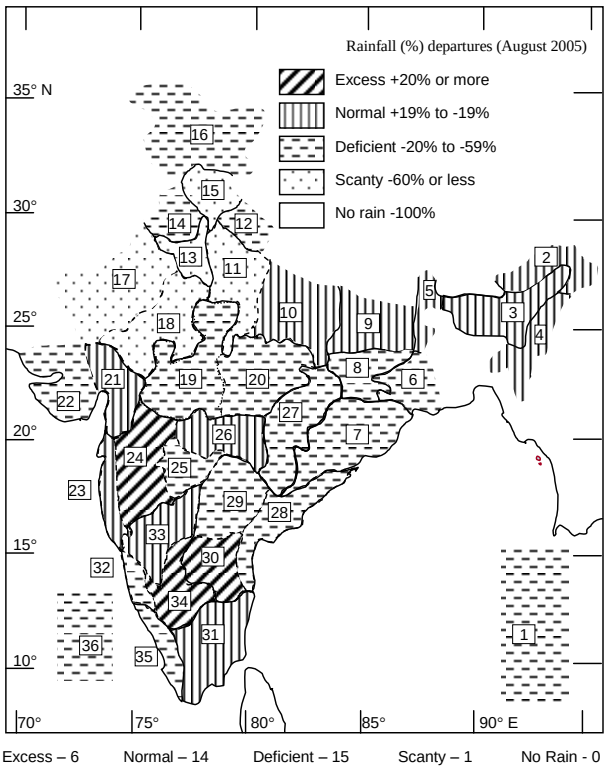


Fig. 5. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (August 2005). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–28	**7**	–45	**13**	–67	**19**	–58	**25**	–40	**31**	–11
2	–7	**8**	–35	**14**	–49	**20**	–23	**26**	–17	**32**	–21
3	3	**9**	13	**15**	–66	**21**	–15	**27**	–33	**33**	8
4	–14	**10**	–19	**16**	–39	**22**	–54	**28**	–37	**34**	34
5	10	**11**	–67	**17**	–73	**23**	5	**29**	–33	**35**	–33
6	–24	**12**	–36	**18**	–64	**24**	27	**30**	26	**36**	–52

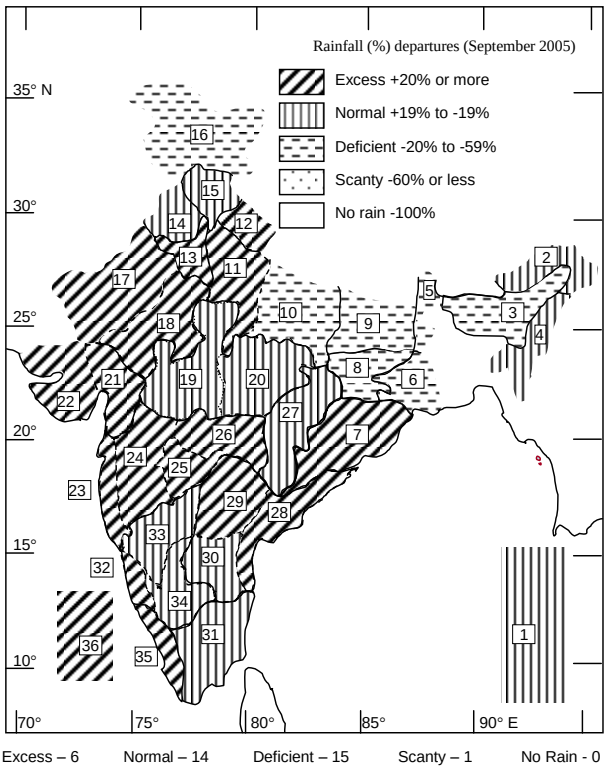


Fig. 6. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (September 2005). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–1	**7**	45	**13**	85	**19**	–6	**25**	25	**31**	1
2	–16	**8**	–41	**14**	8	**20**	2	**26**	41	**32**	24
3	–55	**9**	–54	**15**	15	**21**	120	**27**	16	**33**	7
4	6	**10**	–32	**16**	–26	**22**	233	**28**	88	**34**	5
5	–32	**11**	49	**17**	85	**23**	104	**29**	84	**35**	66
6	–20	**12**	87	**18**	53	**24**	75	**30**	11	**36**	69

scanty rainfall during the period 1 June – 30 September 2005.

Percentage of districts with *excess*/*normal*, and *deficient*/*scanty* rainfall for the years 2000-05 are given in Table 3.

3.6. *Withdrawal of southwest monsoon*

A prolonged absence of rainfall and change of circulation pattern resulted in the withdrawal of southwest monsoon from the extreme west Rajasthan on 2 September, near about the normal date (1 September). Subsequent rapid reversal back to the monsoon flow pattern delayed the further withdrawal till 27 September. Monsoon started steadily withdrawing from the northwestern parts of the country from 28 September onwards and withdrew from entire northwest India by 1 October. Further withdrawal was systematic but rapid. By 10 October, it withdrew from most parts of northeast and central India. Subsequently on 11 October, it withdrew from the remaining parts of northeast and peninsular India and thus from the entire country, the Bay of Bengal and the Arabian Sea. Fig. 8 gives the isochrones of withdrawal of southwest monsoon.

3.7. *El-Nino phenomenon*

The combined oceanographic and atmospheric phenomena, ENSO which is a result of El Nino, the oceanographic phenomenon indicating the anomalous rise in sea surface temperatures over the east Pacific and a seesaw relationship between sea level pressure over the southeastern Pacific Ocean and the Indian Ocean (the

TABLE 2

Rainfall figures* (mm) for each month and season as a whole (June – September 2005)

S. No.	Meteorological sub – divisions	June			July			August			September			Season		
		Actual (mm)	Normal (mm)	Dep. (%)	Actual (mm)	Normal (mm)	Dep. (%)	Actual (mm)	Normal (mm)	Dep. (%)	Actual (mm)	Normal (mm)	Dep. (%)	Actual (mm)	Normal (mm)	Dep. (%)
1.	A. & N. Islands	471	482	–2	348	419	–17	301	416	–28	434	438	–1	1555	1755	–11
2.	Arunachal Pradesh	283	494	–43	595	595	0	363	388	–7	301	358	–16	1541	1835	–16
3.	Assam & Meghalaya	350	567	–38	440	563	–22	445	434	3	144	321	–55	1379	1885	–27
4.	Naga., Mani., Mizo. and Tripura	167	361	–54	256	345	–26	267	309	–14	240	226	6	931	1241	–25
5.	S. H. W. B. & Sikkim	406	496	–18	628	602	4	516	470	10	262	388	–32	1812	1955	–7
6.	Gangetic West Bengal	177	240	–26	342	315	9	239	312	–24	216	270	–20	974	1136	–14
7.	Orissa	205	205	0	414	343	21	199	363	–45	360	248	45	1178	1160	2
8.	Jharkhand	112	193	–42	255	338	–25	215	329	–35	143	244	–41	725	1105	–34
9.	Bihar	86	175	–51	273	348	–22	337	298	13	105	227	–54	801	1048	–24
10.	East Uttar Pradesh	67	105	–36	309	309	0	244	301	–19	135	198	–32	755	914	–17
11.	West Uttar Pradesh	61	69	–11	312	268	16	93	286	–67	223	150	49	690	773	–11
12.	Uttaranchal	94	164	–43	542	425	27	274	426	–36	387	207	87	1297	1223	6
13.	Haryana, Chandigarh & Delhi	60	43	39	198	171	16	55	168	–67	164	89	85	477	470	1
14.	Punjab	47	42	14	200	189	6	87	169	–49	111	102	8	445	502	–11
15.	Himachal Pradesh	53	90	–41	366	288	27	89	262	–66	155	134	15	662	774	–14
16.	Jammu & Kashmir	29	59	–51	252	186	35	106	174	–39	71	95	–26	456	514	–11
17.	West Rajasthan	33	27	24	87	102	–14	26	94	–73	75	41	85	221	263	–16
18.	East Rajasthan	74	61	20	273	224	21	84	233	–64	161	105	53	591	624	–5
19.	West Madhya Pradesh	82	108	–24	379	305	24	132	315	–58	165	177	–6	757	904	–16
20.	East Madhya Pradesh	150	144	4	652	371	76	293	382	–23	205	201	2	1299	1097	18
21.	Gujarat region	402	123	228	385	361	7	246	291	–15	351	160	120	1384	934	48
22.	Saurashtra & Kutch	194	81	139	141	195	–27	63	138	–54	239	72	233	637	486	31
23.	Konkan & Goa	725	675	7	1317	1069	23	750	712	5	708	347	104	3500	2802	25
24.	Madhya Maharashtra	200	134	49	322	238	35	224	176	27	265	151	75	1011	700	44
25.	Marathwada	52	144	–64	388	192	102	117	194	–40	219	174	25	776	704	10
26.	Vidarbha	151	167	–10	391	329	19	248	300	–17	254	180	41	1044	976	7
27.	Chattisgarh	198	189	5	351	394	–11	261	391	–33	270	232	16	1081	1206	–10
28.	Coastal Andhra Pradesh	77	99	–22	151	160	–5	97	154	–37	305	162	88	630	575	10
29.	Telangana	100	135	–26	398	242	64	146	218	–33	315	171	84	959	767	25
30.	Rayalaseema	60	60	–1	132	91	45	123	97	26	147	132	11	462	381	21
31.	Tamil Nadu	28	42	-34	72	71	2	81	90	–11	114	113	1	294	316	–7
32.	Coastal Karnataka	814	901	–10	1127	1188	–5	603	767	–21	395	318	24	2939	3174	–7
33.	North interior Karnataka	96	98	–2	225	126	78	123	113	8	164	153	7	608	491	24
34.	South interior Karnataka	150	132	14	328	225	45	221	164	34	145	137	5	841	659	28
35.	Kerala	635	678	–6	877	758	16	301	447	–33	431	260	66	2245	2143	5
36.	Lakshadweep	249	326	–24	382	282	35	102	213	–52	278	164	69	1011	985	3

* Figures less than 0.5 mm are rounded off to zero.

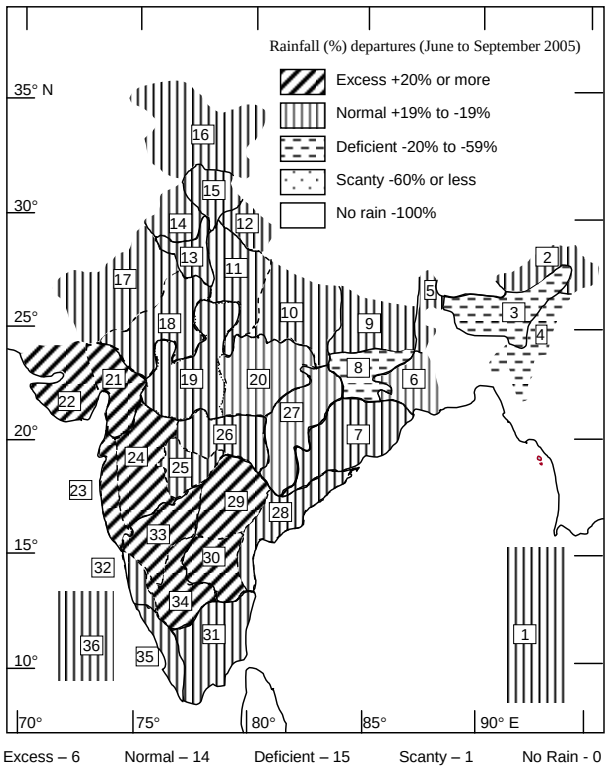


Fig. 7. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (June - September 2005). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–11	**7**	2	**13**	1	**19**	–16	**25**	10	**31**	–7
2	–16	**8**	–34	**14**	–11	**20**	18	**26**	7	**32**	–7
3	–27	**9**	–24	**15**	–14	**21**	48	**27**	–10	**33**	24
4	–25	**10**	–17	**16**	–11	**22**	31	**28**	10	**34**	28
5	–7	**11**	–11	**17**	–16	**23**	25	**29**	25	**35**	5
6	–14	**12**	6	**18**	–5	**24**	44	**30**	21	**36**	3

TABLE 3

Districtwise distribution of monsoon rainfall for the years 2000 - 05

Years	Excess/Normal	Deficient/Scanty
2000	65	35
2001	68	32
2002	39	61
2003	75	25
2004	56	44
2005	72	28

TABLE 4

SST anomaly indices (ENSO)

Month	Pacific SST A (°C) Nino 1+2 0° - 10° S 90° - 80° W	Nino 3 5° N - 5° S 150° - 90° W	Nino 4 5° N - 5° S 60° E - 150° W	SOI
Oct 2004	0.0	0.4	1.1	-0.3
Nov 2004	0.3	0.5	1.2	-0.9
Dec 2004	0.1	0.7	1.1	-1.1
Jan 2005	-0.1	0.3	1.1	0.3
Feb 2005	-0.6	-0.2	0.8	-4.1
Mar 2005	-0.9	-0.1	0.8	-0.2
Apr 2005	-0.6	0.3	0.5	-1.0
May 2005	0.1	0.4	0.5	-1.2
Jun 2005	-0.5	0.4	0.6	0.1
Jul 2005	-0.6	0.4	0.5	0.0
Aug 2005	-0.2	0.2	0.4	-0.8
Sep 2005	-0.8	-0.3	0.4	0.4

Southern Oscillation (SO)), the atmospheric response to the El Nino, during some years indicate an inverse relationship with the Indian summer monsoon rainfall. The phase and magnitude of the ENSO can be indicated either by the sea surface temperature (SST) anomalies over the Pacific or by Southern Oscillation Index (SOI) expressed as the difference in atmospheric surface pressure between Tahiti, an island station in the southeast Pacific Ocean and Darwin, Australia.

Table 4 depicts the monthly values of SST anomaly indices for NINO 4, NINO3 and NINO 1+2 regions and SOI for the period from October 2004 to September 2005. The NINO 1+2 index showed slight cooling from the beginning of the year until the end of monsoon season. The NINO 4 index also showed steady cooling from October 2004 to September 2005. The NINO 3 index showed cooling from October 2004 to March 2005 and warming thereafter till August 2005. The SOI had been –4.1 in February 2005.

4. Chief synoptic features of southwest monsoon

The synoptic disturbances which affected the Indian monsoon region in June, July, August and September are given in Tables, 5, 6, 7 and 8 respectively.

4.1. *Cyclonic storms/depressions*

During the season, one cyclonic storm (this is the first monsoon system intensifying into a cyclonic storm during September, over the Bay after 1997) and 5 depressions formed during the season; two each over the Bay of Bengal and the Arabian Sea and one, a land

TABLE 5

Details of the low pressure systems for the month of June 2005

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Depressions*						
1.	Depression	21–22	Northeast Arabian Sea and adjoining Saurashtra & Kutch	Northwest	Northeast Arabian Sea	It formed under the influence of an upper air cyclonic circulation which moved northwards along the offshore trough during 5 to 20
2.	Do	27 Jun (eve) – 5 Jul	Gangetic West Bengal, close to Kolkata	West-northwest	Northwest Madhya Pradesh, close to Nowgong	It moved very slowly along the monsoon trough and gave rise to very heavy rainfall. It weakened into a well–marked low pressure area over northwest Madhya Pradesh and neighbourhood on 6; low pressure area over west Rajasthan and neighbourhood on 8 and became less marked on 9
(**B**) *Low pressure areas*						
1.	Low pressure area	30 Jun – 1 Jul (eve)	West Madhya Pradesh and adjoining east Rajasthan	Stationary	–	It formed under the influence of an upper air cyclonic circulation present from 26 June onwards
(**C**) *Upper air cyclonic circulation*						
1.	Between 3.1 and 5.8 kms a.s.l.	5 – 20	Lakshadweep area	North	Off north Maharashtra–south Gujarat coast	Under its influence, the first depression of the season formed
2.	Between 3.1 and 7.6 kms a.s.l.	15 – 20	Northeast Bay and neighbourhood	Stationary	*In situ*	Became less marked on 21
3.	Between 3.1 and 5.8 kms a.s.l.	9 – 18	West–central and adjoining southwest Bay off south Andhra–north Tamil Nadu coasts	North	Coastal Andhra Pradesh and neighbourhood	Became less marked on 19
4.	Do	21 – 23	West–central Bay	Northwest	Off north Andhra–south Orissa coasts	Became less marked on 24
5.	Do	24 Jun – 3 Jul	Saurashtra & Kutch and neighbourhood	Quasi-stationary	Gujarat state and neighbourhood	Causing flooding in Gujarat
(**D**) *Systems in westerlies*						
1.	Upper air cyclonic circulation upto mid tropospheric levels	4 – 9	North Pakistan and adjoining Jammu & Kashmir	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 10
2.	Lower tropospheric levels	7 – 8	Northwest Rajasthan and adjoining Punjab	Northeast	Punjab and neighbourhood	Became less marked on 9
3.	Trough in lower and mid tropospheric levels	10 – 15	Long. 90° E, north of Lat. 20° N	Quasi–stationary	Sub-Himalayan West Bengal & Sikkim to northwest Bay	Became less marked on 16
4.	Upper air cyclonic circulation upto mid tropospheric levels	9 eve – 15	North Pakistan and adjoining Jammu & Kashmir	Northeast	Jammu & Kashmir and neighbourhood	Moved away on 16
5.	Do	16 – 19	Do	Do	Do	Moved away on 20
6.	Do	22 – 29	Do	Do	Do	Moved away on 30
(**E**) *Trough of low*						
1.	At sea level	8 – 14	East–central Bay and adjoining north Andaman Sea	Quasi–stationary	Northeast to southeast Bay	It aligned with the sea level (seasonal) trough on 15
(**F**) *Other troughs*						
1.	East–west trough at sea level	4 – 29	West Madhya Pradesh to northwest Bay	Oscillatory	Established as the monsoon trough on 30	Persisted over the northern plains during 4 to 8 and 15 to 30

TABLE 6

Details of the low pressure systems for the month of July 2005

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Depression*					
1.	Deep Depression	29 – 31	Northwest Bay close to Balasore	Westnorthwest	Central parts of Madhya Pradesh	Formed as a low pressure area over northwest Bay and adjoining coastal areas of Gangetic West Bengal and Orissa on 28. Intensified into a Deep Depression on 30. Moved fast and weakened rapidly. Moved as a low pressure area upto southeast Rajasthan and merged with the heat low on 3 August
(**B**)	*Low pressure areas*					
1.	Low pressure area	7 – 9	Northwest and adjoining west–central Bay off Orissa–West Bengal coasts	Westnorthwest	Orissa and neighbourhood	Formed under the influence of and upper air cyclonic circulation. Moved inland as a feeble low pressure area and became less marked. But the associated upper air cyclonic circulation moved westnorthwestwards initially, upto Chattisgarh, which then moved over to Jharkhand and became less marked on 16
2.	Well–marked low pressure area	23 – 28	North Bay and neighbourhood	Westnorthwest	West Madhya Pradesh and neighbourhood	Formed under the influence of an upper air cyclonic circulation over north Bay. Caused the revival of rainfall over the Peninsula. Became well–marked on 24. The associated cyclonic circulation merged with that of the depression on 1 August
(**C**)	*Upper air cyclonic circulation*					
1.	Upto mid tropospheric levels	4 – 5	Southern parts of Bangla Desh and adjoining areas of Gangetic West Bengal and north Bay	West	Gangetic West Bengal and neighbourhood	Became less marked on 6
2.	Do	12 – 17	West Uttar Pradesh and neighbourhood	Westnorthwest	Northeast Rajasthan and neighbourhood	Became less marked on 18
3.	Between 1.5 and 5.8 kms a.s.l.	14 – 21	Southwest Bay off south Tamil Nadu–Sri Lanka coasts	West and then northeast	North Madhya Maharashtra and neighbourhood	Became less marked on 22
(**D**)	*Systems in westerlies*					
1.	Cyclonic circulation upto mid tropospheric levels	1 – 4	North Pakistan and adjoining Jammu & Kashmir	Northeast	Jammu & Kashmir and neighbourhood	Moved away on 5
2.	Do	6 – 9	Do	Do	Eastern parts of Jammu & Kashmir	Moved away on 10
3.	Cyclonic circulation upto 3.6 kms a.s.l.	9 – 20	Northwest Rajasthan and neighbourhood	Quasi–stationary	*In situ*	Became less marked on 21
4.	Cyclonic circulation upto mid tropospheric levels	10 – 12	North Pakistan and neighbourhood	Do	Jammu & Kashmir and neighbourhood	Moved away on 13
5.	Do	15 – 20	North Pakistan and adjoining Jammu & Kashmir	Northeast	Do	Moved away on 21
6.	Do	21 eve – 22	Jammu & Kashmir and neighbourhood	– do –	Do	Moved away on 23
7.	Do	23 – 25	North Pakistan and adjoining Jammu & Kashmir	Eastnortheast	Jammu & Kashmir and neighbourhood	Moved away on 26
8.	Do	27 – 28	North Pakistan, adjoining Jammu & Kashmir and Punjab	Northeast	Do	Moved away on 29

TABLE 7

Details of the low pressure systems for the month of August 2005

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.	Well–marked low pressure area	3 – 4	Northwest Bay and adjoining coastal areas of Gangetic West Bengal and Bangla Desh	West	Northern parts of Chattisgarh and neighbourhood	Formed as an upper air cyclonic circulation over North Bay. Became less marked on 5. The associated cyclonic circulation became less marked on 7
(**B**)	*Upper air cyclonic circulation*					
1.	Upto mid tropospheric levels	8 – 12	Northeast Bay	Northnorthwest	Gangetic West Bengal and adjoining Bangla Desh	It formed in a trough in the lower and mid tropospheric westerlies
2.	Upto 7.6 kms a.s.l.	12 – 18	North and adjoining west–central Bay off Orissa–north Andhra coasts	Westnorthwest	Central parts of Uttar Pradesh	Became less marked on 19
3.	Upto mid tropospheric levels	17 – 24	Northeast and adjoining east–central Bay	Initially northwest and then oscillatory	Bihar and Jharkhand	It was seen as a trough in the westerlies over the region during 25–27
4.	Between 2.1 and 4.5 kms a.s.l.	13 – 21	Gujarat State and neighbourhood	Quasi–stationary	*In situ*	Became less marked on 22
5.	Between 2.1 and 5.8 kms a.s.l.	23 Aug – 1 Sep	Gujarat region	Do	North Gujarat and adjoining south Rajasthan	It was a feeble mid tropospheric cyclonic circulation. Became less marked on 2 September
6.	Upto mid tropospheric levels	23 – 24	South Tamil Nadu	West	Lakshadweep–Maldives areas	Became less marked on 25
7.	Do	30 Aug – 3 Sep	Central parts of Bay	Do	West–central Bay off Andhra coast	Became less marked on 4 September
8.	Between 3.1 and 4.5 kms a.s.l.	26 – 29	Southwest Bay off Tamil Nadu coast	Do	Southeast Arabian Sea	Became less marked on 30
9.	Between 2.1 and 4.5 kms a.s.l.	31 Aug – 7 Sep	Southeast Arabian Sea and adjoining Lakshadweep area	Northnortheast	East–central and adjoining southeast Arabian Sea and costal Karnataka	Became less marked on 8 September
(**C**)	*Systems in westerlies*					
1.	Cyclonic circulation upto mid tropospheric levels	1 – 8	North Pakistan and adjoining Jammu & Kashmir and Punjab	Eastnortheast	Jammu & Kashmir and neighbourhood	Moved away on 9
2.	Do	6 – 15	Do	Northeast	Do	Moved away on 16
3.	Do	16 – 18	North Pakistan and adjoining Jammu & Kashmir	Do	Do	Moved away on 19
4.	Do	19 – 21	North Pakistan and adjoining Punjab and Jammu & Kashmir	Do	Do	Moved away on 22
5.	Trough at 5.8 kms a.s.l.	21	Along Long. 76° E, north of Lat. 27° N	Stationary	*In situ*	Became less marked on 22
6.	Cyclonic circulation upto mid tropospheric levels	22 – 26	North Pakistan and adjoining Jammu & Kashmir	Northeast	Jammu & Kashmir and neighbourhood	Moved away on 27
7.	Do	27 Aug – 1 Sep	Do	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 2 September

TABLE 8

Details of the low pressure systems for the month of September 2005

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**) *Cyclonic storm*						
1.	Cyclonic Storm	17 – 21	Northeast Bay	Initially Westsouthwest and then westnorthwest (after crossing the coast)	North Madhya Maharashtra and adjoining south Gujarat and neighbourhood	The system was steered westsouthwestwards initially by strong northeasterlies. Crossed north Andhra coast near Kalingapatnam. It caused floods in Andhra Pradesh by remaining over there till 2100 UTC of 19. Other details of this system are given in the text
(**B**) *Depressions*						
1.	Depression	12 – 16	Northwest Bay	Westnorthwest	West Uttar Pradesh and neighbourhood	Gave rise to heavy to very heavy rainfall all along its track till dissipation. Details of this system are given in the text
2.	Do	14 – 17	East–central and adjoining northeast Arabian Sea	Northnorthwest and then east	North Gujarat and adjoining parts of Rajasthan	It formed under the influence of the remnant circulation of the low pressure area which dissipated over Andhra Pradesh and neighbourhood. Other details of the system are given in the text
(**C**) *Low pressure areas*						
1.	Low pressure area	7 – 8	West–central and adjoining southwest Bay	West	Andhra Pradesh and neighbourhood	It formed under the influence of an upper air cyclonic circulation. Though became less marked on 9, the associated cyclonic circulation moved westwards and caused the formation of the depression over the Arabian Sea
2.	Well–marked low pressure area	24 Sep – 4 Oct	East–central and adjoining west–central Bay	Initially northwest and then east	Sub-Himalayan West Bengal & Sikkim and neighbourhood	It was initially noticed as a trough of low over north Andaman Sea and adjoining Tenasserim coast. The low pressure area became less marked on 5. The associated upper air cyclonic circulation lay over Assam & Meghalaya on 5 & 6 and moved away northeastwards on 7
(**D**) *Upper air cyclonic circulation*						
1.	Between 1.5 and 3.6 kms a.s.l.	26 Sep – 6 Oct	Gujarat State and neighbourhood	Quasi–stationary	Southern parts of Gujarat State and adjoining north Konkan	Became less marked on 7
(**E**) *Systems in westerlies*						
1.	Cyclonic circulation upto mid tropospheric levels	3 – 6	North Pakistan and neighbourhood	Northeast	Northeastern parts of Jammu & Kashmir	Moved away on 7
2.	Do	6 – 12	Central Pakistan and neighbourhood	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 13
3.	Cyclonic circulation between 1.5 and 3.6 kms a.s.l.	10 – 12	North Rajasthan, Punjab and neighbourhood	Northeast	Punjab and adjoining areas of Himachal Pradesh	Became less marked on 13
4.	Cyclonic circulation upto mid tropospheric levels	13 – 14	North Pakistan and adjoining Jammu & Kashmir	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 15

TABLE 8 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	Cyclonic circulation upto 4.5 kms a.s.l.	15 – 20	Central Pakistan and neighbourhood	Northeast	Eastern parts of Jammu & Kashmir	Moved away on 21
6.	Cyclonic circulation upto 3.6 kms a.s.l.	20 – 22	Punjab and neighbourhood	Do	Do	Moved away on 23
7.	Cyclonic circulation upto 3.1 kms a.s.l.	21 – 26	North Rajasthan and neighbourhood	Do	Do	Moved away on 27
8.	Trough in the mid and upper troposphere	21 – 26	Along Long. 71° E, north of Lat. 24° N.	Stationary	*In situ*	Became less marked on 27
9.	Cyclonic circulation upto mid tropospheric levels	27 – 28	North Rajasthan and adjoining Punjab and neighbourhood	Do	Do	Became less marked on 29
10.	Cyclonic circulation upto 4.5 kms a.s.l.	30 Sep – 1 Oct	Jammu & Kashmir and adjoining north Pakistan	Eastnortheast	Jammu & Kashmir and neighbourhood	Moved away on 2 October

depression. The tracks of the systems are shown in Fig. 9. Details are given below :

4.1.1. *Cyclonic storm over the Bay of Bengal (17-21 September 2005)*

A trough of low at sea level over north Andaman Sea organised into a feeble low pressure area over north Andaman Sea and adjoining Arakan coast on 15 and became a low pressure area over east central Bay and adjoining Arakan coast on 16. It concentrated into a depression and lay centred near Lat. 20.0° N / Long. 90.5° E at 0300 UTC of 17 and near Lat. 20.5° N / Long. 90.0° E at 1200 UTC of 17. It intensified into a deep depression near Lat. 20.5° N / Long. 87.5° E at 0300 UTC of 18 and further into a cyclonic storm near Lat. 19.5° N / Long. 86.5° E at 1200 UTC of 18. It crossed north Andhra coast, close to Kalingapatnam around 0230 UTC of 19 and lay centred near: Lat. 18.5° N / Long. 84.0° E over Kalingapatnam at 0300 UTC of 19 and near Lat. 18.5° N / Long. 83.5° E at 1200 UTC of 19. Moving westwards, it weakened into a deep depression at 2100 UTC of 19 and lay centred near Lat. 18.5° N / Long. 83.0° E and lay centred near Jagdalpur at 0300 UTC of 20. It further weakened into a depression and lay centred: close to Ramagundam (Lat. 19.0° N / Long. 80.5° E) at 1200 UTC of 20; near Chandrapur (Lat. 19.5° N / Long. 79.5° E) at 0300 UTC of 21 and near Jalgaon (Lat. 21.0° N / Long. 76.0° E) at 1200 UTC of 21. It subsequently weakened into a well marked low pressure area over north Madhya Maharashtra and adjoining south Gujarat and southwest Madhya Pradesh on 22 morning and lay over west Madhya Pradesh and adjoining southeast Rajasthan and Gujarat Region on 23. Moving northnortheastwards, it further weakened into a low pressure area over southwest Uttar Pradesh and adjoining northeast Rajasthan on 24. It lay over west Uttar Pradesh and adjoining Uttaranchal on 25 and became less marked on 26.

4.1.2. *Depression over the Arabian Sea (21 – 22 June 2005)*

Under the influence of an upper air cyclonic circulation which moved very slowly northwards along the offshore trough during 5 to 20 June, a depression formed over northeast Arabian Sea and adjoining Saurashtra & Kutch, and lay centred close to Porbandar at 0300 UTC of 21. Moving westnorthwestwards, it lay over northeast Arabian Sea, centred near Lat. 22° N / Long. 68° E at 0300 UTC of 22. It weakened into a well marked low pressure area over there on 23 and became less marked on 24.

Though it did not affect the rainfall activity much, it helped in the establishment of an Mid Tropospheric Cyclone (MTC) over Gujarat and the proper positioning of the east-west shear line across the peninsula for subsequent active period to occur.

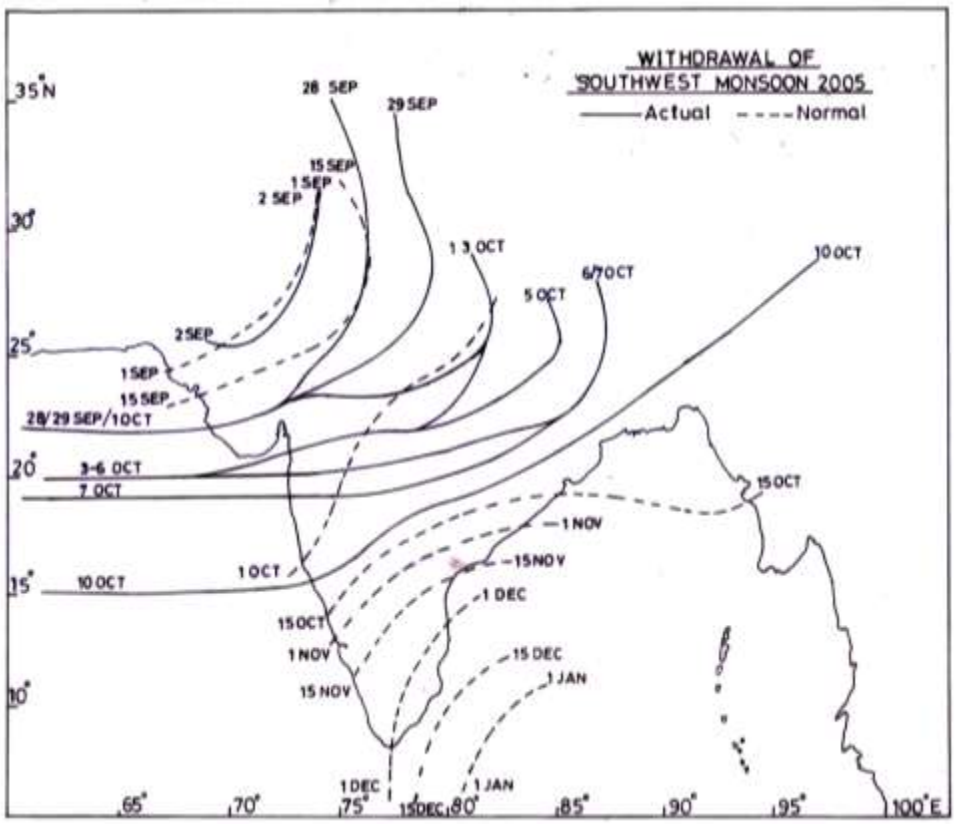


Fig. 8. Isochrones of withdrawal of southwest monsoon

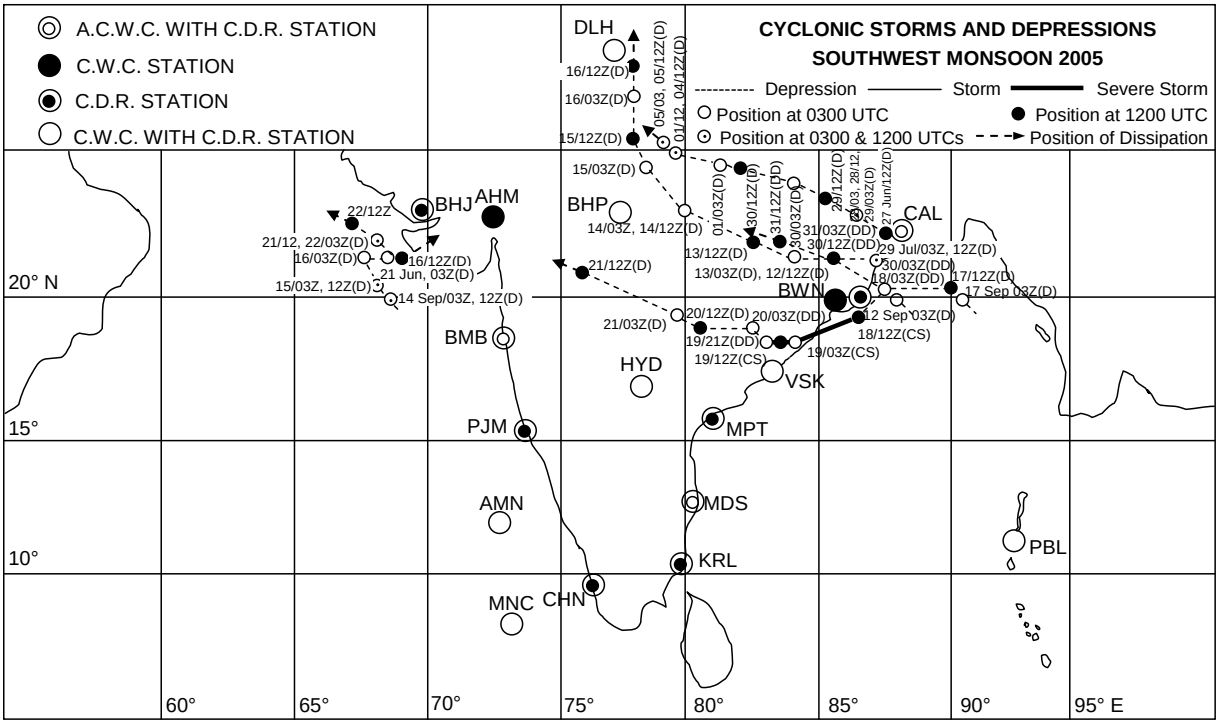


Fig. 9. Tracks of storm and depressions during southwest monsoon 2005

4.1.3. *Depression over the Bay of Bengal (27 June – 5 July 2005)*

Under the influence of an upper air cyclonic circulation over northwest Bay, a low pressure area formed over there on 27 morning, which rapidly moved inland and concentrated into a depression over Gangetic West Bengal and adjoining northwest Bay, close to Kolkata at 1200 UTC of 27. Moving westwards, it lay over Jharkhand, centred near Jamshedpur till 0300 UTC of 29. Subsequently moving in a westnorthwesterly direction, it lay close to Ranchi at 1200 UTC of 29. It lay close to: Daltonganj at 0300 UTC of 30; Sidhi at 1200 UTC of 30 June; Rewa at 0300 UTC of 1 July; Khajuraho from 1200 UTC of 1 to 4 and near Nowgong on 5. It weakened into a well marked low pressure area over northwest Madhya Pradesh and adjoining areas of west Uttar Pradesh and east Rajasthan on 6 morning. It moved over to west Uttar Pradesh and adjoining areas on 7, weakened into a low pressure area over west Rajasthan and neighbourhood on 8 and became less marked on 9.

4.1.4. *Deep depression over northwest Bay off Orissa coast (29 - 31 July)*

A low pressure area formed over northwest Bay and adjoining coastal areas of Gangetic West Bengal and Orissa on 28. It concentrated into a depression on 29 and lay centred close to Balasore till 30 morning when it intensified into a deep depression over there. Moving westwards, it lay over north Orissa, close to Keonjhargarh at 1200 UTC of 30 and 0300 UTC of 31. It lay over Chattisgarh and neighbourhood close to Champa at 1200 UTC of 31. Further moving westnorthwestwards, it rapidly weakened into a well marked low pressure area over central parts of Madhya Pradesh on 1 August and into a low pressure area over west Madhya Pradesh and adjoining southeast Rajasthan on 2. It moved over to southeast Rajasthan and neighbourhood and subsequently merged into the seasonal heat low on 3.

4.1.5. *Depression over northwest Bay (12 – 16 September)*

Under the influence of an upper air cyclonic circulation over west central Bay and adjoining areas of coastal Andhra Pradesh – south Orissa, a low pressure area formed over west central and adjoining northwest Bay off north Andhra – south Orissa coasts on 10. It persisted there on 11, rapidly concentrated into a depression and lay centred at 0300 UTC of 12 near Lat. 20.0° N / Long. 88.0° E. It crossed Orissa coast near Paradip by 0900 UTC of 12 and lay close to Keonjhargarh at 1200 UTC of 12. Moving in a westnorthwesterly direction, it lay close to Jharsuguda and Champa respectively at 0300 & 1200 UTC of 13. Further moving northwestwards, it lay close to Jabalpur at 0300 & 1200 UTC of 14 and about 100 km north of Sagar at 0300 UTC of 15. It subsequently moved northwards and lay close to: Gwalior at 1200 UTC of 15; Agra at 0300 UTC of 16 and about 100 km southeast of Delhi at 1200 UTC of 16. Further moving northwards, it rapidly weakened into a low pressure area over west Uttar Pradesh and neighbourhood on 17 morning and became less marked on 18. However, the associated upper air cyclonic circulation extending upto 1.5 km a.s.l. lay over west Uttar Pradesh and adjoining Uttaranchal on 18 and became less marked on 19.

4.1.6. *Depression over Arabian Sea (14 – 16 September)*

Under the influence of the remnant of a low pressure area, a well marked low pressure area formed over northeast Arabian Sea and adjoining north Konkan - Saurashtra coasts on 11. It lay over south Gujarat region, adjoining north Konkan and northeast Arabian Sea on 12 and over Saurashtra and neighbourhood on 13. Subsequently, it concentrated into a depression over east central and adjoining northeast Arabian Sea and lay centred near Lat. 20.0° N / Long. 68.5° E at 0300 & 1200 UTC of 14. It lay over northeast Arabian Sea near Lat. 20.5° N / Long. 68.0° E at 0300 & 1200 UTC of 15. Moving northnorthwestwards, it lay near Lat. 21.5° N / Long. 67.5° E at 0300 UTC of 16. Then it recurved eastwards and lay centred near Lat. 21.5° N / Long. 69.0° E (about 50 km west of Porbandar) at 1200 UTC of 16. It crossed coast close to Porbandar during the night of 16. Subsequently moving northwards, it rapidly weakened into a low pressure area over northern parts of Gujarat and adjoining Rajasthan on 17 morning. Though it became less marked on 18, the associated upper air cyclonic circulation extending upto 4.5 km a.s.l. lay over: north Gujarat and adjoining areas of south Rajasthan and west Madhya Pradesh on 18; south Gujarat and neighbourhood on 19 & 20 and became less marked on 21.

4.2. *Low pressure areas/well-marked low pressure areas (LPA/WMLPA)*

Altogether 6 low pressure areas / well marked low pressure areas formed during the season. Most of them originated as upper air cyclonic circulations. Except 1, all of them formed over the oceanic area and subsequently moved over to land. Monthwise breakup of the systems are 1 in June, 2 in July, 1 in August and 2 in September. The total number of low pressure areas during the past 5 years *viz*., 2000 to 2005 are 13, 10, 10, 12, 8 & 6 respectively.

TABLE 9(a)

Positions of off-shore troughs during the monsoon period 2005

Date	Location	Date	Location
5 – 6 June	South Karnataka–Kerala coasts	8 – 9 August	Maharashtra to Karnataka coasts
7 – 15 June	South Maharashtra to Kerala coasts (Feeble)	11 – 17 August	Gujarat to north Kerala coasts (feeble)
16 – 19 June	North Maharashtra to Kerala coasts	18 – 21 August	Maharashtra to Karnataka coasts
20 June – 5 July	South Gujarat to Kerala coasts	6 – 7 September	South Gujarat to Kerala coasts
6 – 7 July	Maharashtra to Kerala coasts	10 – 16 September	Gujarat to Kerala coasts
8 July	South Maharashtra to Karnataka coasts	17 September	Gujarat to Karnataka coasts
9 – 10 July	South Maharashtra to Kerala coasts	18 September	Maharashtra to Kerala coasts
11 – 12 July	South Gujarat to Kerala coasts	19 September	Maharashtra to Karnataka coast
13 July	South Gujarat to Karnataka coasts	23 – 24 September	South Gujarat to Kerala coasts (feeble)
14 July – 6 August	Maharashtra to Kerala coasts (active)		

TABLE 9(b)

Details of Off-shore trough from 2000-05

Year	Details of off – shore trough
2005	Present between 5 June to 24 September except during 7 & 10 August, 22 August–5 September, 8–9 September and 20–22 September
2004	Present along different parts of west coast (surface and lower levels) upto 16 September from 19 May except 27 May to 3 June, 8-11 June, 23-24 June and 29 August to 7 September
2003	Present along different parts of west coast (surface and lower levels) observed upto 17 September from 6 June except during 18-21 August, 24-26 August, 4 September, 9-10 September and 12-15 September
2002	Present along different parts of west coast (surface and lower levels) observed upto 17 September except during 4-11 June, 25-31 July, 28-31 August and 14-16 September
2001	Present along different parts of west coast (surface and lower levels) noted upto 13 September except during 1-4 June and 11 September
2000	Present along different parts of west coast (surface and lower levels) persisted on most of the days (From 16 May to 4 September 2000), except for the periods 8-10 June, 16-25 June, 16 July – 7 August, 23-30 August

4.3. *Upper Air Cyclonic Circulations (CYCIR)*

There were 18 upper air cyclonic circulations (in lower and upper tropospheric levels) formed during the season. The monthwise break up of these are 5 in June, 3 in July, 9 in August and 1 in September.

4.4. *Off-shore Trough*

Off-shore trough along different parts of the west coast (surface and lower levels) persisted on most of the days from 5 June to 24 September except during 7 & 10 August, 22 August – 5 September, 8 – 9 September and 20 – 22 September. It was quite feeble on many days during June and August. The details of the position of the Off-shore trough are given in Table 9(a) and that for the years 2000-05 are given in Table 9(b).

4.5. *Eastward moving cyclonic circulations/western disturbances*

There were 28 eastward moving systems as upper air cyclonic circulations. The monthwise break-up is 5 in June, 8 in July, 6 in August and 9 in September.

5. Extra Indian features

5.1. *Cross equatorial flow*

5.1.1. *Over the Bay of Bengal*

The cross equatorial flow was more than normal by about 5 kts in the third week of June and normal during the rest of the month.

TABLE 10

Statistics of mid latitude troughs

Level	June	July	August	September	Total
300 hPa	7	4	3	2	16
500 hPa	5	4	5	3	17

5.1.2. *Over the Arabian Sea*

Cross Equatorial flow was nearly normal (10-12kts) during the monsoon period.

5.2. *Mid-Latitude troughs*

Monthwise break-up of troughs in westerlies found between 60° E – 90° E, reaching upto or south of 30° N is given in Table 10.

There were a total of 17 & 16 mid and upper tropospheric troughs respectively at 500 & 300 hPa during the season.

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

There were in all 15 systems (Tropical depression stage and above) in the northwest Pacific Ocean / South China Sea during June – September 2005. The month wise break-up is shown in Table 11.

5.4. *Systems in southern hemisphere*

5.4.1. *Tropical storms/ depressions*

Not a single tropical storm or depression has formed during June to September 2005 in the South Indian Ocean.

5.4.2. *Mid and upper tropospheric westerly troughs over the Indian Ocean*

There were in all 18 upper air troughs in westerlies (6 each in June & July, 4 in August and 2 in September) 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 2005. (Source: INSAT full disc pictures).

5.4.3. *Mascarene High*

The intensity of Mascarene High pressure at 30° S / 60° E was above normal in September by 2.5 hPa, by 1.0 hPa in June and normal in August. It was below normal by about 1.5 hPa during July. Source (Climate Diagnostic Bulletins, NOAA, June to September 2005, Departures are taken from the 1979 – 95 base period monthly means). The intensity of Mascarene High along with that for the past 5 years, are given in Table 12.

TABLE 11

Statistics of systems in northwest Pacific Ocean/south China Sea during June to September 2005

Weather systems	June	July	August	September	Total
T.D.	0	0	0	0	0
T.S.	0	3	1	1	5
Typhoon	0	2	4	4	10
Total	0	5	5	5	15

5.4.4. *Australian high*

The intensity of Australian high pressure at 30° S / 140° E was above normal in August by 1.5 hPa and normal in July. It was below normal by about 2.5 hPa in the month of September and by 4 hPa in June. Source (Climate Diagnostic Bulletins, June, July, August, September 2005, Departures are taken from the 1979 – 95 base period monthly means). Summary of the intensity of Australian High for the past 5 years are given in Table 13.

6. Semi-permanent systems

6.1. *Heat low*

Heat low made its appearance in its near normal position by 4 June and remained more or less in its normal position (though diffused or even less marked on many days during June & August) until 8 September. The lowest and the second lowest pressure values of the heat low were :

Jun : 988 hPa (on 26) and 990 hPa (on 18 & 19)

Jul : 988 hPa (on 1 & 2) and 990 hPa (on 11)

Aug : 990 hPa (on 1 & 2) and 992 (on 16)

Sep : 996 hPa (on 1) and 997 hPa (on 4, 5 & 6)

Details of the lowest observed isobaric values of the Heat Low during past five years are given in Table 14.

6.2. *Axis of the monsoon trough*

A diffused heat trough made its appearance over the northern plains during 4 to 8 June. Thereafter it gradually

TABLE 12

Intensity of Mascarene High during monsoon season for the years 2000-05

Year	June		July		August		September	
	Pressure (hPa)	Departure (%)	Pressure (hPa)	Departure (%)	Pressure (hPa)	Departure (%)	Pressure (hPa)	Departure (%)
2000	1026	2	1022	-2	1024	0	1023	-1
2001	1023	0	1024	-1	1028	2	1022	-3
2002	1024	2	1027	1.5	1030	4	1024	0.5
2003	1023	– 1.5	1025.5	– 1	1026	– 1	1023.5	3
2004	1028	5	1026	0.5	1026	0	1023	– 0.5
2005	1024	1	1024	-1.5	1026	0	1026	2.5

TABLE 13

Intensity of Australian High during monsoon season for the years 2000-05

Year	June		July		August		September	
	Pressure (hPa)	Departure (%)	Pressure (hPa)	Departure (%)	Pressure (hPa)	Departure (%)	Pressure (hPa)	Departure (%)
2000	1029	8	1024	4	1024	4	1024	5
2001	1020	2	1021	1	1019	– 1	1017	– 1
2002	1022	0	1022	0	1022	1.5	1017	– 1
2003	1022	– 1	1022	1	1020.5	– 1.5	1018	– 2
2004	1022	0	1022	0	1017	– 3.5	1020	2
2005	1018	– 4	1022	0	1022	1.5	1015.5	– 2.5

TABLE 14

Details of lowest observed isobaric values (hPa) of the heat low during past 5 years

Month	Year				
	2000	2001	2002	2003	2004
June	989.0 (13th, 14th, 16th & 25th)	987.0 (20th & 21st)	988.0 (21st & 22nd)	986.0 (7th ,8th & 27th)	990.0 (17th)
July	989.0 (7th)	989.0 (12th)	988.0 (2nd)	990.0 (4th, 9th & 30th)	992.0 (7th)
August	990.0 (30th)	990.0 (29th)	998.0 (11th)	991.0 (9th)	991.0 (2nd)
September	992.0 (1st)	995.0 (5th & 10th)	997.0 (4th)	993.0 (2nd)	998.0 (9th & 10th)

shifted northwards and disappeared from the sea level chart, until a part of it reappeared over the eastern half of the country on 15 June. Subsequently it was well marked during most of the remaining days.

Monsoon trough got established to the south of its normal position on 30 June and remained so till 6 July. Thereafter it remained in the normal position for about a week and started shifting gradually to the north during 14 to 20 July. Subsequently it regained its southward position and remained there until the first week of August. Almost during the whole of August, it remained north of its normal position and many a times (for example 11 & 12 August, 24-27 August) it lay close to the foothills of Himalayas invoking break like conditions. Southwest monsoon started withdrawing from the extreme northwestern parts of the country on 2 September, and thereafter, though low pressure systems formed and provided copious rainfall over the country, the characteristic heat trough was not pronounced at sea level.

For ready comparison, a brief data on monsoon trough in the past five years are given below :

Year	*Axis of monsoon trough*
2000	Established on 2 July. Less marked on 22 September. Break from 1 to 4 August.
2001	Established on 3 July. Less marked on 20 September.
2002	Established on 15 August. Less marked on 16 September.
2003	Established on 5 July. Less marked on 16 September.
2004	Established on 18 July. Less marked on 22 September.

6.3. *Tibetan Anticyclone/High*

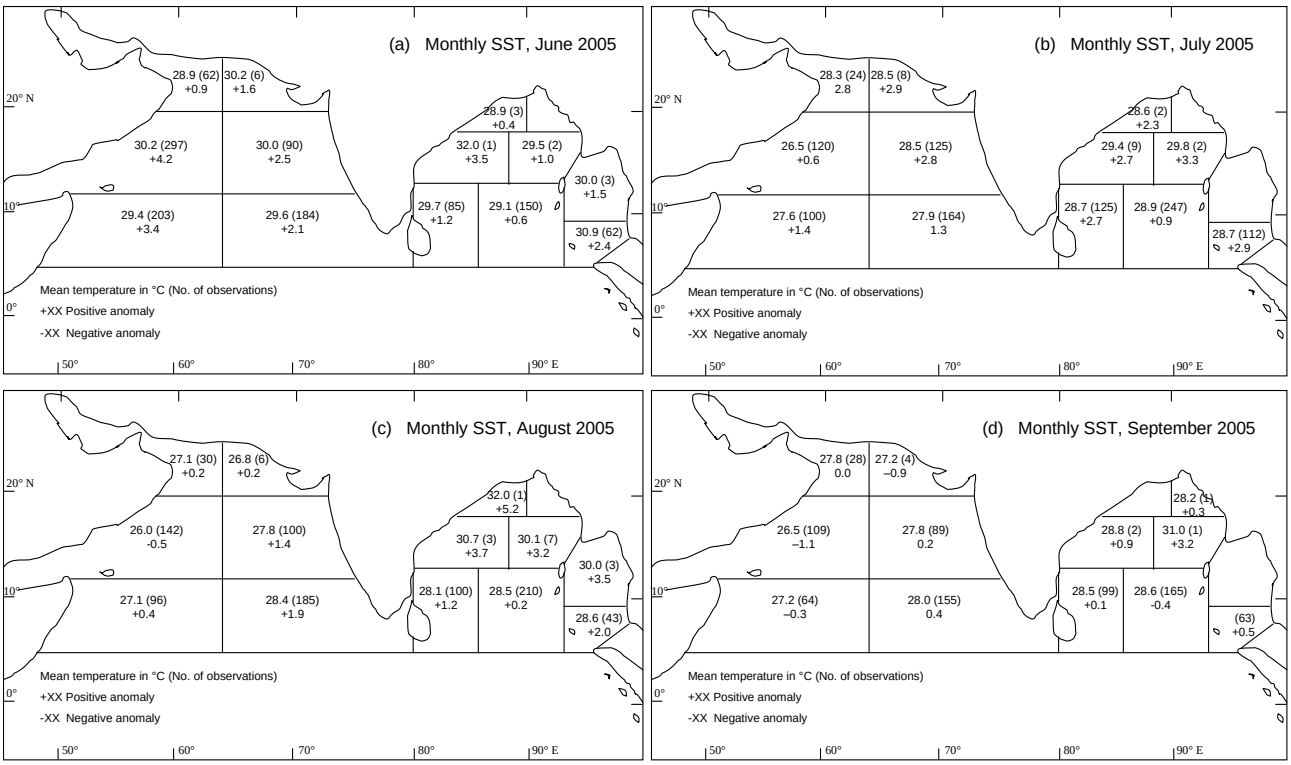
Tibetan Anticyclone (TA) was established in its near normal position at 500, 300 & 200 hPa levels on 26 June 2005. It remained more or less in its normal position during July and slightly to the southeast in August. During September, it remained to the north of its normal position and was present until 27 September. The details of Tibetan Anticyclone for the past five years are given below.

Year	*Tibetan anticyclone*
2000	Appeared on 5 June.
2001	Established on 12 June. Not seen in the last week of August. Less marked on 13 September.
2002	Established on 11 July. Not seen in July at 500 hPa. Less marked on 12 September.
2003	Established on 15 June. Not seen at 500 hPa during June & first half of July. Less marked on 14 September.
2004	Established on 13 June. Not seen at 500 hPa during June & first half of July. Less marked on 18 September.

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

STWJ was seen over Srinagar upto 22 June. Though it shifted northwards thereafter, made casual re-appearances over many stations like Delhi, Lucknow, Gwalior, Ranchi etc. during second half of July and of August. Later on, it was noticed over Delhi, Srinagar and Lucknow on 15 September, 23 September and 30 September respectively. The days during which the Sub Tropical Westerly Jet was observed in the past five years are given below.

Year	*Sub-Tropical Westerly Jet (STWJ)*
2000	Appeared on 5 June, 24 June & 16 July and re-appeared in the last week of September.
2001	Seen over north India during last week of May and reappeared in the last week of September.
2002	Seen over north India during first week of June and reappeared in the last week of September.
2003	Seen over Srinagar on 5 June. Reappeared on 1 October.
2004	Seen over Srinagar upto 23 June, over Ranchi until 20 June and reappeared in the first week of October.



Figs. 10(a-d). SST and SST anomaly in (°C) for (a) June, (b) July, (c) August and (d) September. The numbers inside the brackets indicate the number of observation

6.5. *Tropical Easterly Jet (TEJ)*

Jet speed winds were observed at Thiruvananthapuram from 6 June to 28 September. The maximum wind speed reported was 110 kts (at 198 hPa; 0000 UTC of 31 July). It was seen over Chennai from 15 June to 15 September. Maximum wind speed noticed was 110 kts at 100 hPa (on 8 July at 1200 UTC). Over Minicoy, it appeared from 7 June and was noticed upto 15 September. Over here, a maximum wind speed of 100 kts was reported at 167 hPa on 21 June (0000 UTC). Over Port Blair, it appeared on 2 June and was noticed till 2 October, though being absent on many occasions within the season. Its appearance over Mumbai was almost simultaneous with that of Chennai *i.e.*, on 15 June and was present there until 22 September. The maximum wind noticed was 90 kts (at 142 hPa on 25 July, 1200 UTC) and at 120 hPa on 5 August (0000 UTC).

Also quite often, winds of jet speed were reported over Visakhapatnam, Hyderabad, Bhubaneswar, Kolkata, Ranchi etc.

Details of TEJ in the past five years are as follows.

Year	*Tropical Easterly Jet (TEJ)*
2000	Seen from 1 week of June, till the end of September. Maximum wind speed 155 kts at 177 hPa on 6 September.
2001	Seen from 24 May, till 15 September. Maximum wind speed 150 kts at Hyderabad at 115 hPa on 21 July.
2002	Seen from 7 June, till the end of September. Maximum wind speed 105 kts at 137 hPa over Chennai on 18 June.
2003	Seen from 9 May to 25 September. Maximum wind speed 125 kts at 116 hPa over Minicoy on 25 July.
2004	Seen from 10 May to 30 September. Maximum wind speed 180 kts at 118 hPa over Minicoy on 22 June.

TABLE 15

Zonal wind anomalies

Levels (hPa)	Week ending dates: 7 Jun	14 Jun	21 Jun	28 Jun	5 Jul	12 Jul	19 Jul	26 Jul	2 Aug	9 Aug	16 Aug	23 Aug	30 Aug	6 Sep	13 Sep	20 Sep	27 Sep	4 Oct
Thiruvananthapuram (TRV)																		
850	0.3	–0.5	5.6	1.2	–0.3	2.5	–7.2	3.2	11.1	3.6	2.5	–2.5	–9.2	–0.7	3.3	1.6	0.1	–3.7
500	–0.7	2.9	–2.3	–6.4	–1.0	–6.4	–14.8	1.5	10.0	–1.2	6.8	–5.9	–7.7	–5.5	3.0	0.5	–0.4	–4.5
200	–5.9	8.6	–16.1	–17.2	–18.1	4.8	5.2	–1.6	–3.5	–7.4	0.1	–10.4	0.7	10.6	1.8	–11.0	–4.2	–8.7
Chennai (MDS)																		
850	–7.4	–0.7	–3.2	6.6	5.5	–0.4	–17.2	7.4	19.5	12.8	11.1	–4.3	–9.0	–11.5	9.6	11.8	5.9	–2.1
500	2.1	7.5	–8.1	–4.1	4.3	–2.5	–26.1	13.9	7.4	1.1	6.8	–1.5	–19.7	–19.9	2.9	–1.0	–3.8	4.3
200	–6.4	18.6	–10.2	–5.7	–	15.7	–18.9	30.8	13.9	–6.3	7.4	–2.1	–2.8	29.3	12.2	–10.3	–0.4	–6.2
Mumbai (BMB)																		
850	–0.4	–1.2	–12.0	10.4	10.9	–2.9	–10.1	2.8	8.5	0.4	5.7	3.0	–5.2	–12.6	8.5	18.8	15.0	–0.3
500	–3.7	3.1	–5.2	–0.7	9.9	–	–6.2	–8.6	3.3	3.2	3.2	3.0	–3.2	–12.1	0.9	7.5	8.3	2.9
200	–0.7	8.1	4.2	–11.7	–0.3	–7.5	–6.0	–1.1	4.7	3.7	–0.9	–9.5	–6.4	–2.9	15.8	–1.1	–1.2	–10.8
Nagpur (NGP)																		
850	2.9	–2.5	6.7	8.6	23.6	2.2	–7.3	–4.0	9.9	15.1	2.9	13.3	–0.4	–7.4	2.6	–	11.6	0.8
500	6.2	–0.1	–2.2	2.1	15.9	–5.5	8.7	–8.1	0.5	7.4	–1.3	3.6	3.3	–2.3	–1.5	–	7.7	–1.6
200	3.2	8.4	–28.7	6.8	4.1	–6.6	–1.2	4.8	13.9	1.4	–16.1	–10.2	–4.9	–16.5	–28.4	–	–39.3	–25.7

Note : 1. Easterly anomalies (-ve) at 850 hPa means that westerlies are weaker than normal.
2. Westerly anomalies (+ve) at 200 hPa means that easterlies are weaker than normal.
3. A station reporting '–' means no data.

7. Sea surface temperature (SST)

Monthly mean SST values for June, July, August and September 2005 for Arabian Sea, Bay of Bengal as well as Andaman Seas are discussed below:

In the Figs. 10(a-d), the monthly mean SST values alongwith the anomalies in NW, NE, WC, EC, SW, SE blocks of both the seas and also for North and South Andaman Sea, for the months June, July, August and September are given. The normal values for each block for calculating the anomalies have been estimated from the isopleths of normal values given in the publication "Climatic Atlas of the Indian Ocean, Part I" by Stephan Hastenrath and Peter J. Lamb. In all the above cases, if the number of observations in each block is less than 10, the mean and anomaly are not considered in the description.

7.1. *June*

The SST over all the sectors of Arabian Sea, Bay of Bengal and Andaman Sea were warmer than normal with high positive anomaly being 4.2° C in the WC Arabian Sea and 3.5° C in WC Bay.

7.2. *July*

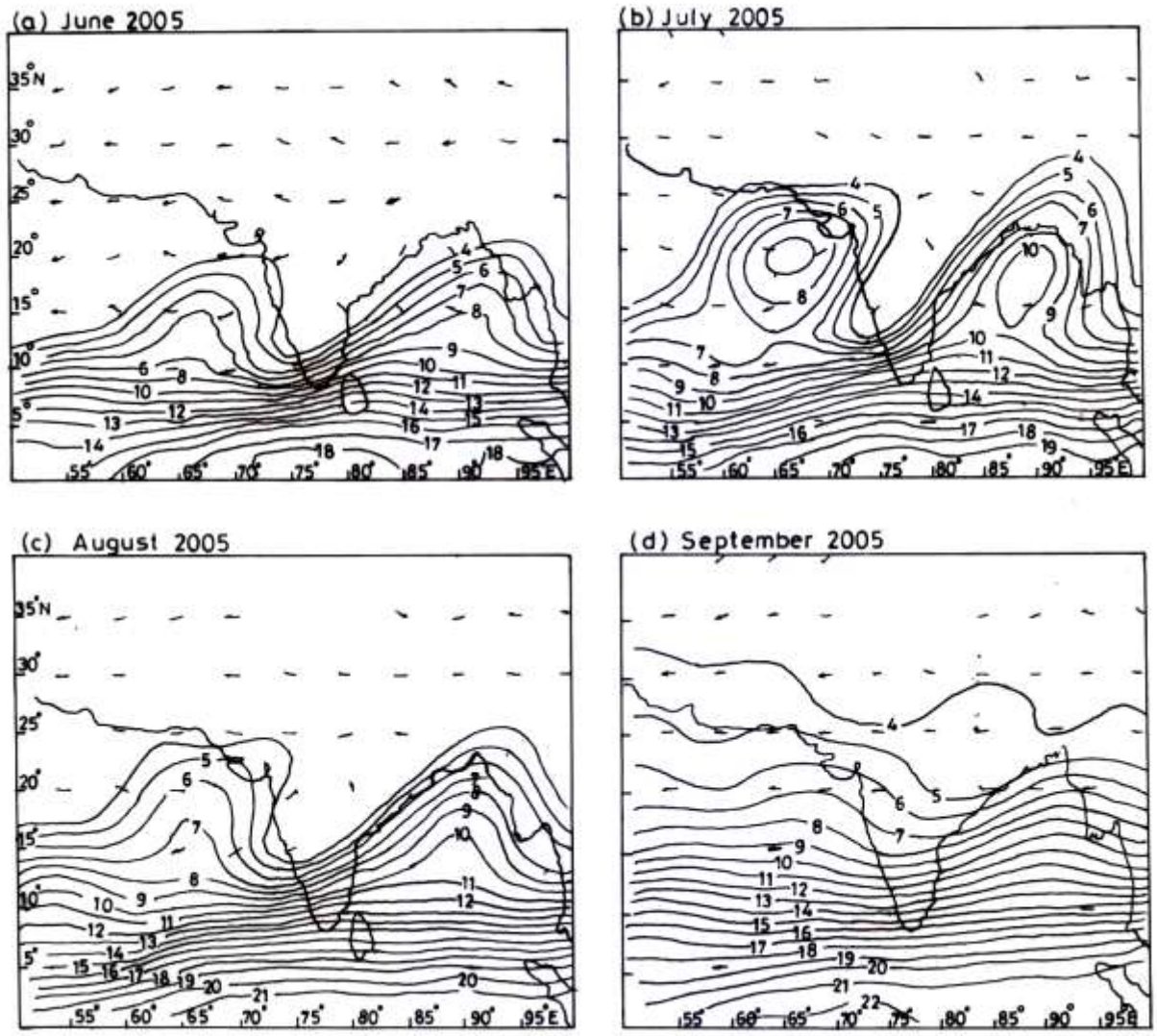
Except NE Bay of Bengal and North Andaman Sea, the SST over all the sectors of Arabian Sea and Bay of Bengal were warmer than normal with high positive anomaly of 2.9° C over NE Arabian Sea and 3.3° C over EC Bay of Bengal.

7.3. *August*

Except WC Arabian Sea, all sectors of Arabian Sea were warmer than normal with highest positive anomaly of 1.9° C in SE Arabian Sea. All the sectors of Bay of Bengal and Andaman Sea, the SST anomaly were positive.

7.4. *September*

The EC and SE Sectors of Arabian Sea were warmer than normal and remaining sectors were cooler than normal. All the sectors of Bay of Bengal were warmer than normal with highest positive anomaly of 3.2° C over EC Bay. The SST anomaly over Andaman Sea was also positive.



Figs. 11(a-d). Monthly anomalous vector winds at 30 hPa during southwest monsoon 2005 for the month (a) June, (b) July, (c) August and (d) September 2005

8. Other features

8.1. *Weekly upper wind anomalies in southwest monsoon 2005*

The circulation anomaly features during SW Monsoon Season 2005 are discussed below monthwise at lower, middle and upper tropospheric levels (850, 700 & 200 hPa). Also the zonal wind anomalies observed at 4 different stations over the peninsula are given in Table 15.

8.1.1. *June wind anomaly features*

In monthly anomaly winds, the anomaly ridge was seen over the central parts of the country at 850 and 700 hPa levels. At 500 and 300 hPa levels, the ridge is seen along 20° N.

In the weekly pattern, the anomaly ridge was seen persisting till week ending 21 June over the central region. On week ending 28 June the ridge is replaced by the anomaly trough between 850 and 500 hPa levels. The westerly anomaly winds over peninsula seen on week ending 28 June indicates strengthening of south-west monsoon.

8.1.2. *July wind anomaly features*

In monthly pattern the anomaly trough was seen between 15 to 20° N at 850, 700 and 500 hPa levels. Another trough was seen over southern parts of peninsula

between 850 and 500 hPa levels. Easterly anomaly winds were observed aloft at 300 and 200 hPa levels south of 20° N. In weekly pattern, the anomaly trough is seen along 25° N for the week ending 5 July at 850 and 700 hPa levels and in the subsequent weeks the anomaly ridge is observed between 20° N & 25° N. A trough is also seen along 15° N on the last week of the month - from 850 hPa to 300 hPa levels.

8.1.3. *August wind anomaly features*

In the monthly pattern, the anomaly ridge between 20° N to 25° N between 850 to 200 hPa levels. Easterly anomaly winds prevailed to the south of 20° N.

In the weekly pattern, the anomaly trough along 15° N seen in the last week of July moved northward and was seen on week ending 2 August along 25° N and extending upto 200 hPa level. The anomaly cyclonic circulation observed over Gangetic West Bengal at 850 and 700 hPa levels till week ending 16 August. On week ending 23 August, the ridge at about 10° - 15° N shifted northward and was seen at about 20° N by the end of the month.

8.1.4. *September wind anomaly features*

In the monthly pattern, the anomalous trough between 20° - 25° N was seen at 850 and 700 hPa levels. The easterly anomaly winds prevailed at 300 & 200 hPa levels.

In the weekly pattern, the anomaly ridge of week ending 6 September was replaced by trough till week ending 20 September along 20° N. During the remaining period, the westerly anomaly winds were seen between 850 and 500 hPa levels and easterlies at 300 & 200 hPa levels over peninsula.

8.2. *Stratospheric features*

The NCEP/ NCAR reanalysis data were used for the analysis of stratospheric circulation over India. Figs. 11(a-d) shows the monthly stratospheric circulation at 30 hPa anomalous wind patterns for the four months of the monsoon season 2005. The anomalies are based on the 1968-96 climatology. As seen in the figure, during all the four months, the anomalous winds over the Indian region were mainly easterly with wind speed maximum over the equatorial region. During the first three months, secondary maxima were observed over both the Indian seas. Particularly during July, the secondary maxima were more visible. Climatologically easterly winds are observed over Indian region with core of wind speed in the 15° - 20° N latitudinal range. This indicates that during 2005, the

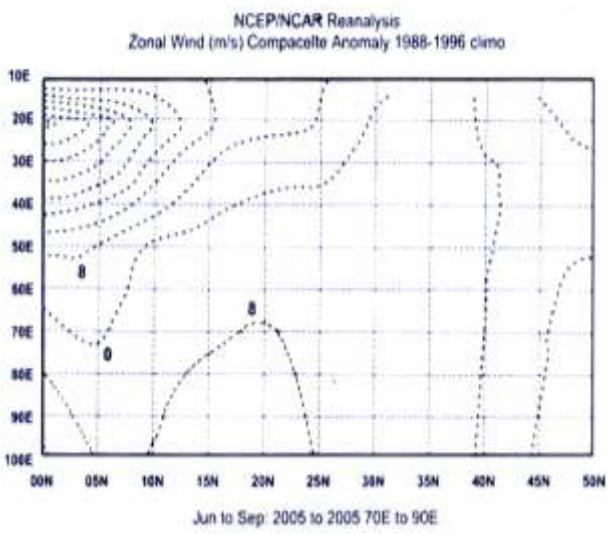


Fig. 12. Latitude height diagram of zonal anomalies for June – September 2005

climatological easterlies were stronger than normal. During the last year (2004), anomalous westerly winds were observed south of 22.5° N.

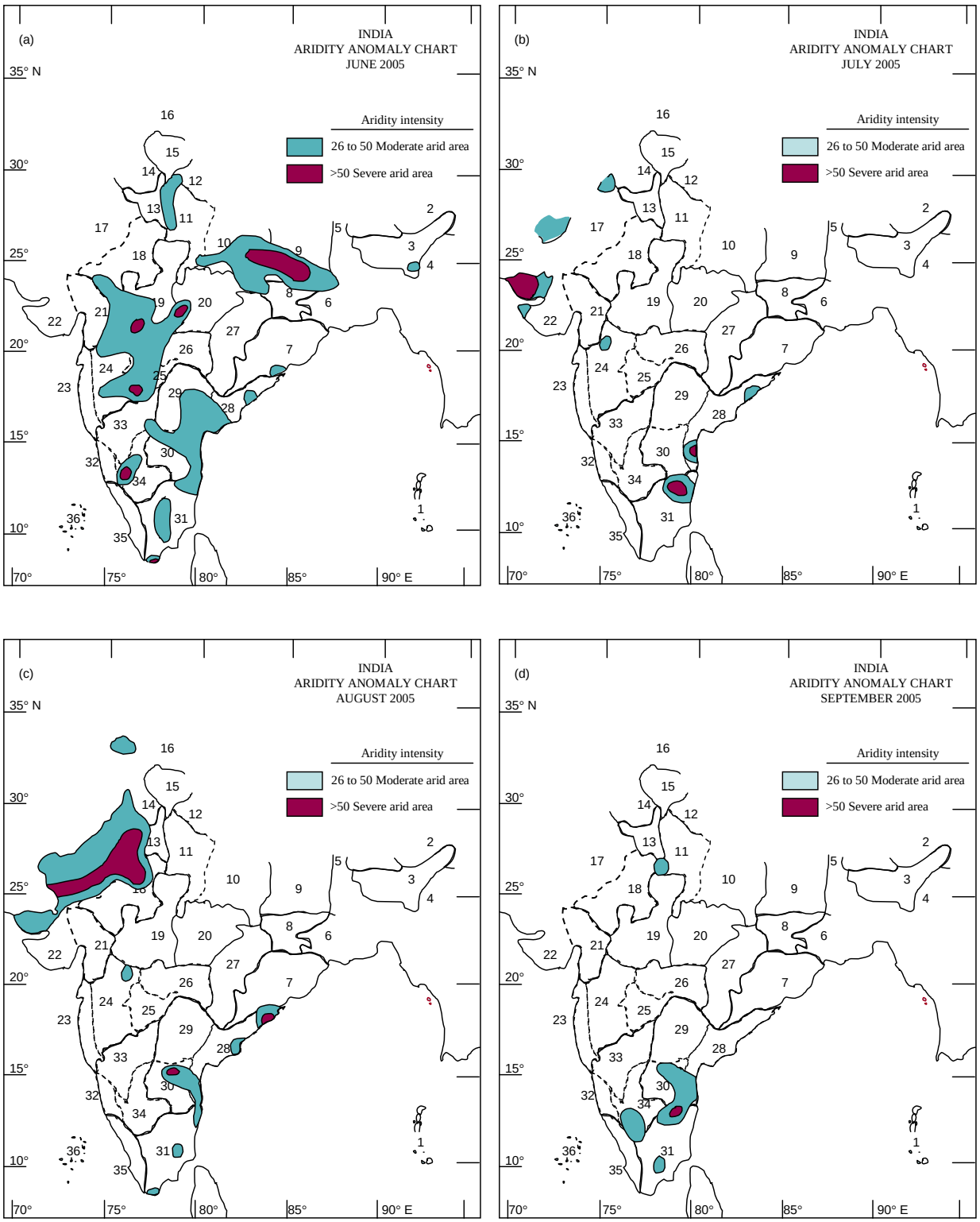
Fig. 12 shows the latitude – height diagram of zonal wind anomalies for the monsoon season (June-September) 2005 averaged over the longitudinal zone of 70° - 90° E. The anomalies are based on the 1968-96 climatology. As seen in this figure, the wind anomalies at and above 30 hPa were easterly over entire Indian latitudes. From 30° N towards the equator, the easterly anomalies were penetrating into the low altitudes. Close to equator, the easterly anomalies extended downwards upto around 70 hPa.

8.3. *Aridity conditions during southwest monsoon 2005*

Aridity Index (AI) is computed based on Thornthwaite's formula :

$$AI = \frac{PE - AE}{PE} \times 100$$

Where, *PE* is potential evapotranspiration, *AE* denotes the Actual Evapotranspiration and *PE – AE* denotes the water deficiency. *PE* is computed by Penman's modified equation and *AE* is obtained from the



Figs. 13(a-d). Aridity anomaly chart for the month (a) June, (b) July (c) August and (d) September 2005

water balance procedure, which takes into account the water holding capacity of the soil.

The aridity anomaly is worked out by considering the difference between actual Aridity and normal aridity for the month. Aridity of a particular region is decided based on the aridity anomalies, which have been classified as follows :

Aridity anomaly	*Class*
0 or less	non-arid
1 to 25	mild arid
26 to 50	moderate arid
more than 50	severe arid

Aridity anomaly maps for June, July, August and September are given in Figs. 13(a-d).

Moderate to severe arid conditions were noticed in small northern, central, southern and southeastern parts of the country in June. In July, these areas over the country except some western parts have decreased. In August, these areas increased over northwestern part. In September, these areas over northwestern parts have wiped out.

Details of severe and moderate arid conditions which prevailed over the country during southwest monsoon months are given below :

8.3.1. *June*

(a) *Severe arid areas*

(*i*) Small areas of central parts of Bihar and adjoining parts of East Uttar Pradesh and Jharkhand.

(*ii*) Isolated areas around Seoni (east Madhya Pradesh), Khandwa (west Madhya Pradesh), Osmanabad (Marathwada), Chickmagalur (South Interior Karnataka) and Kanyakumari (Tamil Nadu).

(b) *Moderate arid areas*

(*i*) Large parts of Bihar, west Madhya Pradesh, Marathwada, Vidarbha and Coastal Andhra Pradesh.

(*ii*) Small areas of central and eastern parts of East Uttar Pradesh; northwestern and northeastern parts of Jharkhand and adjoining northern part of Gangetic West Bengal and southern part of Sub Himalayan West Bengal; western and northern parts of West Uttar Pradesh and adjoining part of Uttaranchal; southern parts of East Rajasthan; northern and southeastern parts of Madhya Maharashtra; southwestern parts of East Madhya Pradesh; southeastern parts of Telangana; northern part of Rayalaseema; northern and eastern parts of North Interior Karnataka; central parts of South Interior Karnataka and adjoining southern part of Coastal Karnataka; northern, central and southern parts of Tamil Nadu.

(*iii*) Isolated areas around Visakhapatnam (Coastal Andhra Pradesh), Gopalpur (Orissa) and Imphal (Nagaland-Manipur-Mizoram-Tripura).

8.3.2. *July*

(a) *Severe arid areas*

(*i*) Small areas of western parts of Saurashtra & Kutch.

(*ii*) Isolated areas around Nellore (Coastal Andhra Pradesh) and Tirupattur (Tamil Nadu).

(b) *Moderate arid areas*

(*i*) Small areas of northern and western parts of West Rajasthan; western parts of Saurashtra & Kutch; southern parts of Coastal Andhra Pradesh and northeastern parts of Tamil Nadu and adjoining part of South Interior Karnataka.

(*ii*) Isolated areas around Malegaon (Madhya Maharashtra) and Visakhapatnam (Coastal Andhra Pradesh).

8.3.3. *August*

(a) *Severe arid areas*

(*i*) Small areas of central and eastern parts of West Rajasthan; northwestern parts of East Rajasthan and adjoining western parts of Haryana.

(*ii*) Isolated areas around Dwarka (Saurashtra &Kutch), Kalingapatnam (Coastal Andhra Pradesh) and Nandyal (Rayalaseema).

(b) *Moderate arid areas*

(*i*) Large areas of Punjab and West Rajasthan.

(*ii*) Small areas of western parts of Jammu & Kashmir; central and northwestern parts of Haryana; northern and central parts of East Rajasthan; northern and western parts of Saurashtra & Kutch ; northeastern parts of coastal

TABLE 16

Representative rainfall amounts (>7 cm) during June – September 2005

Date (1)	June (2)	July (3)	August (4)	September (5)
1	Bantwal 16, Chepan 12, Maya Bandar & Champasarai 8 each	Vyara 55, Balasinor 44, Anand 41, Padra & Songadh 35 each, Vallabh Vidyanagar & Kalol 34 each, Valod 31, Baroda 30, Bayad, Navsari & Bardoli 29 each, Gandhinagar, Kadi & Mahuva 28 each, Ahmedabad & Savli 24 each, Gandevi & Palsana 23 each, Waghodia & Wanakban 22 each, Mansa & Kottighera 21 each, Mudigere & Bhagamandala 20 each, Radhanagari 17, Quilandy 14, Junagarh, Dharamshala & Mahabaleshwar 13 each, Sidhi, Umaria, Matheran, Sawantwadi & Munnar 12 each, Belthangady 11, Sabroom, Chepan, New Kandla & Jashpurnagar 10 each, Beki Road Bridge, Mathanguri & Londa 9 each, Gajoldoba, Katghora & Naduvattam 8 each, Diamond Harbour, Bilara, Degna, Pandoh & Jammu 7 each	Koyna 45, Tamini 36, Dawdi 35, Ambone 34, Lonawala & Shirgaon 33 each, Mahabaleshwar 31, Dungerwadi 30, Khopoli & Vihar 28 each, Chiplun 27, Karjat & Khalapur 26 each, Palanpur, Songadh, Mahad & Matheran 25 each, Bhira, Walwan & Thane–Belapur 24 each, Vyara & Pali 23 each, Dharavi & Peermade 22 each, Mahuva, Mumbai (SCZ), Panvel, Poladpur & Uran 21 each, Mangrol, Bhivpuri, Bhandup & Kalyan 20 each, Gaganbavda & Munnar 19 each, Katangi 18, Deori, Agumbe & Mudigere 17 each, Indore, Mhow & Thygarthy 16 each, Gudalur Bazar 14, Naduvattam 11, Ramgarh, Dehra Dun, Danpur & Kollur 10 each, Bihubar, Purushottampur, Mount Abu, Arang & Siddapura 8 each	Shirahatti 9, Mannargudi, Muthupet & Yelburga 7 each
2	Maya Bandar 14, Cuttack & Gangtok 9 each, Passighat 8, Matunga & North Lakhimpur 7 each	Madhuban 33, Silvasa 29, Katni 28, Vythiri 24, Daman 23, Maihar 22, Dahanu & Mahabaleshwar 18 each, Karjat 17, Peint 16, Bhagamandala 13, Jafrabad 12, Vallabhipur, Khonsa & Londa 11 each, Kottighera 10, Kashipur & Irikkur 9 each, Cherrapunji, Imphal, Subramanya, Siddapura & Khanapura 8 each, Pindwara, Sanchore & Rajnandgaon 7 each	Lonavala, Dawdi & Mahabaleshwar 39 each, Tamini 35, Walwan & Dungarwadi 33 each, Shirgaon 32, Vihar 31, Bhagamandala 30, Bhira & Khopoli 27 each, Vaitarna, Sringeri & Agumbe 24 each, Shirota & Tulsi 21 each, Ahwa, Sagbara, Wangaon & Arnod 20 each, Jaddol 19, Naduvattam 18, Gudalur Bazar & Siddapura 17 each, Kollur 16, Munnar15, Sringeri, Piravom & Pindwara 13 each, Jamnagar, Wadhvan & Londa 12 each, Pali & Rohat 11 each, Uttarkashi, Kottayam & Tonkhurd 10 each, Tangi 7	Deodurga & Napoklu 11 each, Pochampalli 10, Vediapatti 9, Tiruppuvanam & Konanur 8 each
3	Port Blair 9, Sulya 7	Banda 26, Songadh 22, Valod 21, Satna 19, Mahabaleshwar 17, Bhira 16, Uttarkashi & Karjat 13 each, Peint 12, Kurwai 11, Tantloi 10, Kashipur & Londa 9 each, Suwasarmandi & Agumbe 8 each, Passighat, Mahuva, Kolayat & Kollur 7 each	Jawahar 22, Bhoond 20, Mavli & Kadi 19 each, Sagar Island, Dharoi & Mahabaleshwar 18 each, Dahanu 16, Bankura & Jhadol 14 each, DP Ghat & Patti 13 each, Junagadh, Mudigere & Munnar 11 each, Cherrapunji, Daltonganj & Patan 10 each, Bhograi, Ramgarh, Bosan, Karkala, Londa & Jayapura 9 each, Siddapura 8, Jamsolaghat & Morvi 7 each	Karkala 16, Namsai 13, Mulki & B. Durga 12 each, Chitradurga & Virudhuchalam 11 each, Murud & Palacode 10 each, Tadipatri & Enamackel 9 each, Balasore, Daund & Perumbavur 8 each, Kandi, Gulbarga & Ramanagar 7 each
4	Kalimpong & Solagiri 7 each	Sagar 48, Sheri 30, Patan 21, Wadhavan 19, Mahabaleshwar 18, Suri 16, Limbdi 15, Agumbe 14, Sripalpur, Naraingarh & Mount Abu 13 each, T.P. Barrage 12, Lalitpur & Navapur 11 each, Barpur & Mokhada 9 each, Port Blair, Manoharthan Amrohall, Mukteshwar, Chanchonda, Badwani & Thodupuzha 8 each, Cherrapunji, Londa & Jawahar 7 each	Kadi 27, Danta 21, Raigarh 14, Siddapura 12, Mahabaleshwar & Bantwal 11 each, Navrangpur, Daltonganj & Sakti 10 each, Bhalukpong, Kotda, Hosanagara & Linganamakki 9 each, Jhumpura, Kalagarh, Vallabhipur & Ratnagiri 8 each, Kolkata, Uttarkashi, Bhira, Tekra & Kaleswaram 7 each	Mekhliganj 16, Alipurduar, Bangarpet & Bhagamandala 13 each, Cooch Behar & Kotdwar 12 each, Dengraghat, Channapatna, Selu & Idukki 11 each, Fatehpur & Polur 10 each, Umrer & Sathyamangalam 9 each, Bhalukpong, Baltara, Uttarkashi, Mumbai, Parola, Thodupuzha, Bageshwar & Subramanya 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
5	Kumarakom 9, Kochi, Alapuzha & Minicoy 8 each, Dhenkanikottai & Palacode 7 each	Tendukheda 34, Narsinghpur & Garhakota 23 each, Agumbe 19, Bhatkal & Valpoi 18 each, Dharampur, Aklera, Sagar & Sangad 17 each, Londa 15, Cherrapunji & Munnar 14 each, Chandigarh, Pachmarhi, Joida & Mahabaleshwar 13 each, T.P. Barrage, Anandpur, Salur & Kotdwar 12 each, Sripalpur, Chachraulli, Jagadhari, S. Baji, Mohrani, Sringeri, Bhira & Thodupuzha 11 each, Kalimpong 10, AIE-NH Xing, Putki, Rajpura, Bhopal & Nandurbar 9 each, Port Blair, Messanjore & Naduvattam 8 each, Bhalukpong, Kolkata, Malda, Jaleswar, Bhagalpur, Songadh & Gudalur Bazaar 7 each	Korba 20, Pali 11, Navrangpur, Sahabad, Dahanu, Murbad & Kaleswaram 10 each, Raipur, Umargaon & Valsad 9 each, Ambala, Cherrapunji, Solangnala & Sompeta 8 each	Bhalukpong 27, Mulbagai 23, Konni 16, Agathi 15, Kanjirapally & Piravom 14 each, Chalakudy, Kashipur, Matheran & Shahapur 13 each, Venkatagirikota 12, Mekhliganj & Virudhachalam 11 each, Mazbat, Basua, Karnaprayag, Valparai, Kundapura & Challakere 10 each, Chargharia & Udupi 9 each, Kampur, Gajoldoba & Gaganbavda 8 each, Palliakalan, Bangalore & Khalapur 7 each
6	Konni 20, Kodungallur 12, Paravur & Kunnamkulam 9 each, Mavelikara 8, Kanjirapally 7	Garhakota 17, Athagarh 13, Tadong 12, Gangtok, Sundernagar & Nahan 11 each, Amraghat, Gharmura, Chhabra & Biora 10 each, Chachraulli, Manoharthana, Chachanda, Thodupuzha, Banda & Vythiri 9 each, Car Nicobar & Lakkavalli 8 each, Sankalan, Araria, Nandadih, Sujangarh, Uttarkashi & Karkala 7 each	Mahabaleshwar 23, Kalagarh 20, Sabroom 16, Poladpur 14, Pantnagar, Umaria & Ajaygarh 12 each, Matunga 11, Khanapura, Vidisha & Bhiwani 10 each, Naraingarh 9, Mungeli 8, Durg 7	Gajoldoba 16, Peermade 12, Gingee 10, Munger, Khagaria, Kursela, Haripur, Mokhada & Mahabaleshwar 9 each, Palliakalan, Ukhimath, Tirupattur & Kotdwar 8 each, Diana, Kaleswaram, Perur & Yeola 7 each
7	Mangalore 11, AIE NH X-ing 8, Tangla & Kasargode 7 each	Vythiri 29, Pathankot 27, Udhampur 18, Jind 17, Batote 16, Dhundhi, Bahadurgarh & Ottapalam 15 each, Uchana & Govindgarh 14 each, Mananthavady & Adampur 13 each, Solangala & Athagarh 11 each, Maya Bandar, Angul, Agra, Mathura, Satna & Arjunimoregaon 8 each, Kurkheda 7	Diana 27, Ankinghat 21, Beki Road Bridge 15, Taibpur & Varanasi 12 each, Katerniaghat 11, Manas NH-Xing & Gangtok 10 each, Sripalpur 9, Songadh 7	Thodupuzha 11, Kanjirapally 10, Ahwa, Kaleshwaram, Srisailam & Vandavasi 9 each, Rahli 8, Jaunpur, Marmugao & Arani 7 each
8	Port Blair 14, Sambre 11, Maya Bandar, Matunga & Dabolim 7 each	Kurkheda 22, Deori 13, Gharmura 12, Bhamragad 11, Palari 10, Udhampur 9, Neora & Rania 8 each, Bhalukpong, Sorada, Hissar, Bhatinda, Begumganj & Idukki 7 each	Gajoldoba 29, Baghdogra 22, Galgalia 12, Cherrapunji 11, Bhalukpong, Chouldhowaghat & Canning Town 9 each, Kakrahi 7	Srisailam 20, Peermade 18, Gudivada 10, Bhim, Ambejogai, Bapatla & Rajsamund 9 each, Palakkad, Karipur & Dapoli 8 each, Tangi, Eturnagaram, Amini Divi, Hatkanangale, Chittapur & Jeewargi 7 each
9	Port Blair & Nagrakata 10 each, Neora, Shirur & Sri Perumbudur 7 each	Peleru Bridge 18, Munnar 14, Yellandu, Chandrapur & Saoli 13 each, Neora 12, Gajoldoba & Thrithala 11 each, Khammam 10, Bhopal 9, Bolangir 8, Dibrugarh, Cherrapunji, Arang & Purushottampur 7 each	Beki Mathanguri, Cherrapunji, Rewari & Karwar 9 each, Mahabaleshwar 7	Peermade 21, Puri 18, Mundali 16, Gaganbavda 14, Indapur & Idukki 11 each, Port Blair 10, Bhokardan 9, Jaisalmer, Aurangabad & Agumbe 8 each, Diana, Surat, Poladpur, Chenbarambakkam, Achampet & Mauranipur 7 each
10	Port Blair 20, Mandya 14, Tilupur & Thodupuzha 11 each, Aryankavu 10, Hut Bay, Vembayi & Vaniyambadi 7 each	Kaleswaram 20, Passighat 19, Diana 18, Wani 17, Hasimara & Triveni 14 each, Kotdwar 13, Manjlegaon 11, Tangi, Kakrahi & Huzurabad 10 each, Gudari, Rishikesh, Medikeri, Kottayam & Thiruvalla 9 each, Dhollabazar, Barely, Wardha & Bhalki 8 each, Balrampur & Sukuma 7 each	Baitara 21, Colgaon 20, Baroda 10, Cherrapunji 9, Passighat & Kurnool 8 each, Khonsa & Naharkatia 7 each	Vihar 34, Bhandup 27, Dharavi 23, Mumbai 22, Matheran 21, Tuni 16, Vyara & Dhoraji 15 each, Digha, Balasore, Athagarh, Silvasa, Ahwa, Mahabaleshwar, Kolhapur & Peermade 11 each, Bhoond & Lilia 9 each, Diamond Harbour, Patti, Bhopal & Garh 8 each, Ludhiana, Khairi, Barisadri & Katra 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
11	Srungavarappukottai & Thondebhavi 9 each, Gowribidanur 8	Roing 32, Hasimara 27, Alipurduar 23, Agathi 22, Bhatkal 18, Chouldhowaghat 16, Paonta & Naraingarh 15 each, Tezu & Katol 14 each, Neemsar 13, Kotdwar, Dehra Dun & Udhampur 12 each, Dhollabazar, Mathura, Banwasa, Lanji & Saoner 11 each, Kangra & Kishanganj 10 each, Hirakund, Katerniaghat, Anta, Cancona, Honavar & Kasargode 9 each, Palliakalan, Dadupur, Mapusa, Piravom & Vengurla 8 each, Triveni, Deogarh, Batala, Aurad & Amini Divi 7 each	Mohitnagar 17, North Lakhimpur & Cherrapunji 10 each, NH-31 9	Vyara & Peermade 17 each, Maya Bandar, Junagadh, Mahabaleshwar & Yellandu 14 each, Murbad 12, Songadh, Keshod & Rajnandgaon 11 each, Bhograi, Bosan, Bodhan, Jawahar & Pattambi 10 each, Tajewala & Sawai Madhopur 9 each, Digha, Machilipatnam & Dhar 8 each, Jaleswar, Nimarana, Nizamabad, Lanjhi, Gaganbavda, Malkapur & Thuckalay 7 each
12	Khonsa 11, Gadag 7	Bharatpur 23, Jind 22, Manki 20, Dharamsala 18, Dabolim & Gaganbavada 17 each, Bhatkal & Vabharwadi 16 each, Roing & Kotkasim 15 each, Ferozepur, Jhirka, Hoshangabad & Kudal 13 each, Tezu, Pathankot & Karwar 12 each, Dalmau, Mathura, Kotdwar & Keotari 11 each, Beki Mathanguri, Sabour, Agra, Gomatia & Korba 10 each, Dillighat, Bani & Marora 9 each, Jharsuguda & Uttarkashi 8 each, Nancowry, Cooch Behar, Buxar, Halwara, Bhopal & Mahendragarh 7 each	Sonbarsa 15, Guwahati 13, Darjeeling & Galgalia 10 each, Jhanjharpur 9, Mahabaleshwar & Agumbe 7 each	Nawarangpur 30, Jeypore, Murbad 17, Kalyan 15, Matheran 13, Sihor & Thane Belapur 12 each, Mahabaleshwar, Deobhog & Gariaband 11 each, Padra, Ranawav, Sompeta, Durg & Peermade 9 each, Raipur 8, Bangana, Binag, Valsad, Gaganbavda, Dharmasthala & Bandipura 7 each
13	Alipurduar 9, Goalpara & Khonsa 7 each	Turtipar 22, Darauli 17, Bhalukpong 15, Bansi 13, Sawantwadi 12, Dhubri, Vengurla & Jurala Project 11 each, Satna 10, Malda & Suri 9 each, Tantloi & Paradip 8 each, Itanagar, Dhollabazar, Atmakur & Karwar 7 each	Tanakpur 19, Goalpara & Gossaigaon 12 each, Port Blair 11, Tilpara Barrage 9, Nahan & Mahad 8 each, Hut Bay, Suri, Banbasa & Poladpur 7 each	Bhavanipatna 27, Hindol 23, Narsinghpur 22, Phulbani, Junagarh, Nayagarh & Lanjigarh 21 each, Mangrol 20, Gaganbavda 16, Gariaband 14, Keshod, Kondagaon & Balod 13 each, Mahabaleshwar 12, Bhira 11, Bhagamandala & Gondia 10 each, Deoni & Matheran 9 each, Midnapore, Kapurthala & Agumbe 8 each
14	Kudulu 10, Mannarkad & Mangalore 8 each, Lakhipur, Kembhavi & Hangal 7 each	Bamanwas 23, Cherrapunji 22, Manmathanagar & Gangapur 20 each, Basirhat 19, Udala, Shrimusnam & Harihara 14 each, Dhubri, Tenughat & Nayakanhatti 11 each, Benibad, Valparai, Bhatkal, Gokarna & Hanumansagara 10 each, Gadag & Panna 9 each, Chepan, Shikohabad & Ambala 8 each, Mathabhanga, Pallahara, Sambalpur, Samastipur, Shehra, Ambah, Munnar, Sangraha & Boath 7 each	Digha 14, Passighat & Gaganbavda 11 each, Cooch Behar & Sandighat 10 each, Rajapur 9, Aizwal & Nagrota Surian 8 each, Maya Bandar, Champasarai & Sonbarsa 7 each	Rajghat 27, Digha 24, Dongargarh 23, Bhograi & Mohadi 22 each, Bhandara 21, Dongilohana 20, Kalaikunda 18, Multai 16, Port Blair 15, Nagpur 14, Visakhapatnam 12, Champa 11, Kannod 9, Hanumangarh, Pushkar, Mahabaleshwar, Asthi, Balaghat & Siddapura 8 each, Long Island, Tohana & Seoni 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
15	Daporijo 13, Subramanya 8, Matizuri 7	Khandar 28, Nandigram & Hubli 19 each, Shahpura & Sapotra 17 each, Messanjore 15, Malda, Putki & Ariyalur 14 each, Kerur 12, Cherrapunji, Kibbanahalli, Tiptur, Kangayam, Dharamshala & Shimla 11 each, Tantloi & Sheopur Kalan 10 each, Jowai, Dehri, Sundernagar, Tikamgarh & Sambhal 9 each, Neemapara 8, Khonsa, Paradip, Mussoorie, Parbhani, Rayadurg, Nowgong, Daltonganj, Minicoy, Mathura & Hindupur 7 each	Bhograi 17, Taibpur & Chargharia 15 each, Digha 14, Jaleshwar & Basti 13 each, Goalpara 12, Sagar Island & Kurkheda 11 each, Bokajan & Cooch Behar 10 each, Alipurduar, Gorakhpur & Kangra 9 each, Mukteshwar, Mahabaleshwar, Pali & Agumbe 7 each	Danpur & Lanji 19 each, Jallandhar, Kesarpura & Mandla 18 each, Bhograi & Sailana 16 each, Jabalpur 15, Tumsar & Kottigehara 14 each, Agumbe, Amgaon & Warud 12 each, Multai 11, Maya Bandar, Thakurmunda & Palanpur 9 each, Paradip, Meghraj & Thane 8 each, Mahabaleshwar, Arang, Avrug & Akbarpur 7 each
16	Dhubri 12, Thodupuzha 11	Cherrapunji 28, Bhatkal 21, Hasimara & Sheopur Kalan 18 each, Jalpaiguri 13, Kursela 12, Gossaigaon, Subramanya, Bangarpet & Bayana 11 each, Rosera, Agathi & Dholpur 10 each, Sholingur, Hospet, Warationi & Sultanpur 9 each, Passighat, Dunguripalli, Mudgal, Kolar, Lans Down & Baijnath 8 each, Dhubri, Padampur, Katra Vidisha, Maski, Turtipar, Moth, Chachraulli & Nahan 7 each	Rishikesh 18, Bhagamandala 24, Kollur 15, Katra, Thodupuzha & Kammardi 14 each, RS Dam Sites 13, Khanapura & Shahpurkandi 12 each, Narsinghpur & Dharamshala 11 each, Miao & Udhampur 10 each, Bhoond 9, Tezpur, Jagdalpur & Balod 8 each, Kohima, Dehra Dun, Mahabaleshwar, Lanji, Kolaras & Pathankot 7 each	Anta 20, Kusganj 17, Baran 16, Kanpur 15, Lucknow, Iglas & Pindwara 13 each, Auraiya & Ankinghat 11 each, Srimusham 10, Bareilly & Bali 9 each, Jalore, Panna, Deesa & Lansdowne 8 each, Car Nicobar, Imphal & Mani 7 each
17	Kodungallur 31, Aluva 17, Thodupuzha 15, Gajoldoba 14, Majbat 13, Mudibidre 10, Jalpaiguri 9, Lakhipur, Honavar & Karkala 7 each	Sawai Madhopur & Mangrol 15 each, Bharatpur, Subramanya & Akbarpur 12 each, Oranandu & Salempur 11 each, Roing, Baghdogra, Haripur, Lunkarsar, Siddapura, Arkalgud & Indapur 10 each, Beki Road Bridge, Champasari, Kakrahi, Sheopur Kalan, Tiruthuraipoondi, Ranebennur & Jagadhari 9 each, Galgalia, Agathi & Dharmanagar 8 each, Ghazipur, Bosan, Ambala, Katra, Tirupattur, Tavargere, Darauli, Chatra, Mainpuri & Rishikesh 7 each	Mahabaleshwar 15, Banda 13, Dabolim, Valpoi & Lakkavalli 12 each, Jabalpur 10, Dharmasthala, Jagalbet & Jandutla 9 each, Kishangarh & Kottigehara 8 each, Pantnagar, Bolangir, Nowgong, Delhi, Chandigarh & Basoli 7 each	Billari 33, Hasanpur 30, Bareilly 27, Srinagar & Shantipuri 24 each, Muradabad 23, Amrohi 22, Nainital 20, Bhinga 18, Pantnagar 17, Kasol 16, Bahraich 12, Port Blair, Manmathanagar, Mahabaleshwar, Beawar & Katri 8 each, Indrapuri, Narora & Wada 7 each
18	Passighat 17, Chouldhowaghat 13, Cherrapunji, Neora & Ankola 12 each, North Lakhimpur & Panjim 11 each, Jalpaiguri 10, Gaganbavda & Karwar 8 each, Dibrugarh 7	Kakardharighat 15, Karimganj 14, Bhinga 13, Khonsa, Mussoorie & Quepam 12 each, Bahalpur, Diana, Uttarkashi, Rajakhera & Jurala Project 11 each, Gajoldoba, Shahpura, Sedam & Rajpur 10 each, Passighat, Cherrapunji, Pushkar & Senguem 9 each, Auraiya, Beed, Tavaragere & Thodupuzha 8 each, Dehra Dun, Kotdwar, Wai & Saoner 7 each	Diana 26, Agumbe 14, Hasanganj 13, Ankinghat 12, Paonta, Dholpur, Bhira & Gaganbavda 9 each, NH-31, Poladpur & Sulya 8 each, Hardwar, Mahabaleshwar & Siddapura 7 each	Radhanpur 29, Kashipur 20, Kheralu, Morvi & Tikabali 15 each, Kalagarh, Jamnagar, Mount Abu, Kotagarh, Kotdwar & Bijnore 13 each, Sirohi 12, Kansabati Dam, Pantnagar & Igatpuri 10 each, Mohana, Phulbani, Gaya, Nagrotasurain & Gondia 9 each, Tusuma, Jawahar & Nandurbar 8 each, Patiala & Guler 7 each
19	Cherrapunji 13, Gangtok & Alibag 11 each, Siddapura Thiruvalla 10, Tadong, Bajpe, Puttur & Irikkur 9 each, Panjim 8, Dholai, Dhubri, Gaganbavda & Thrissur 7 each	Kakardharighat 23, Beki Mathanguri 22, Matunga 17, Kakrahi & Ghumarwin 12 each, Bhinga 10, Roing & Hasimara 9 each, Balurghat 8, Tezu, Etawah, Mangalore, Gohad, Shardanagar & Bajpe 7 each	Sonepur 26, Chatia 21, Khairamal 20, Guwahati & Annapurna Ghat 14 each, Motihari 11, Kakrahi, Lanji & Akbarpur 10 each, Kurkheda & Amgaon 9 each, Bansi & Umaria 8 each, Bhalukpong, Bakani, Gaganbavada & Agumbe 7 each	Kalingapatnam 35, Jeypore & Pindwara 20 each, Pottangi 19, Vyara 18, Mount Abu 15, Modasa 14, Visakhapatnam 13, Tekkali 12, Wardha & Nagrakata 9 each, Kaleswaram, Matheran & Igatpuri 8 each, Jagdalpur & Perur 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
20	Bhatkal 23, Bajpe & Kollur 22 each, Mani 20, Kokrajhar 16, AIE NH X-ing 15, Nancowry & Bhalukpong 14 each, Sanguem & Thalasserry 11 each, Sevoke & Irrikur 10 each, Car Nicobar, Neora, Konkona & Talaguppa 9 each, Baghdogra & Araria 8 each, Itanagar, Kolkata, Nayagarh, Champa & Thirthahalli 7 each	Diana 26, Nagrakata 18, Bhatkal 15, Kumtha 13, Aurangabad 11, Chouldhowaghat, Tikabali, Sujanpura Tira & Pathardi 10 each, Sikandarpur 9, Chatia, Berthin, Nagarjunasagar, Biligi & Gudiyatham 8 each, Alibag, Ananthapur, Bhagamandala, Yercaud & Etawah 7 each	Langhi & Malajkhand 17 each, Cherrapunji & Jhumpura 14 each, Kharagpur 13, Gaganbavda & Deori 12 each, Akbarpur & Kotdwar 11 each, Sagar Island, Pantnagar, Roha, Mahabaleshwar, Dhantari & Gandal 9 each, Khonsa, Matunga, Bahraich, Varanasi, Mathura & Bhira 8 each, Passighat, Munger, Sonbarsa & Kalpi 7 each	Kunnavaram 49, Koida 48, Kakinada 28, Khammam 24, Bhadrachalam 23, Dowlaiswaram 21, Rajamundry 20, Madhindra 19, Narsapur 17, Konta 16, Lengpui 14, Mahabaleshwar, Tikabali 11, Borsad 10, Padra, Ankola & Thirthahalli 9 each, Karkalla & Agumbe 8 each, Botad, Dholai, Sonamura, Gaganbavda & Daringibadi 7 each
21	Bhatkal 29, Vythiri 19, Shirali, Mangalore, Kannur & Hosanagara 16 each, Irikkur 15, Goalpara 14, Panjim 12, Port Blair, Domohani & Medikeri 10 each, NH-31 & Gaganbavda 9 each, Veraval, Tirupathi & Valparai 7 each	Mhasala 17, Dharavi 15, Ayodhya, Hardwar & Peermade 14 each, Pallahara 13, Kotdwar 12, Kalaikunda & Mangalore 11 each, Palliakalan, Madhuban & Karimganj 10 each, Birpur & Cherrapunji 9 each, Dharamshala, Kharagpur, Naraingarh, Sriperumbudur, Tiruttani, Ambala & Dharamtul 8 each, Balimundali, Sonbarsa, Igatpuri, Kaij, Konni & Irkal 7 each	Cherrapunji 12, Mahabaleshwar & Banda 11 each, Rajnandgaon & Durg 10 each, Nalbari, Bhira & Lanjhi 9 each, Paikmal, Tilaiya, Vapi & Matheran 8 each, Delhi, Valsad & Amgaon 7 each	Medak 19, Jagitiyal 18, Konta, Aurad & Mominabad 13 each, Billoli 11, Imphal, Mahabaleshwar & Parbhani 10 each, Nagrakata & Ratnagiri 9 each, Bokajan, Bhira & Jhawa 8 each, Kailashahar, Lakhipur, Daman & Medikeri 7 each
22	Cancona 26, Karwar 23, Honavar 22, Dabolim 21, Panjim 20, Dhubri & Mathabhanga 16 each, Taibpur 15, Dengraghat 13, Pallahara 11, Irikkur 10, Goalpara, Kodinar & Mangrol 9 each, Jaipatna 8, Cooch Behar, Gaganbavda, Medikeri & Kozhikode 7 each	Devgad 20, Alibag 19, Igatpuri 16, Ratnagiri 14, Dharampur 13, Mohitnagar, Swampatna, Udupi, Panambur & Bhatkal 10 each, Karanjia, Ayodhya & Varanasi 9 each, Champasarai, Mahabaleshwar, Gaganbavda & Manora 8 each, Deoband 7	Maihar 22, Cherrapunji & Ajaygarh 16 each, Ayodhya 13, Cooch Behar 10, Tilaiya, Banda & Mahabaleshwar 9 each, Sabroom & Sulya 8 each, Konner, Kursela & Kalpi 7 each	Poladpur & Gaganbavda 18 each, Panjim, Mahabaleshwar & Roing 17 each, Dahanu 15, Bansda 13, Valsad & Kallamnuri 12 each, Nasik 11, Ambala, Belgaum & Londa 10 each, Beed & Tezu 9 each, Dharmanagar, Cherrapunji, Mahuva, Vallabhipur & Kangra 8 each, Buldhana 7
23	Chargharia 28, Araria 25, Guhagar 24, Alibag & Mumbai 21 each, Cherrapunji 20, Chepan 19, Cooch Behar 18, North Lakhimpur, Kodinar & Honavar 10 each, Rajula 9, Gaganbavda 8, Simulia, Paikmal, Lucknow, Kadda, Kondagaon, Agumbe, Hosdurg & Kasargod 7 each	Murud 15, Dharamanagar 14, Chiplun 13, Kailashahar 12, Dehra Dun & Mahbubnagar 11 each, Rayaganj, Bijepur, Subramanya & Chandrapur 9 each, Ankinghat, Mukteshwar, Karkalla, Kotdwar & Durg 8 each, Long Island, Muradabad, Gaganbavda, Gulbarga, Sringeri, Agumbe & Khandapada 7 each	Cherrapunji 19, Chepan 14, Sabroom 11, Alipurduar & Basti 10 each, Jaunpur & Chengam 9 each, Tirukattupalli 8, Khonsa, Sonamura & Paradip 7 each	Vyara 22, Halol & Sankheda 21 each, Matheran 19, Passighat, Palitana & Wada 18 each, Bhira 16, Kumta, Londa & Igatpuri 13 each, Bhavnagar 12, Honavar 10, Gaganbavda 9, Mahabaleshwar & Tiruvallur 8 each, Shajapur, Ranasthalam, Tekkali, Shirali, Belgaum & Polur 7 each
24	Cherrapunji 38, Talasari 22, Vasai 21, Madhuban 14, Mekhliganj & Mahabaleshwar 13 each, Laikera 12, Basti, Kodinar & Sakoli 9 each, Adilabad, Bhiwani & Agumbe 8 each, Bassi & Pachmarhi 7 each	Hosanagara & Linganamakki 23 each, Poladpur 21, Honavar 19, Panjim 18, Subramanya & Vengurla 17 each, Nawrangpur, Mahabaleshwar & Prakasam Barrage 13 each, Vijaywada, Ramgundam & Kaleswaram 12 each, Chhindwara, Medikeri, Thodupuzha, Mananthavady & Dharamshala 10 each, Balimundali, Sultanpur & Gudalur Bazar 9 each, Lengpui & Mathura 8 each, Bihubar, Dholai, Aizwal, Sagar, Valparai, Mangrulpir & Naduvattam 7 each	Cherrapunji 48, Alipurduar & Mukhlishpur 19 each, Chepan 17, Ghazipur 14, Salem 11, Tezu, Chouldhowaghat, Sardarnagar, Bangana & Venkata Giri Kota 10 each, Passighat, Sonamura & Mandya 9 each, Gannavaram, Chikkanahalli & Kuppam 8 each, Dharmapuri 7	Deoband 23, Dholka 17, Passighat & Udaipur 16 each, Roing & Kadi 15 each, Visnagar & Sahranpur 14 each, Mellabazar, Matunga & Degana 13 each, Dabolim & Nathdwara 12 each, Jallar, Jind & Bhira 10 each, Ghogha & Rajgarh 9 each, North Lakhimpur, Bosan, Paonta & Mahabaleshwar 8 each, Diana, Bhalukpong, Ukimath & Kota 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
25	Valsad 25, Bardoli 20, Pallahara 19, Cherrapunji & Amraoti 17 each, Agumbe 15, Thakurmunda & Vasai 12 each, Ambarnath & Mangrol 10 each, Midnapore, Kaleswaram & Dharmasthala 9 each, Bhalukpong, Durgachak, Udgir & Sriramsagar 8 each, Porbandar, Selu, Deoli, Thalasserry & Thodupuzha 7 each	Roha 48, Chiplun & Valpoi 36 each, Gaganbavada 26, Senguem 25, Mangaon 24, Asifabad, Pen, Mhasala, Margoa & Ponda 23 each, Panjim & Mahabaleshwar 22 each, Sawantwadi & Dabolim 21 each, Mahad, Shrivardhan & Sirsa 20 each, Koida, Mani & Londa 18 each, Vidisha & Agumbe 17 each, Sorab 15, Jeypore, Kotdwar 14, Kotagarh & Thodupuzha 13 each, Raisen, Shahuwadi, Khanapura & Kallamnuri 12 each, Hingoli 11, Agartala, Cherrapunji, Kanker, Mungeli, Simga, Umrer & Mananthavady 10 each, Rajamundry, Lanji & Chandrapur 7 each	Motihari 52, Chanpatia 24, Cherrapunji 16, Birdghat & Regoli 13 each, Dehra Dun 12, North Lakhimpur 10, Chouldhowaghat 9, Barobhisa & Kolkata 8 each, Mussoorie & Keeranur 7 each	Kashipur 30, Nainital 22, Tadong 21, Deoband 20, Kalagarh 18, Muzaffarnagar 17, Mangaliwas 16, Bhinay 15, Gangtok 14, Luni 12, Passighat, Sonepat & Narora 11 each, Kotputli 10, Port Blair, Nangal Chaudhary, Ponneri, Jawda & Rajgarh 9 each, Karimganj, Gannaur & Thiruvallur 8 each
26	Gandevi 37, Dharampur 32, Valsad 30, Padra 28, Navsari 23, Pardi 21, Chikhli 20, Wada 19, Peint 15, Warora 14, New Kandla 13, Mahabaleshwar 12, Morvi & Dantewada 11 each, Chandigarh 10, Nagpur, Purihansa & Burdhwan 9 each, Jeypore & Haridwar 8 each, Patiala, Cherthala, Kashipur, Kollur & Agumbe 7 each	Poladpur 59, Pali 52, Mahabaleshwar 43, Gandevi 37, Mangaon & Matheran 36 each, Dharampur 32, Valsad 30, Karjat & Khalapur 29 each, Padra 28, Paud 26, Wadgaon Mawal 25, Navsari & Kallamnuri 23 each, Pardi 21, Chikhili 20, Sirsi, Lakkavalli & Somwarpet 18 each, Jagalbet & Nippani 17 each, Sankeshwara 15, New Kandla 13, Mahabaleshwar 12, Mananthavady, Morvi, Dantewada & Panjim 11 each, Chandigarh & Koida 10 each, Ambalavayal, Purihansa, Burdhwan, Gudalur Bazar, Gariaband, Deori & Bodhan 9 each, Haridwar & Langi 8 each, Patiala & Cherthala 7 each	Sonbarsa & Cherrapunji 21 each, Saulighat 14, Namakkal & Tiruppuvanam 10 each, Khonsa 9	Banbasa & Beki Mathanguri 13 each, Bareilly, Mukteshwar, Hasimara & Seppa 11 each, Nagrakata & Bhalukpong 8 each, Gangtok & Arani 7 each
27	Dharampur 26, Surgana 25, Pardi & Bhira 21 each, Dongargaon 14, Dongargarh 13, Pallahara 12, New Kandla & Lanjigarh 9 each, Hoshangabad 8, Phaphamau, Guna & Rajula 7 each	Vihar 104, Mumbai (SCZ) 94, Bhandup 81, Dharavi 49, Mahabaleshwar & Parbhani 26 each, Basmat & Kalamnuri 23 each, Gaganbavda 15, Somwarpet, Thodupuzha & Shiralkoppa 13 each, Bhanjanagarh 12, Deori, Madapura & Joida 11 each, Tangla, Valparai, Kollur & Nilambur 10 each, Bihubar, Ahwa, Umrer, Metapalli, Sriramsagar & Paonta 9 each, Aizwal, Mathura, Loharia, Naghulaganj, Narsinghpur, Shenkottah, Londa & Nasrullagay 8 each, Anandpur, Garhi, Shujalpur & Vidisha 7 each	Kumbakonam 13, Aluva 11, Passighat, Kolkata, Chalakudy, B. Durga & Nagapattinam 9 each, Kotdwar 7	Yelburga 12, Nagrakata 11, Sankalan 9, Koppal 8, Daporijo 7

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
28	Dharampur 39, Thakurmunda 38, Telkoi & Pallahara 34 each, Broach, Valod 27, Pardi 25, Ahwa, Valsad 24, Bansda, Mahuva, Navsari & Songadh 23 each, Bardoli & Daman 22 each, Mahabaleshwar 20, Mahuva 16, Londa & Linganamakki 15 each, Jafrabad & Gaganbavda 14 each, Dhanora 13, Arang & Valpoi 12 each, Raipur 11, Kalaikunda, Durgachak, Viratnagar & Khanapura 10 each, Muzzaffarnagar, Bhira & Siddapura 9 each, Mandawar & Talaguppa 8 each, Sarsawa & Sirsi 7 each	Igatpuri 27, Mhow & Khon 25 each, Pratapgarh & Jhabua 24 each, Nithua 23, Banswara, Ghatol & Petlabad 21 each, Danpur, Kushalgarh & Sabla 20 each, Surgana 16, Agumbe 14, Rajapur & Linganamakki 13 each, Jhalod 12, Narsinghpur, Dahanu & Yellapur 11 each, Dohad, Tendukheda & Mananthavady 10 each, Cherrapunji, Bhinmal, Kollur & Vythiri 9 each, Gudalur Bazar & Londa 8 each, Naduvattam & Dadatu 7 each	Jalpaiguri 12, Murti, Ranasthalam & Rayadurg 11 each, Yercaud, Arsikere, Subramanya & Chepan 10 each, Namakkal, Rampur & Purushottampur 9 each, Passighat 8, Dhubri, Nagrakata, Katemiaghat & Tajewala 7 each	Yedwad 9, Karaikal & Ramdurg 8 each
29	Songarh 55, Brahampur 49, Gandevi 47, Bansda & Madhuban 44 each, Chikhli 35, Pardi, Khamba 33, Navsari & Valod 32 each, Pallahara & Borsad 30 each, Mahuva & Amreli 29 each, Vapi & Bilaspur 28 each, Valsad 27, Palitana 25, Mahabaleshwar 24, Sihor 23, Padra & Silvasa 22 each, Rajula 21, Sankheda, Vyara & Lilia 20 each, Raigarh 19, Deogarh 18, Linganamakki 17, Matheran 15, Siddapura 14, Bagidora & Patan 11 each, Magra & Badhore 10 each, Tantloi, Didihat & Bhira 9 each, Bihubar 8, Chouldhowaghat, Gangtok & Muktsar 7 each	Visnagar 32, Vijapur 27, Chandbali 25, Kheralu 24, Thakurmunda 23, Prantij 22, Idar 21, Mansa 20, Mahabaleshwar 17, Jaswantpura, Mount Abu & Thodupuzha 15 each, Gaganbavda 14, Dariabad 12, Bhira, Rajapur & Peermade 11 each, Somwarpet 10, Jamnagar, Meipalli & Agumbe 9 each, Bilara & Subramanya 8 each, Uttarkashi, Rewa, Koppa, Sriramsagam & Valparai 7 each	Murti 11, Yercaud, Sholapur & Gooty 10 each, Namakkal 9, Koratagere 8, Nagrakata, Bhalukpong, Bihubar & Subramanya 7 each	Hubli 17, Papanasam 15, Mannargudi & Drathanadu 12 each, Balurghat & Hosur 9 each, Kolkata 8, Belgaum, Harapanahalli & Madhugiri 7 each
30	Ahwa 36, Gandevi 31, Vyara 30, Bansda 26, Kamrej 25, Malajkhand, Navsari, Khambha & Mahabaleshwar 24 each, Dhandhuka, Vallabh Vidyanagar, Chikhli, Surat, Limbdi & Muli 22 each, Mahuva 21, Navapur 19, Ambikapur & Bhira 17 each, Dahanu & Agumbe 15 each, Kottigehara 14, Joida, Londa & Champa 12 each, Belthangady & Dindori 11 each, Margherita & Darjeeling 10 each, Belonia 8, Hemgiri, Salumber & Khanapura 7 each	Tikarpada & Rairakhol 31 each, Athagarh & Khandapada 29 each, Hindol 27, Akhuapada 25, Chandbali, Naraj & Athamalik 24 each, Mundali 23, Rajkanika, Rajkishorenagar & Dhenkanal 22 each, Cuttack & Jamankira 21 each, Pallahara, Rengali & Talcher 20 each, Agumbe 18, Jamnagar 17, Thodupuzha 14, Didihat, Bhira, Mahabaleshwar & Ranawar 13 each, Piravom, Korba, Manki & Londa 12 each, Kakatpur, Mahasamund & Linganamakki 11 each, Gaganbavda & Kollur 10 each, Mahasala 9, Chintapalli 8, Deogarh 7	Sholapur & Gooty 10 each, Jorhat 9, Khonsa 8, Bihubar & Sindagi 7 each	Joshal 12, Virudhachalam, Khonsa & Dholai 10 each, Vaniyambadi 9, Pottangi 8, Venkatagiri Kota & Silchar 7 each
31		Ambabhona 31, Thodupuzha 28, Bhagamandala 27, Pallahara 26, Mahabaleshwar 25, Peermade 22, Bargarh 21, Bijepur & Valparai 20 each, Katghora, Korba & Agumbe 19 each, Raipur 18, Matheran 17, Murud 16, Chandigarh, Baraseoni & Aluva 11 each, Dorimanna 10, Gudalur Bazar 9, Patti, Naduvattam, Nadbai, Sabalgarh & Kollur 8 each, Osain, Jamnagar & Chintapalli 7 each	Hubli 18, Murti 11, Yercaud, Jayapura & Thodupuzha 10 each, Pottangi, Namakkal, Tumkur, Ketti, Musiri & Anantpur 9 each, Nagrakata, Agathi & Arogyavaram 8 each, Savanur 7	

Andhra Pradesh and adjoining part of Orissa; southern part of Coastal Andhra Pradesh and adjoining northern part of Tamil Nadu and eastern part of Rayalaseema.

(*iii*) Isolated areas around Jalgaon (Madhya Maharashtra), Kakinada (Coastal Andhra Pradesh), Tiruchirapalli and Kanyakumari (Tamil Nadu).

8.3.4. *September*

(a) *Severe arid areas*

(*i*) Isolated areas around Vellore (Tamil Nadu).

(b) *Moderate arid areas*

(*i*) Small areas of southern parts of Coastal Andhra Pradesh; eastern and southern parts of Rayalaseema; northern and northwestern parts of Tamil Nadu and southern and southeastern parts of South Interior Karnataka.

(*ii*) Isolated areas around Agra (West Uttar Pradesh) and Madurai (Tamil Nadu).

9. Significant spells of heavy rains

Amounts of *heavy* and *very heavy* rainfall are given in Table 16 and the spatial distribution of *heavy* and *very heavy* rainfall is given in Table 17. Table 17 also indicates the *activity* of monsoon and sub-divisionwise extent of rainfall in terms of number of days when it was *widespread* or *fairly widespread*. Monthwise description is given below :

9.1. *Heavy rainfall during June*

During the month, *very heavy* rain occurred on 8 to 10 days in Assam & Meghalaya and Konkan & Goa; on 4 to 7 days in Sub-Himalayan West Bengal & Sikkim, Gujarat State, Madhya Maharashtra and coastal & south interior Karnataka and on 1 to 3 days in Andaman & Nicobar Islands, Arunachal Pradesh, Orissa, Bihar, Uttaranchal, east Rajasthan, east Madhya Pradesh, Vidarbha, Chattisgarh, coastal Andhra Pradesh, north interior Karnataka and Kerala. Also *heavy* rainfall occurred on 8 to 12 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, coastal & south interior Karnataka and Kerala; on 4 to 7 days in Andaman & Nicobar Islands, Arunachal Pradesh, Gangetic West Bengal, Orissa, Saurashtra & Kutch, Konkan & Goa and Madhya Maharashtra and on 1 to 3 days in Nagaland-Manipur-Mizoram-Tripura, Bihar, Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, east Rajasthan, west Madhya Pradesh, Marathwada, Vidarbha,

TABLE 17

Characteristics of monsoon rainfall

S. No.	Sub – division	(No. of days)			
		Vig.	Act.	V. Heavy	Heavy
1.	Andaman & Nicobar Island	–	–	6	15
2.	Arunachal Pradesh	–	23	12	33
3.	Assam & Meghalaya	–	11	28	43
4.	Naga., Mani., Mizo. & Trip.	2	9	3	18
5.	S.H.W.B. & Sikkim	1	24	20	37
6.	Gangetic West Bengal	4	15	6	22
7.	Orissa	7	14	23	38
8.	Jharkhand	1	15	2	7
9.	Bihar	2	13	8	19
10.	East Uttar Pradesh	–	3	10	24
11.	West Uttar Pradesh	–	3	3	22
12.	Uttaranchal	3	4	11	16
13.	Haryana	1	2	5	14
14.	Punjab	1	2	1	12
15.	Himachal Pradesh	2	8	4	23
16.	Jammu & Kashmir	–	–	2	2
17.	West Rajasthan	–	–	5	8
18.	East Rajasthan	–	–	14	20
19.	West Madhya Pradesh	3	12	7	19
20.	East Madhya Pradesh	5	13	10	19
21.	Gujarat Region	18	13	23	13
22.	Saurashtra & Kutch	18	6	12	13
23.	Konkan & Goa	4	31	28	29
24.	Madhya Maharashtra	1	22	28	40
25.	Marathwada	5	11	5	10
26.	Vidarbha	–	–	10	21
27.	Chattisgarh	2	16	8	21
28.	Coastal Andhra Pradesh	6	11	3	12
29.	Telangana	8	15	8	13
30.	Rayalaseema	8	6	1	13
31.	Tamil Nadu & Pondicherry	2	1	5	34
32.	Coastal Karnataka	–	18	18	40
33.	North interior Karnataka	8	16	10	25
34.	South interior Karnataka	11	17	28	37
35.	Kerala	4	19	22	29
36.	Lakshadweep	–	–	1	5

Chattisgarh, Telangana, Rayalaseema, Tamil Nadu and north interior Karnataka.

9.2. *Heavy rainfall during July*

The *exceptionally heavy* rainfall of 94.4 cm recorded at Mumbai (Santacruz) on 27 July, being a remarkable event of the season, is dealt in detail in a separate section under floods.

During the month, *very heavy rain* occurred on 12 to 14 days in Konkan & Goa, Madhya Maharashtra, south interior Karnataka and Kerala; on 8 to 9 days in Orissa, east Rajasthan and coastal Karnataka; on 4 to 6 days in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, east Uttar Pradesh, Uttaranchal, Haryana, Madhya Pradesh, Gujarat Region, Telangana and north interior Karnataka and on 1 to 3 days in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Jharkhand, Bihar, Punjab, Himachal Pradesh, Jammu & Kashmir, west Rajasthan, Saurashtra & Kutch, Marathwada, Vidarbha, Chattisgarh and Tamil Nadu. Also *heavy rain* occurred on 18 days in Assam & Meghalaya; on 14 to 16 days in Sub-Himalayan West Bengal & Sikkim, Orissa, west Uttar Pradesh, east Madhya Pradesh and coastal & north interior Karnataka; on 8 to 12 days in Arunachal Pradesh, Bihar, east Uttar Pradesh, Himachal Pradesh, east Rajasthan, west Madhya Pradesh, Vidarbha, Chattisgarh, Telangana, Tamil Nadu, south interior Karnataka and Kerala; on 4 to 6 days in Andaman & Nicobar Islands, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Uttaranchal, Haryana, Punjab, west Rajasthan, Konkan & Goa, Madhya Maharashtra, Marathwada and coastal Andhra Pradesh and on 2 to 3 days in Jharkhand, Jammu & Kashmir, Gujarat State, Rayalaseema and Lakshadweep.

9.3. *Heavy rainfall during August*

During the month, *very heavy rain* occurred on 11 days in Assam & Meghalaya; on 4 to 7 days in Sub-Himalayan West Bengal & Sikkim; Orissa, Bihar, east Uttar Pradesh, Gujarat Region, Madhya Maharashtra and south interior Karnataka and on 1 to 3 days in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Jharkhand, Uttaranchal, Himachal Pradesh, Jammu & Kashmir, east Rajasthan, Konkan & Goa, Vidarbha, Chattisgarh, Tamil Nadu, coastal & north interior Karnataka and Kerala. Also *heavy rain* occurred on 11 to 13 days in Arunachal Pradesh, Assam & Meghalaya, Madhya Maharashtra and south interior Karnataka; on 8 to 10 days in Sub-Himalayan West Bengal & Sikkim, Orissa, east Uttar Pradesh, Konkan & Goa and coastal Karnataka; on 4 to 7 days in Andaman & Nicobar Islands, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Jharkhand, Bihar, west Uttar Pradesh, Uttaranchal, Haryana, Himachal Pradesh, Madhya Pradesh, Gujarat Region, Vidarbha, Chattisgarh and Rayalaseema and on 1 to 3 days in Punjab, west Rajasthan, east Madhya Pradesh, Saurashtra & Kutch, coastal Andhra Pradesh, north interior Karnataka, Kerala and Lakshadweep.

9.4. *Heavy rainfall during September*

During the month, *very heavy rain* occurred on 6 to 8 days in Orissa and Gujarat Region; on 3 to 5 days in Andaman & Nicobar Islands, Arunachal Pradesh, Sub-Himalayan West Bengal & Sikkim, west Uttar Pradesh, Uttaranchal, Rajasthan, Saurashtra & Kutch, Konkan & Goa, Madhya Maharashtra, Marathwada, Chattisgarh, Telangana, interior Karnataka and Kerala and on 1 to 2 days in Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, east Uttar Pradesh, Madhya Pradesh, Vidarbha, coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, coastal Karnataka and Lakshadweep. *Heavy rain* also occurred on 13 to 15 days in Madhya Maharashtra and Tamil Nadu; on 6 to 8 days in Orissa, Gujarat Region, Konkan & Goa, Vidarbha, coastal & south interior Karnataka and Kerala; on 3 to 5 days in Arunachal Pradesh, Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, West Bengal & Sikkim, Bihar, east Uttar Pradesh, Uttaranchal, Haryana, Himachal Pradesh, west Madhya Pradesh, Saurashtra & Kutch, Marathwada, Chattisgarh, coastal Andhra Pradesh, Telangana, Rayalaseema and north interior Karnataka and on 1 to 2 days in Andaman & Nicobar Islands, west Uttar Pradesh, Punjab, Rajasthan, east Madhya Pradesh and Lakshadweep.

10. Significant temperature during the season

As mentioned earlier, during the period of hiatus in the further advance of monsoon, which might have been caused by the westerly intrusion and the prevalence of an anticyclone over central India, *severe heat wave conditions* occurred over many parts of the country including Orissa and coastal Andhra Pradesh. Talcher, a non departmental observatory in Orissa, recorded a maximum temperature of 50° C on 17 June 2005.

During the month of June, *Severe heat wave conditions* prevailed on 8 to 9 days in Orissa and Jharkhand; on 4 to 7 days in east Uttar Pradesh, Vidarbha, Chattisgarh and coastal Andhra Pradesh and on 1 day each in Gangetic West Bengal, west Uttar Pradesh, Rajasthan, Madhya Pradesh, Madhya Maharashtra and Telangana. Also *heat wave conditions* prevailed on 9 to 12 days in east Uttar Pradesh, Madhya Pradesh, Vidarbha and Chattisgarh; on 4 to 7 days in Jharkhand, Bihar, Haryana, Rajasthan, coastal Andhra Pradesh and Telangana and on

TABLE 18

The meteorological aspects of severe floods during southwest monsoon 2005

S. No. (1)	Region affected (2)	Period (3)	Cause (4)	Damage (5)	Synoptic feature prevailed (6)
1.	Kinnaur and Kullu districts of Himachal Pradesh	26 – 29 June 2005	A landslide created lake on the Parechu river in Tibet overflowed due to heavy rains and snowmelt. Meteorological data not available	It flooded large areas of Kinnaur and Kullu districts, forcing evacuation of 5,000 people. Six people died, several bridges and roads were destroyed, 2 villages inundated and 50 houses submerged	Not available
2.	Southern and central parts of Gujarat	28 June – 15 July 2005	Continuous spell of heavy rains caused rivers to overflow	According to media reports, 202 people lost their lives, more than 7,200 villages were inundated and around 1,76,000 people left homeless	Major synoptic features which caused the heavy rainfall : (*i*) A land depression moved in a westnorthwesterly direction across the country from Gangetic West Bengal to west Rajasthan (low pressure area) during 27 June to 8 July. (*ii*) A mid tropospheric cyclonic circulation between 3.1 & 5.8 km a.s.l. over Gujarat State and neighbourhood during 24 June to 3 July and (*iii*) The offshore trough at sea level from south Gujarat to Kerala coasts during 20 June to 5 July
3.	Baitarnii river and it's tributaries in Orissa	29 June – 3 July 2005	Heavy rain	It flooded the areas in Bhadrak, Jajpur, Anandpur, Dhamnagar and Chandbali districts, killed 1 person and 220 villages were evacuated	The land depression referred to above remained stationary over Jharkhand, centred close to Jamshedpur on 28 & 29 June
4.	Sagar, Chattarpur & Damoh districts in Madhya Pradesh	2 – 15 July 2005	Persistent exceptionally heavy rainfall	Sixty two people lost their lives and 1 million people in 6 towns and 358 villages were severely affected. Sagar, Chattarpur, Damoh, Sahra, Riva and Katni were the worst affected areas	(*i*) The land depression referred to in the above two cases, had a too slow translatory movement on 30 June. It remained stationary near Khajuraho during 1 evening to 4 July and near Nowgong on 5 July. This was typical of monsoon depressions, being embedded in an environment of westerlies to the south and easterlies to the north. The upper level easterlies also had been quite weak. (*ii*) Also there was another low pressure area over west Madhya Pradesh and adjoining east Rajasthan on 30 June & 1 July
5.	Northwest India	5 – 26 July 2005	Heavy rainfall and landslides	Forty people died and thousands of people were evacuated in Kullu region of Himachal Pradesh. Landslides and flash floods triggered by torrential rains in Jammu & Kashmir forced the Amarnath yatra to be suspended, even as thousands of pilgrims were stranded along yatra route. There was widespread damage as flood waters ravaged area around river banks and landslides cut off access to different areas in the state. Water flowed above the danger mark in 3 rivers – Chenab, Tawi and Ujj in Jammu region. Haryana also experienced damage when Jhelum river remained above the danger level during 21 to 23 July	Southwest monsoon had been quite active and at the same time, eastward moving systems in the westerlies to the north also contributed to rainfall in the northern hilly regions

TABLE 18 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)
6.	Uttar Pradesh and Uttaranchal	7 – 27 July 2005	Heavy rainfall triggered flash floods and landslides. Also, the water released by Nepal into Sharda and Gandak rivers on 20 July flooded 20 villages in Uttar Pradesh	Fifty five people died and 4,000 were evacuated from the Ganges river banks in Uttar Pradesh	Same as described above
7.	Northeast India, Bihar and Gangetic West Bengal	7 – 27 July 2005	Heavy rainfall	Fifteen people died in Assam, 1.9 million people were displaced and 400 villages were under water in Assam. In Arunachal Pradesh 4,000 people were left homeless	Remnants of the monsoon low pressure systems as upper air cyclonic circulations over Orissa, Jharkhand etc and the occasional shifting of the eastern end of the monsoon trough towards NE India, gave rise to heavy rainfall over Bihar, Gangetic West Bengal and NE India respectively
8.	Andhra Pradesh	10 & 11 July 2005	Incessant rain	Twelve people died and thousands of people in low lying areas were evacuated	Formation of a low pressure area over NW and adjoining west central Bay off Orissa-West Bengal coasts and its moving over to land
9.	Nagpur	11 July 2005	Flash floods in River Dhawanda due to breach of a dam because of heavy down pour	Two villages were swept away causing the death of 7 people	An upper air cyclonic circulation extending upto mid tropospheric levels over Chhatisgarh and adjoining east Madhya Pradesh during the period
10.	Maharashtra and Goa states:	26 July – 2 August 2005	Exceptionally heavy rainfall	The death toll was estimated to be nearing 1000. Heavy rains during 25 & 26 July severely affected Goa, leaving 7 labourers dead in a landslide. The unprecedented heavy rainfall of 94.4 cm recorded at Mumbai (Santacruz) on 27 July crippled the lifeline infrastructure at Mumbai for days together. More than 150 people were killed in Raigad district in the worst floods and landslides in 16 years. About 400 people died in Mumbai alone and 969 for Maharashtra state. About 76,000 animals have been killed and 7,00,000 hectares of land and 2,83,000 houses have been damaged. 16,000 villages were affected by the floods. The damages were estimated to be of the order of several billion rupees in Maharashtra. 2,25,000 hectares of crops in 15 districts were destroyed	Presence of a well marked low pressure area over Madhya Pradesh, marked off shore trough at the surface along the west coast and a well marked east-west oriented shear line in the lower troposphere caused the enhanced rainfall activity. The record rainfall at Mumbai might be attributed to the interaction of enhanced monsoon westerly current (low level jet speed 60 kts at Mumbai), Orography and the offshore vortices giving rise to enhanced phenomenal convection of Mesoscale dimension
11.	Karnataka state	3 August 2005	Water released from the over full dams of Maharashtra	10,000 evacuated from 202 villages along Krishna river in Bagalkot and Bijapur in Karnataka. Flood situations claimed 109 lives and 83,000 hectares of crops were destroyed	Nil
12.	Telangana region	10 – 23 July 2005	Continuous heavy rains	27 people died and more than 5000 were left homeless	Monsoon lows in their formative stage over the north Bay caused enhanced monsoon flow

TABLE 18 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)
13.	Orissa	30 July – 3 August 2005	The break/release of dams following heavy rainfall	Eight people died. Bramhani and Kharashrota rivers breach 23 embankments in Jajpur districts marooning 320 villages. 800 houses were damaged. 75,780 hectares of crops submerged in Bhadrak district and 3,44,857 people were evacuated	Monsoon lows (a deep depression and a well marked low pressure area) forming over northwest Bay and moving across the state in a series
14.	Andhra Pradesh	14 – 26 September 2005	Heavy rainfall	Seventy-four people died, 2,00,000 were displaced or homeless, 1,11,299 hectares of crops were destroyed	A depression formed over northwest Bay and the active monsoon conditions followed
15.	Chattisgarh	14 – 26 September 2005	Heavy rainfall	Nine people died, 2,50,000 left homeless and 835 villages in the above two districts were inundated	Same as in the above case
16.	Uttar Pradesh and Uttaranchal	16 – 30 September 2005	Floods and landslides due to heavy rain	Thirteen people died and 32 villages were devastated by floods from Ganga canal	The monsoon depression mentioned in the above case moved northwards over to this area

1 to 3 days in Gangetic West Bengal, Orissa, west Uttar Pradesh, Uttaranchal, Punjab, Gujarat Region and Madhya Maharashtra.

Day temperatures were *appreciably to markedly above normal* on 1 to 2 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Orissa, Jharkhand, Uttar Pradesh, Uttaranchal, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Madhya Pradesh, Madhya Maharashtra, Marathwada and Rayalaseema. They were *appreciably above normal* on 17 days in Madhya Maharashtra; on 10 to 14 days in Sub-Himalayan West Bengal & Sikkim, Orissa, east Rajasthan, Madhya Pradesh, Gujarat Region, Marathwada, Vidarbha and Telangana; on 6 to 9 days in Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Jharkhand, Bihar, Uttar Pradesh, Uttaranchal, Haryana, Himachal Pradesh, west Rajasthan, Saurashtra & Kutch and Chattisgarh; on 3 to 5 days in Punjab, Jammu & Kashmir, Konkan & Goa and coastal Andhra Pradesh and on 1 to 2 days in Rayalaseema, Tamil Nadu and Karnataka. They were *appreciably to markedly below normal* on 1 day in west Madhya Pradesh and were *appreciably below normal* on 3 to 4 days in Punjab and Jammu & Kashmir and on 1 to 2 days in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, west Uttar Pradesh, Haryana, Konkan & Goa and Madhya Maharashtra, during the month of June. During the rest of the season, temperature departures were within the normal limits other than some random fluctuations noticed during some lengthy rainless period over a particular region, mostly in August.

11. Disastrous weather events and damage during monsoon months

11.1. *June*

During the month, the thunderstorm activity, took a toll of 14 lives in Assam & Meghalaya and 6 in Madhya Pradesh. Heat waves and sunstrokes caused a death toll of 186 in Orissa, 70 in Bihar, 39 in West Bengal and 3 in Maharashtra (Vidarbha). Heavy rains and flood took the lives of 40 in Gujarat, 15 in Kerala, 12 in Karnataka, 11 in Madhya Pradesh and 6 in Maharashtra.

11.2. *July*

During the month, Maharashtra and Gujarat were the worst affected States due to heavy rain and flood. On the 27 July, Mumbai (SCZ) recorded highest ever rainfall of 94.4 cms which caused its isolation from the remaining parts of the country. It also damaged properties worth Crores of rupees and rendered many people homeless in these regions. Heavy rain and flood related events took a toll of 831 in Maharashtra, 202 in Gujarat, 62 in Madhya Pradesh, 24 in Goa, 13 in Assam & Meghalaya, 12 in Andhra Pradesh, 11 in Kerala, 9 in Karnataka. Also more than 1.5 Lakh of people were affected by flood in Assam & Meghalaya and 26 people died due to thunderstorm.

11.3. *August*

Heavy rain and flood claimed the lives of 1000 people in Maharashtra including 425 people from

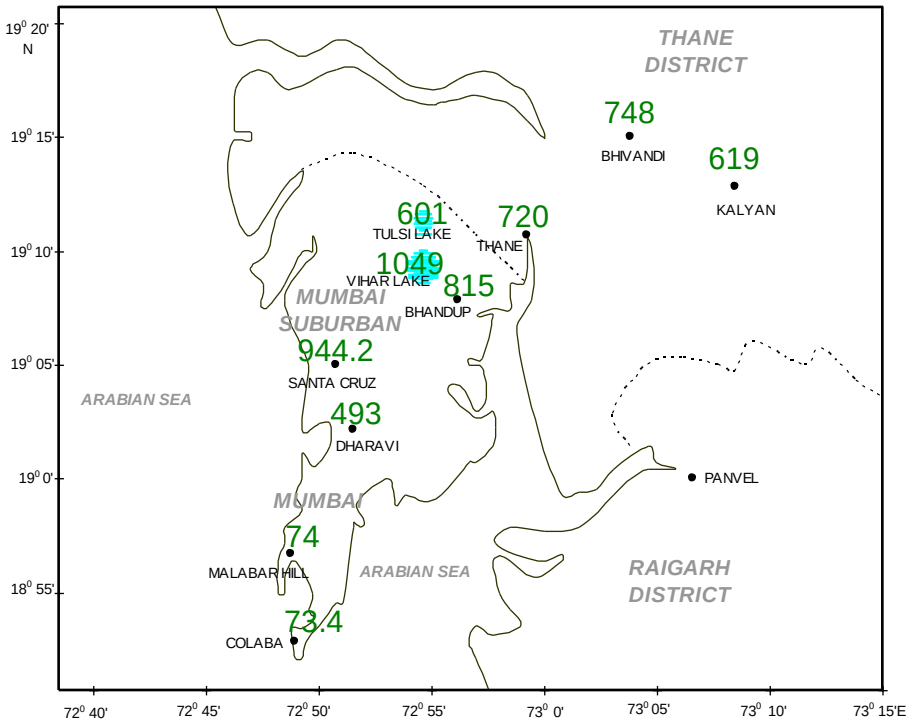


Fig. 14. Rainfall (mm) over Santacruz (Mumbai) and neighbourhood on 26-27 July 2005

Mumbai, 29 in Assam & Meghalaya, 15 in Kerala and 13 in Karnataka.

11.4. *September*

Heavy rains and floods related incidents claimed 13 lives in Gujarat and 5 in Maharashtra. Cyclonic storm in the mid of the month took a toll of 56 lives in Andhra Pradesh.

12. Damage due to floods etc. during monsoon season

According to some available reports floods, heavy rain, landslides, lightning etc. took a toll of about 1543 human lives in various parts of the country. Maharashtra was the worst affected state, where 1015 people lost their lives, due to floods and heavy rain. Gujarat was the second worst affected state, where 215 people lost their lives. Assam (78), Andhra Pradesh (77), Madhya Pradesh (68), Kerala (54), Goa (24) and Karnataka (12) were the other affected states.

Some of the major flood events occurred during the season are summarised in Table 18. The data are compiled from various sources like www.dartmouth.edu, press reports and other disaster reports.

This seasonal summary will not be completed without an account of the deluge at Mumbai. The following section gives a brief summary.

12.1. *Exceptionally heavy rainfall over Mumbai (26–27 July 2005)*

Mumbai (SCZ) recorded an unprecedented heavy rainfall of 944.2 mm on 27 July morning. The heaviest rainfall in 24 hrs recorded earlier in Mumbai was on 5 July 1974, when Colaba and Santacruz recorded 575.6 mm and 375.2 mm respectively.

On the same day, many other stations in the vicinity and to the north of Santacruz also reported rainfall of similar magnitude. Fig. 14 shows the rainfall recorded at Santacruz and surrounding stations on 27 July 2005.

The synoptic features prevailed during the period are given in Table 18.

Acknowledgements

Valuable inputs from the offices of India Meteorological Department *viz*., (*i*) Additional Director

General of Meteorology (Hydromet), New Delhi and (*ii*) Additional Director General of Meteorology (Research), Pune are gratefully acknowledged. Thanks are due to S/Shri M. V. Mande, A. D. Khutwad, P. N. Chopade, P. S. Kulkarni, Smt. Bharati Sabade and V. S. Khobragade for their help in bringing out this report.

Appendix

Definitions of the terms given in '*Italics*'

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 %.

Widespread (Most places) - 75% or more stations of a meteorological sub-division reporting at least 2.5 mm rainfall.

Fairly widespread (Many places) - 51% to 74% stations of a meteorological sub-division reporting at least 2.5 mm rainfall.

Heavy rain - rainfall amount from 6.5 cm to 12.4 cm.

Very heavy rain - rainfall amount more than 12.5 cm.

Exceptionally heavy - when the amount is a value near about the highest recorded rainfall at or near the station for the month or season. The highest ever recorded should be more than 12 cm.

Monsoon activity

Active - average rainfall of a sub-division is more than 1 ½ to 4 times the normal with minimum 5 cm along the west coast and 3 cm elsewhere in atleast 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 atleast two stations in the sub-division.

LRF Terminology

Normal monsoon - 90 to 110 percent of long period average seasonal rainfall.

Maximum/day temperatures

According to the new criteria, since 1st March 2002, Heat Wave will be declared only when the maximum temperature of a station reaches at least 40° C for plains and at least 35° C for Hilly regions.

Severe heat wave conditions - departure of maximum temperature from normal is +6° C or more for the regions where 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 - + 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. (declared only when the maximum temperature of a station reaches at least 40° C for Plains and at least 30° C for Hilly region).

Markedly above normal - departure of maximum temperature from normal is between +5° C to +6° C for the regions where the normal maximum temperature is 40° C or less

Appreciably above normal - +3° C to +4° C for the regions where the normal maximum temperature is 40° C or less.

Appreciably below normal - departure of maximum temperature from normal is –3° C to –4° C.

Markedly below normal - departure of maximum temperature from normal is –5° C or less.