MAUSAM, **56**, 3 (July 2005), 721-756

Weather in India

MONSOON SEASON (June to September 2004)†

1. Introduction

Southwest monsoon 2004 was characterised by it's a typical early onset over Kerala on 18 May. This occurred in consequence to a cyclonic storm that formed over the Bay of Bengal during the third week of May, causing a strong surge of cross equatorial flow which heralded the commencement of monsoon rains over Kerala coast. During the period 1901–2004, there had been 14 cases in which monsoon onset over Kerala was close to or prior to this date. They are, 1918 & 1955 (11 May), 1960(14 May), 1932 & 1962 (15 May), 1956 (16 May), 1925, 1942 & 1969 (17 May), 1933 & 2004 (18 May) and 1927, 1961 & 1990 (19 May). Though it was mentioned as a 'temporary advance' on operational basis, this onset date was confirmed later on by various broad scale circulation patterns and also by the rainfall that followed. Irrespective of its early onset over Kerala, the further progress across the country was sluggish. It took about 2 month's time to cover the entire country.

The seasonal rainfall for the country as a whole was 87% of its long period average. Rainfall was not distributed in the time domain, owing to the prolonged weak or break conditions that prevailed during late June, most of July, late August and early September. However, there were no *excess** or *scanty* sub-divisions by the end of the season and also the rainfall deficiency was not too high. The total area of the country, which experienced drought conditions was 18% and thus the year was not classified as an all India drought.

The unusual warming took place over the equatorial central Pacific during the period triggered the enhanced typhoon activity over there. Instead of following a westward course, most of them moved in a north and northeasterly direction. This might be one of the main reasons for the below normal rainfall of southwest monsoon 2004.

2. Characteristic features of southwest monsoon 2004

2.1. Southwest monsoon set in over Kerala on 18 May, two weeks ahead of the normal date. It was in association with a very severe cyclonic storm formed over the Bay of Bengal during 16–19 May.

2.2. It covered the entire country on 18 July, with a delay of 3 days from the normal date.

2.3. Only three monsoon depressions formed during season; one each over the Arabian Sea and the Bay of Bengal in June and the third one in September over the land. July & August were devoid of depressions. Also a cyclonic storm formed over the Arabian Sea towards the end of September.

2.4. Out of the 36 Met. sub-divisions 23 received *normal* rainfall while the remaining 13 were *deficient*.

2.5. The seasonal rainfall for the country as a whole was 87% of its long period average and thus had been a *deficient* rainfall year.

2.6. Southwest monsoon withdrew from the extreme west Rajasthan on 24 September, with a delay of about 3 weeks. It withdrew from the entire country on 18 October, with the simultaneous commencement of northeast monsoon rains over the southern peninsula.

2.7. Northwest Pacific witnessed an above normal typhoon activity during the period. Altogether 22 systems formed over there, during June to September, out of which 11 attained typhoon intensity. Most of them moved northwards and recurved, thereby, perhaps, adversely affecting the Indian summer monsoon rainfall.

3. Features of monsoon

3.1. *Advance of southwest monsoon*

The monsoon current reached south Andaman Sea on 13 May. It covered southern parts of the Bay and the Andaman Sea on 14 May, 6 days prior to the normal date.

The monsoon onset over Kerala was in association with a *very severe cyclonic storm* over the Bay of Bengal during 16–19 May, which crossed Myanmar coast on 19 May. Monsoon covered the entire northeast India by 23 May, 2 weeks ahead of its normal date. Further advance was rather sluggish, until the almost simultaneous formation of two deep depressions, one over the Arabian Sea and the other over the Bay of Bengal. The movement of the system from the Bay of Bengal to west Uttar Pradesh across the country helped

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

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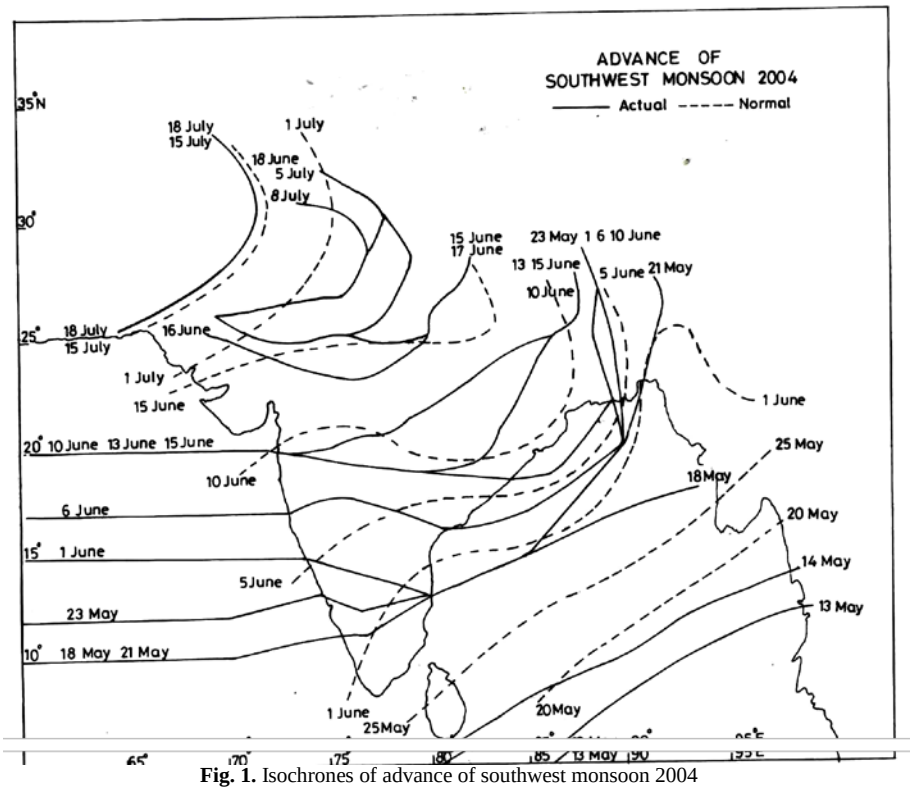


Fig. 1. Isochrones of advance of southwest monsoon 2004

the smooth advance of monsoon over the remaining peninsula, most parts of central India and parts of northwest India, by 18 June, close to normal dates. Subsequently, there was a prolonged hiatus during 19 June to 3 July when weak monsoon conditions prevailed all over the country.

Monsoon revived as a weak current during the first week of July with the formation of a low pressure area over the Bay of Bengal. It's movement towards northwest India helped monsoon to advance over some parts of Rajasthan. It covered most of the areas of the country outside, parts of Rajasthan, Haryana and Punjab by 8 July. But with the thermal trough shifting once again to the foothills, the second prolonged hiatus occurred during 9–17 July. It was after the formation of another low pressure area over the Bay of Bengal on 13 July and its movement towards the central India, that the monsoon further advanced and covered the entire country on 18 July. 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 19 weeks (2 June to 6 October) are given in Fig. 2(a).

Rainfall activity was generally good over the Peninsular India during the first half of June. Thereafter it remained subdued during the period 17 June to 7 July and 15 July to 1 September. September rainfall over Peninsular India was rather good. Over the central parts of the country, rainfall was subdued during 24 June to 28 July, received good rainfall during August and again subdued rainfall during the initial 3 weeks of September. Northwest India received good rainfall only during the weeks ending on 9 June, 23 June, 4 August and 18 August. But this region received good rainfall in the beginning of October, which gave rise to some relief for the deficient monsoon rains. Northeast India also, the rainfall was not well distributed in time, with the good rainfall activity confining to the period from 17 June to 21 July and towards the end of September.

3.2.2. *Weekly cumulative rainfall distribution*

Meteorological sub-divisionwise cumulative rainfall departures (percentage departure from normal) during the southwest monsoon season from 1 June to 30 September comprising of 17 weeks are given in Fig. 2(b).

TABLE 1

Advance of Southwest Monsoon 2004

Date	Region covered	Remarks
13 May 2004	Parts of south Andaman Sea and of southeast Bay	-
14 May 2004	Some parts of southwest Bay, some more parts of southeast Bay and of south Andaman Sea	6 days ahead
18 May 2004	Most parts of south Arabian Sea, Kerala and of Tamil Nadu, entire south Bay, parts of central Bay and entire Andaman Sea	Temporary advance was declared on operational basis due to the cyclonic storm over Bay of Bengal, which was confirmed later on
21 May 2004	Some more parts of central Bay, some parts of north Bay, entire Nagaland-Manipur-Mizoram-Tripura, some parts of Assam & Meghalaya and entire Arunachal Pradesh	Two weeks ahead in the northeastern states
23 May 2004	Entire south Arabian Sea, some parts of east central Arabian Sea and of coastal and south interior Karnataka, some more parts of Tamil Nadu and of north Bay, entire Assam & Meghalaya and some parts of Sub-Himalayan West Bengal & Sikkim	Two weeks ahead
1 Jun 2004	Some more parts of central Arabian Sea, coastal Karnataka, most parts of south interior Karnataka, some parts of Rayalaseema, some more parts of north Bay and entire Sub-Himalayan West Bengal	Five days ahead in most of the regions
6 Jun 2004	Some more parts of central Arabian Sea, remaining parts of coastal and south interior Karnataka, some parts of Konkan & Goa and Madhya Maharashtra, most parts of north interior Karnataka, entire Rayalaseema, some parts of Telangana and of coastal Andhra Pradesh and some more parts of west central and northwest Bay	More or less in the normal date
10 Jun 2004	Entire central Arabian Sea, most parts of Konkan & Goa, some more parts of Madhya Maharashtra and of Marathwada, most parts of Telangana, some parts of Chattisgarh and of Orissa, most parts of coastal Andhra Pradesh, entire west central and some more parts of northwest Bay	Near normal dates in the western parts and five days delay in the eastern parts
13 Jun 2004	Some more parts of Chattisgarh, most parts of Orissa, rest parts of northwest Bay, entire West Bengal and Sikkim and parts of Jharkhand and Bihar	In the near normal date
15 Jun 2004	Some more parts of Madhya Maharashtra, most parts of Marathwada, Vidarbha, Chattisgarh and of Jharkhand, rest parts of Orissa and some more parts of Bihar	Do
16 Jun 2004	Entire Arabian Sea, most parts of Gujarat state, entire Maharashtra state, some parts of west Madhya Pradesh, most parts of east Madhya Pradesh, entire Chattisgarh, Jharkhand & Bihar and some parts of east Uttar Pradesh	Do
17 Jun 2004	Entire Gujarat state, southern parts of Rajasthan, southern most parts of west Uttar Pradesh and some more parts of Madhya Pradesh	Do
18 Jun 2004	Most parts of west Madhya Pradesh, entire east Madhya Pradesh and east Uttar Pradesh, some more parts of west Uttar Pradesh, most parts of Uttaranchal, Himachal Pradesh and Jammu & Kashmir	A few days ahead in the northern parts
5 Jul 2004	Some parts of Rajasthan, entire west Madhya Pradesh, most parts of west Uttar Pradesh, some parts of Haryana (including Delhi) and of Punjab	Three to five days delay
8 Jul 2004	Some more parts of Haryana and most parts of Punjab	One week delay
18 Jul 2004	Rest parts of Haryana, Punjab and Rajasthan and thus the entire country	Three days delay

Even though sub-divisions receiving *scanty* rainfall was less (only Assam & Meghalaya for week ending on 16 June and west Rajasthan for week ending on 28 July) those sub-divisions which fell under the category of *deficient* monsoon remained so during most parts of the season.

Week by week rainfall during SW Monsoon 2004

1 June – 30 September 2004

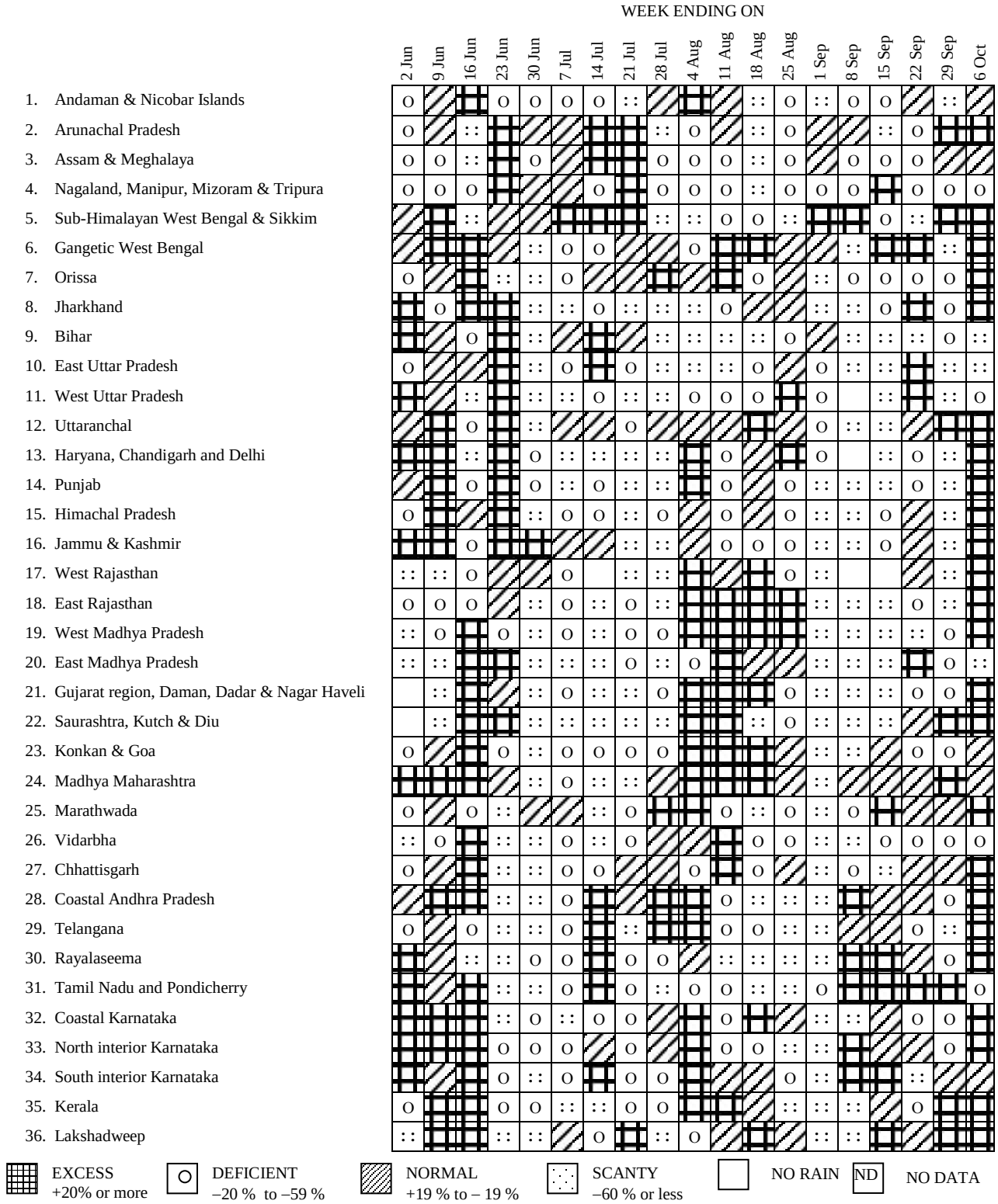


Fig. 2(a). Week by week rainfall during SW Monsoon 2004

Week by week cumulative rainfall

1 June – 30 September 2004

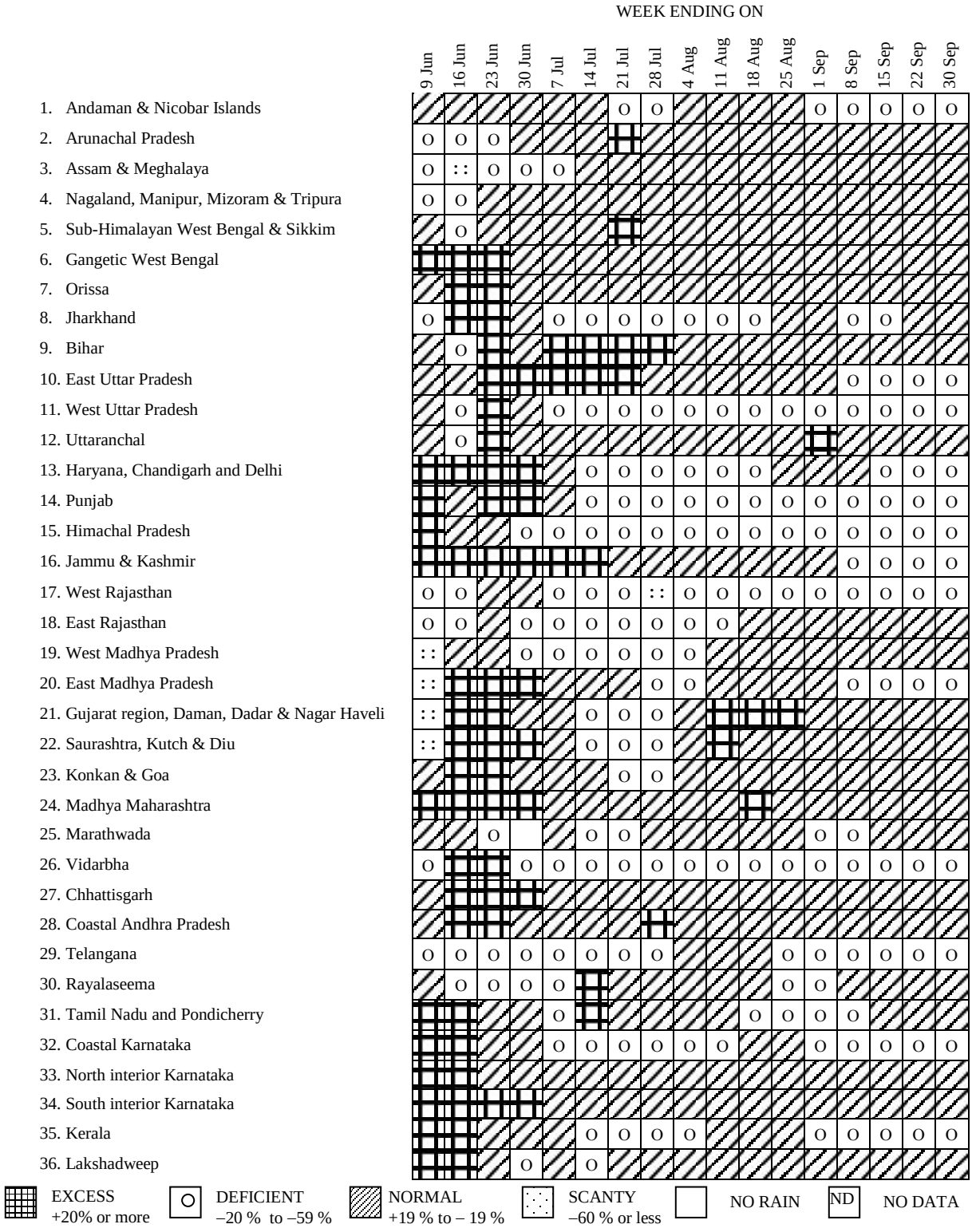


Fig. 2(b). Week by week cumulative rainfall during 1 June to 30 September 2004

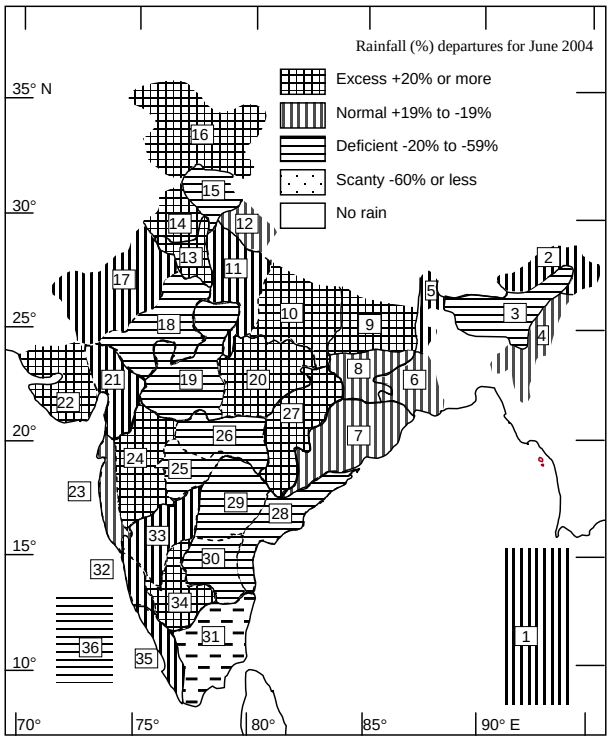


Fig. 3. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (June 2004). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–11	**7**	5	**13**	51	**19**	–25	**25**	–21	**31**	–7
2	–15	**8**	1	**14**	24	**20**	55	**26**	–20	**32**	–11
3	–32	**9**	35	**15**	–30	**21**	7	**27**	26	**33**	–1
4	–9	**10**	75	**16**	65	**22**	21	**28**	9	**34**	24
5	–12	**11**	–9	**17**	–3	**23**	–5	**29**	–55	**35**	–1
6	3	**12**	–8	**18**	–27	**24**	41	**30**	–53	**36**	–23

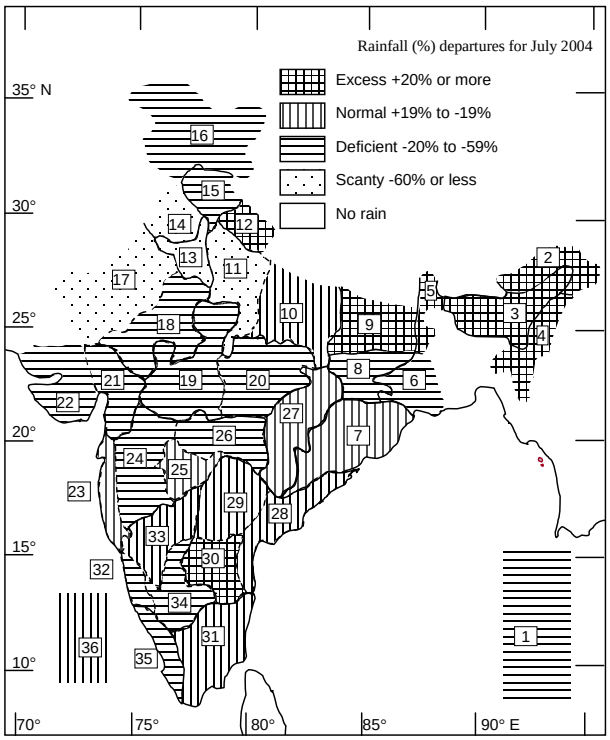


Fig. 4. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (July 2004). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–26	**7**	–4	**13**	–88	**19**	–30	**25**	13	**31**	–4
2	28	**8**	–34	**14**	–62	**20**	–46	**26**	–31	**32**	–42
3	34	**9**	21	**15**	–56	**21**	–31	**27**	–14	**33**	–11
4	43	**10**	–18	**16**	–22	**22**	–55	**28**	5	**34**	–27
5	25	**11**	–60	**17**	–73	**23**	–16	**29**	–3	**35**	–49
6	–21	**12**	24	**18**	–54	**24**	–37	**30**	27	**36**	0

Punjab and Himachal Pradesh were the maximum rainfall *deficient* sub-divisions followed by west Rajasthan. They remained *deficient* from 14 July, 30 June and 7 July respectively. Also there were 6 sub-divisions which remained *excess/normal* all through the season, *viz*., Gangetic West Bengal, Orissa, Chattisgarh, coastal Andhra Pradesh and north and south interior Karnataka.

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 23 and *deficient* in the remaining 13 met. sub-divisions. There were no sub-divisions which were *excess* or *scanty* at the end of the season.

3.5. *Districtwise distribution of monsoon rainfall*

Fifty six percent of the districts received *excess/normal* rainfall and the rest 44% received *deficient/ scanty* rainfall during the period 1 June – 30 September 2004.

Percentage of districts with *excess/normal* and *deficient/scanty* rainfall for the years 1999-2004 are given in Table 3.

3.6. *Withdrawal of southwest monsoon*

Southwest monsoon withdrew from parts of west Rajasthan and Punjab on 24 September, with a delay of

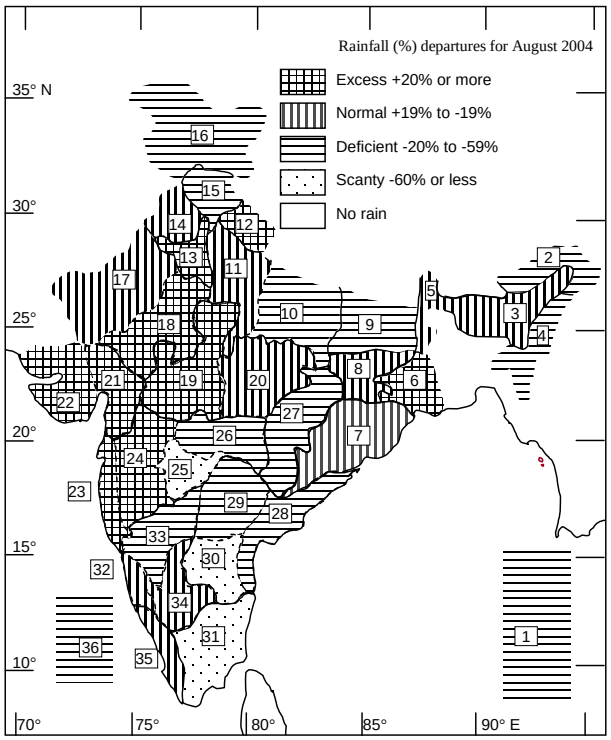


Fig. 5. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (August 2004). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–26	**7**	–3	**13**	49	**19**	34	**25**	–60	**31**	–68
2	–27	**8**	–13	**14**	–14	**20**	–8	**26**	–23	**32**	4
3	–36	**9**	–48	**15**	–25	**21**	89	**27**	–22	**33**	–32
4	–32	**10**	–44	**16**	–37	**22**	72	**28**	–39	**34**	–3
5	–30	**11**	–18	**17**	1	**23**	50	**29**	–31	**35**	–5
6	20	**12**	24	**18**	70	**24**	62	**30**	–75	**36**	–20

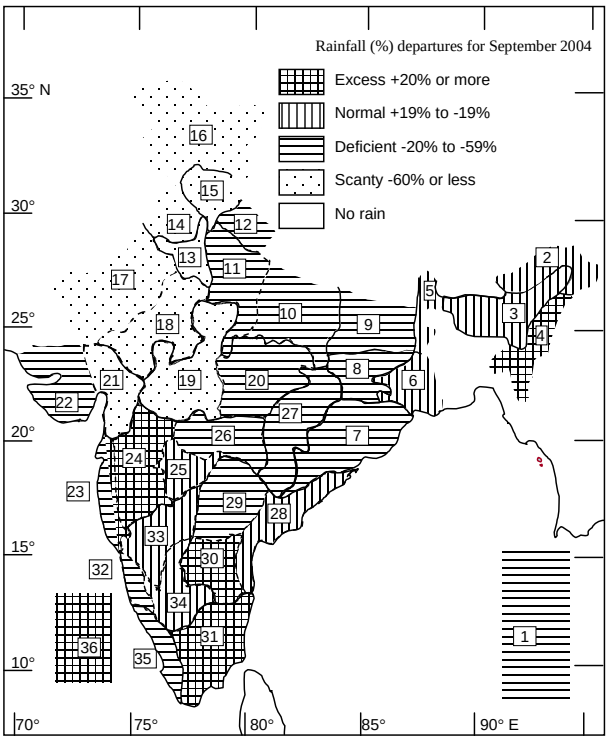


Fig. 6. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (September 2004). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–36	**7**	–40	**13**	–76	**19**	–73	**25**	7	**31**	87
2	–9	**8**	–27	**14**	–88	**20**	–48	**26**	–51	**32**	–49
3	–10	**9**	–59	**15**	–71	**21**	–68	**27**	–41	**33**	–6
4	27	**10**	–34	**16**	–61	**22**	–52	**28**	–2	**34**	–5
5	–2	**11**	–37	**17**	–79	**23**	–30	**29**	–31	**35**	–27
6	–6	**12**	–24	**18**	–74	**24**	25	**30**	34	**36**	22

about 3 weeks, due to the prevalence of circulation patterns causing rainfall over the region. It further withdrew from most parts of northwest India and parts of west central India on 27 September, more parts of central and north India by 8 October, most parts of southern peninsula and northeast India by 11 October and from the entire country on 18 October (with a delay of 3 days). Simultaneously northeast monsoon rains also commenced over Tamil Nadu, Kerala and adjoining areas of Karnataka and Andhra Pradesh on 18 October. Fig. 8 gives the isochrones of withdrawal of southwest monsoon.

3.7. *El-Nino phenomenon*

ENSO, the combined effect of Southern Oscillation (SO) and the Oceanic response El-Nino, is normally indicated 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. In general, during some years an inverse relationship between ENSO and Indian summer monsoon rainfall has been observed.

Table 4 depicts the monthly values of SST anomaly indices for NINO 4, NINO 3 and NINO 1+2 region and SOI for the period from October 2003 to September 2004. The monthly SST generally showed neutral condition across the Tropical Pacific. The NINO 1+2 index showed slight cooling from February 2004 until the end of monsoon season. On the other hand, the NINO 4 index showed persistent warming since October 2003 until September 2004. After its neutral conditions in April 2004, NINO 3 index remained negative during May to July 2004 and thereafter showed positive value during August and September 2004.

TABLE 2

Rainfall figures (mm) for each month and season as a whole (June – September 2004)

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	427	482	–11	309	419	–26	307	416	–26	283	438	–36	1326	1755	–24
2.	Arunachal Pradesh	419	494	–15	764	595	28	283	388	–27	325	358	–9	1791	1835	–2
3.	Assam & Meghalaya	385	567	–32	753	563	34	280	434	–36	289	321	–10	1707	1885	–9
4.	Naga., Mani., Mizo. and Tripura	329	361	–9	494	345	43	209	309	–32	288	226	27	1321	1241	6
5.	S. H. W. B. & Sikkim	436	496	–12	751	602	25	331	470	–30	379	388	–2	1896	1955	–3
6.	Gangetic West Bengal	247	240	3	248	315	–21	376	312	20	254	270	–6	1125	1136	–1
7.	Orissa	215	205	5	331	343	–4	352	363	–3	150	248	–40	1048	1160	–10
8.	Jharkhand	196	193	1	223	338	–34	286	329	–13	179	244	–27	884	1105	–20
9.	Bihar	237	175	35	423	348	21	155	298	–48	93	227	–59	906	1048	–14
10.	East Uttar Pradesh	185	105	75	253	309	–18	169	301	–44	131	198	–34	738	914	–19
11.	West Uttar Pradesh	63	69	–9	107	268	–60	233	286	–18	94	150	–37	497	773	–36
12.	Uttaranchal	151	164	–8	526	425	24	527	426	24	157	207	–24	1360	1223	11
13.	Haryana, Chandigarh & Delhi	65	43	51	21	171	–88	250	168	49	22	89	–76	358	470	–24
14.	Punjab	51	42	24	71	189	–62	145	169	–14	13	102	–88	280	502	–44
15.	Himachal Pradesh	63	90	–30	126	288	–56	197	262	–25	39	134	–71	425	774	–45
16.	Jammu & Kashmir	96	59	65	144	186	–22	110	174	–37	37	95	–61	387	514	–25
17.	West Rajasthan	26	27	–3	27	102	–73	95	94	1	9	41	–79	157	263	–40
18.	East Rajasthan	44	61	–27	103	224	–54	398	233	70	27	105	–74	571	624	–8
19.	West Madhya Pradesh	81	108	–25	215	305	–30	423	315	34	47	177	–73	765	904	–15
20.	East Madhya Pradesh	222	144	55	200	371	–46	353	382	–8	104	201	–48	879	1097	–20
21.	Gujarat region	131	123	7	247	361	–31	549	291	89	51	160	–68	979	934	5
22.	Saurashtra & Kutch	98	81	21	88	195	–55	238	138	72	35	72	–52	459	486	–6
23.	Konkan & Goa	641	675	–5	894	1069	–16	1070	712	50	242	347	–30	2847	2802	2
24.	Madhya Maharashtra	189	134	41	151	238	–37	285	176	62	190	151	25	815	700	16
25.	Marathwada	113	144	–21	218	192	13	79	194	–60	186	174	7	595	704	–16
26.	Vidarbha	133	167	–20	225	329	–31	230	300	–23	89	180	–51	678	976	–31
27.	Chattisgarh	238	189	26	339	394	–14	306	391	–22	137	232	–41	1020	1206	–15
28.	Coastal Andhra Pradesh	109	99	9	167	160	5	94	154	–39	159	162	–2	529	575	–8
29.	Telangana	61	135	–55	235	242	–3	149	218	–31	118	171	–31	564	767	–27
30.	Rayalaseema	28	60	–53	116	91	27	25	97	–75	177	132	34	346	381	–9
31.	Tamil Nadu	39	42	–7	68	71	–4	29	90	–68	213	114	87	348	316	10
32.	Coastal Karnataka	804	901	–11	687	1188	–42	798	767	4	161	318	–49	2449	3174	–23
33.	North interior Karnataka	97	98	–1	113	126	–11	77	113	–32	144	153	–6	431	491	–12
34.	South interior Karnataka	164	132	24	165	225	–27	160	164	–3	130	137	–5	619	659	–6
35.	Kerala	693	702	–1	398	782	–49	439	461	–5	192	262	–27	1723	2206	–22
36.	Lakshadweep	251	326	–23	281	282	0	169	213	–20	200	164	22	902	985	–8

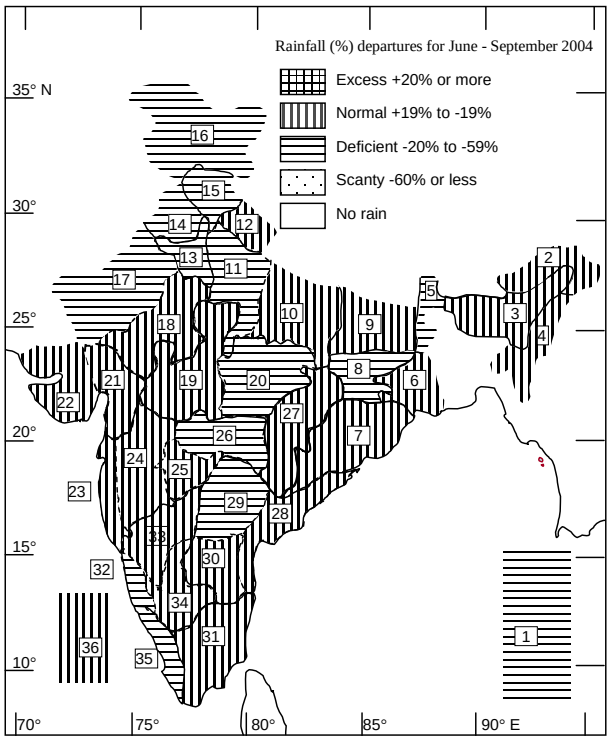


Fig. 7. Sub-divisionwise seasonal rainfall departure from normal (%) for the period (June - September 2004). 36 Sub-divisions are indicated by numbers on the map & bold letters in legend below. The rainfall anomaly values for these sub-divisions are indicated below :

1	–24	**7**	–10	**13**	–24	**19**	–15	**25**	–16	**31**	10
2	–2	**8**	–20	**14**	–44	**20**	–20	**26**	–31	**32**	–23
3	–9	**9**	–14	**15**	–45	**21**	5	**27**	–15	**33**	–12
4	6	**10**	–19	**16**	–25	**22**	–6	**28**	–8	**34**	–6
5	–3	**11**	–36	**17**	–40	**23**	2	**29**	–27	**35**	–22
6	–1	**12**	11	**18**	–8	**24**	16	**30**	–9	**36**	–8

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, 3 depressions (Two deep depressions and one land depression) and 1 cyclonic storm formed over the Arabian Sea and the Bay of Bengal. July and August were devoid of depressions. The tracks of the systems are shown in Fig. 9. Details are given below:

4.1.1. *Severe Cyclonic Storm (SCS) over the Arabian Sea (30 September-3 October)*

A trough of low organised into a low pressure area over Lakshadweep area and adjoining southeast Arabian Sea on 29, became well marked over east central Arabian Sea on 30 September morning. It concentrated into a depression at 0900 UTC of 30 and lay centred near Lat. 16.0° N / Long. 69.0° E. It further concentrated into a Deep Depression, centred near Lat. 16.5° N / Long. 68.5° E at 1200 UTC of 30 and near Lat. 19.0° N / Long. 67.0° E at 0300 UTC of 1 October. It intensified into a cyclonic storm and lay centred near Lat. 19.5° N / Long. 66.5° E at 0900 UTC of 1 and remained near Lat. 20.0° N / Long. 66.5° E at 1200 UTC of 1 and near Lat. 21.0° N / Long. 66.5° E at 0300 UTC of 2. It intensified into a severe cyclonic storm at 0900 UTC of 2 and lay centred near Lat. 21.5° N / Long. 67.0° E. It lay centered near Lat. 22.0° N / Long. 67.5° E at 1200 UTC of 2. It weakened into a cyclonic storm and lay centred near Lat. 23.0° N / Long. 68.5° E at 0000 UTC of 3. It further weakened into

TABLE 3

Districtwise distribution of monsoon rainfall for the years 1999 – 2004

Years	Excess/Normal	Deficient/Scanty
1999	67	33
2000	65	35
2001	67	33
2002	39	61
2003	77	23
2004	56	44

TABLE 4

SST anomaly indices (ENSO)

Month	Pacific SSTA (°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 2003	0.1	0.4	0.8	0.1
Nov 2003	0.3	0.5	1.0	0.3
Dec 2003	0.2	0.5	0.8	0.2
Jan 2004	0.1	0.3	0.7	0.1
Feb 2004	-0.2	0.1	0.6	-0.2
Mar 2004	-0.5	0.1	0.3	-0.5
Apr 2004	-0.2	0.0	0.3	-0.2
May 2004	-1.3	-0.3	0.5	-1.3
Jun 2004	-1.4	-0.1	0.5	-1.4
Jul 2004	-1.1	-0.2	0.8	-1.1
Aug 2004	-1.2	0.1	0.9	-1.2
Sep 2004	-0.4	0.3	1.1	-0.4

TABLE 5

Details of the weather systems during June 2004

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Depressions*					
1.	Deep Depression	10-13	East-central Arabian Sea	Northwest & then north	Northern parts of central Arabian Sea	Formed under the influence of an upper air cyclonic circulation. Moved along the off-shore trough, intensified into a Deep Depression on 11. Subsequently weakened gradually into a low pressure area over the sea, which became less marked on 16
2.	Deep Depression	11-14	East-central Bay	West-northwest & finally westnorthwest	Northwest Chattisgarh & adjoining east Madhya Pradesh	Formed as a trough of low, intensified into a Deep Depression on 12, weakened gradually into a low pressure area over northeast Madhya Pradesh & neighbourhood on 15. Shifted northwards thereafter & was caught in the westerlies, thus moved eastwards again, became less marked as a trough in westerlies over northeast India on 25
(**B**)	*Upper air cyclonic circulations*					
1.	Upto mid tropospheric levels	14-20	Off Maharashtra-Goa coasts	North	South Pakistan & neighbourhood	Become less marked on 21
2.	At 5.8 km a.s.l.	25-26	West-central Bay off Andhra coast	West	Telangana & neighbourhood	Became less marked on 27
3.	Between 5.8 & 7.6 km a.s.l.	27-29	West-central Bay off south Orissa - north Andhra coasts	Westnorthwest	Orissa & neighbourhood	Became less marked on 30
4.	Between 1.5 & 5.8 km a.s.l.	29 Jun – 8 Jul	Northeast Arabian Sea & adjoining Gujarat state	North	West Rajasthan & adjoining south Pakistan	Became less marked on 9 July
(**C**)	*Systems in westerlies*					
1.	Upper Air Cyclonic Circulation upto mid tropospheric levels	5-10	North Pakistan & adjoining Jammu & Kashmir	Eastnortheastwards	Eastern parts of Jammu & Kashmir & neighbourhood	Moved away on 11
2.	Do	10-17	North Pakistan & neighbourhood	Do	Do	Moved away on 18
3.	Do	17-19	North Pakistan & adjoining Jammu & Kashmir	Northeast	Jammu & Kashmir & neighbourhood	Moved away on 20
4.	Do	20-23	Do	Eastnortheast	Eastern parts of Jammu & Kashmir & neighbourhood	Moved away on 24
5.	Upper air cyclonic circulation between 2.1 & 4.5 km a.s.l.	22 Jun – 2 Jul	Central Pakistan & adjoining Punjab	North-northeast	Northern parts of Jammu & Kashmir neighbourhood	Moved away on 3 July
6.	Upper air cyclonic circulation upto mid tropospheric levels	23 eve – 25	North Pakistan and adjoining Jammu & Kashmir	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 26

TABLE 6

Details of weather system during July 2004

S. No.	Systems	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Low pressure areas*					
1.	Low pressure area	1-4	North & adjoining central Bay	Northwest	Jharkhand & neighbouring areas	Rapidly moved inland & weakened. The associated upper air cyclonic circulation lay over Chattisgarh & adjoining east Madhya Pradesh on 5, over northwest Madhya Pradesh & neighbourhood on 6 & became less marked on 7
2.	Well marked low pressure area	13-16	West central & adjoining northwest Bay off north Andhra - south Orissa coasts	Westnorthwest	Northern parts of east Madhya Pradesh & Chattisgarh	Became well marked on 15. Associated upper air cyclonic circulation extending upto mid tropospheric levels lay over northeast Madhya Pradesh & adjoining east Uttar Pradesh on 17 & became less marked on 18
3.	Low pressure area	23-24	Northwest & adjoining central parts of Bay off West Bengal - Orissa coasts	West	Northwest Bay & adjoining areas of west central Bay & coastal areas of south Orissa & north Andhra	Associated upper air cyclonic circulation extending upto 7.6 km a.s.l. tilting southwestwards with height persisted, which in turn influenced the formation of the subsequent low pressure area
4.	Low pressure area	27 Jul – 2 Aug	Northwest & adjoining west central Bay off north Orissa - West Bengal coasts	Westnorthwest	Central parts of Uttar Pradesh & adjoining north Madhya Pradesh	Associated upper air cyclonic circulation drifted southwestwards & formed the mid tropospheric cyclonic circulation over Gujarat region & neighbourhood which persisted there till 18 August
(**B**)	*Upper air cyclonic circulations*					
1.	Upto lower levels	2-4	East Uttar Pradesh & neighbourhood	West	West Uttar Pradesh & neighbourhood	A trough was seen aloft
2.	Between 3.1 & 5.8 km a.s.l.	12-14	Gujarat region & neighbourhood	Quasi-stationary	*In situ*	Became less marked on 15
3.	Do	10-11	Southwest Bay off Tamil Nadu coast	Do	Do	Became less marked on 12
4.	Between 3.1 & 7.6 km a.s.l.	12	Gangetic West Bengal & adjoining northwest bay	Stationary	Do	Tilted southwestwards with height & got merged with the circulation associated with the low pressure area on 13
5.	Between 3.1 & 5.8 km a.s.l.	15-21	Madhya Maharashtra & adjoining Gujarat region	Oscillatory	East-central Arabian Sea off Goa - Karnataka coasts	Became less marked on 22
6.	Between 2.1 & 4.5 km a.s.l.	22-23	Gujarat & neighbourhood	Stationary	*In situ*	Became less marked on 24
7.	Between 2.1 & 7.6 km a.s.l.	26 Jul – 3 Aug	North Maharashtra & adjoining Gujarat	Quasi-stationary	Gujarat region & neighbourhood	Became less marked on 4 August
8.	Upto mid tropospheric levels	30 Jul – 1 Aug	North Orissa & adjoining Jharkhand	Northwest	Jharkhand & neighbourhood	Became less marked on 2 August

TABLE 6 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**C**)	*Systems in westerlies*					
1.	Upper Air cyclonic circulation upto mid tropospheric levels	3-6	North Pakistan & adjoining northwest Rajasthan & Punjab	Northeast	Northeastern parts of Jammu & Kashmir	Moved away on 7
2.	Do	5-8	Punjab, Haryana & neighbourhood	Quasi-stationary	Punjab & adjoining Haryana	Became less marked on 9
3.	Upper air trough	7-9	Along Long. 80° E, to the north of Lat. 24° N	Northeast	Along Long. 82° E, north of Lat. 20° N	Moved away on 10
4.	Upper air trough at 7.6 km a.s.l.	9-10	Along Long. 76° E, north of Lat. 21° N	Do	Along Long. 89° E, north of Lat. 20° N.	Moved away on 11
5.	Upper air cyclonic circulation upto mid tropospheric levels	10-14	Central Pakistan & adjoining west Rajasthan	Northeast	Jammu & Kashmir & neighbourhood	Moved away on 15
6.	Do	15-20	North Pakistan & adjoining Jammu & Kashmir	Eastnortheastwards	Eastern parts of Jammu & Kashmir	Moved away on 21
7.	Do	21-22	Do	Northeast	Jammu & Kashmir & neighbourhood	Moved away on 23
8.	Do	23-24	Do	Do	Do	Moved away on 25
9.	Do	25-27	Do	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 28
10.	Do	28-29	Do	Northeast	Jammu & Kashmir & neighbourhood	Moved away on 30
11.	Do	30-31	Do	Northeast	Do	Moved away on 1 August
12.	Do	31 Jul – 4 Aug	Central Pakistan & adjoining areas of west Rajasthan & Punjab	Eastnortheast	Northwest Rajasthan & neighbourhood	Became less marked on 5 August

a Deep Depression over the same area at 0300 UTC of 3 and into a Depression at 1200 UTC of 3 over the same region. The system weakened into a well marked low pressure area over northeast Arabian Sea off Kutch coast on 4 morning.

4.1.2. *Deep depression over the Arabian Sea (10 – 13 June)*

Under the influence of an upper air cyclonic circulation, a low pressure area formed in the off-shore trough over east central Arabian Sea on 8. It lay as a well marked low pressure area off south Maharashtra-Goa coasts with associated cyclonic circulation extending upto mid tropospheric levels on 9. It concentrated into a depression and lay centred at 0300 UTC of 10 near Lat. 17.5° N / Long. 67.5° E. Moving slightly westwards, it intensified into a deep depression which lay centred near Lat. 17.5° N / Long. 66.5° E at 0900 & 1200 UTC of 10. It then moved northwestwards and lay centred near Lat. 18.0° N / Long. 66.0° E at 0300 UTC and remained practically stationary till 0300 UTC of 12. Moving westwards, it weakened into a depression and lay centred near Lat. 18.0° N / Long. 65.5° E at 1200 UTC of 12 and near Lat. 18.0° N / Long. 65.0° E at 0300 UTC of 13. It weakened into a well marked low pressure area over there on 13 evening.

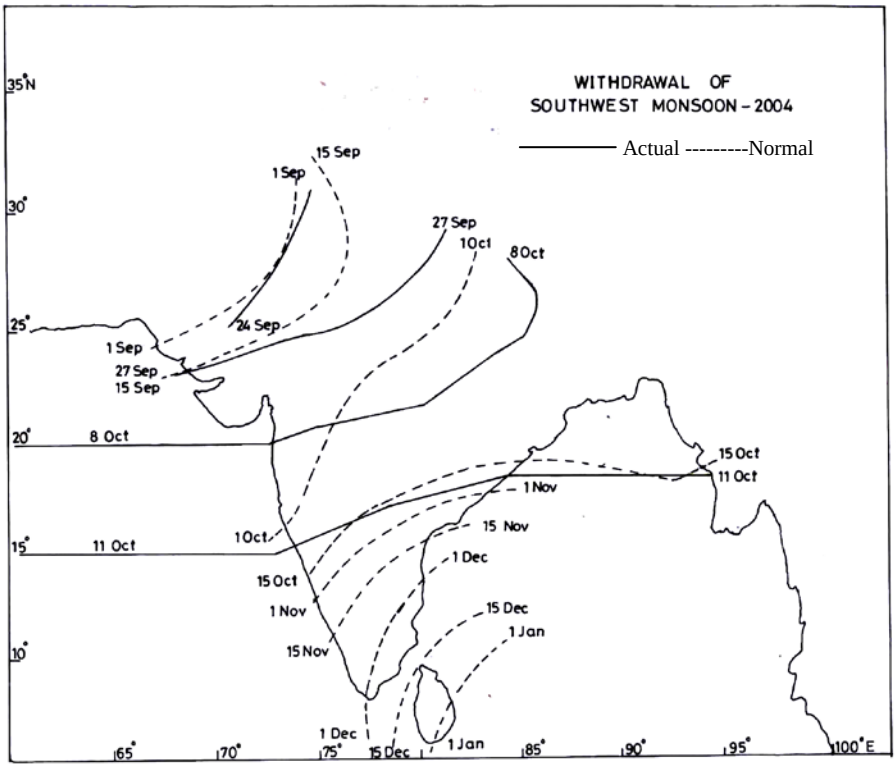
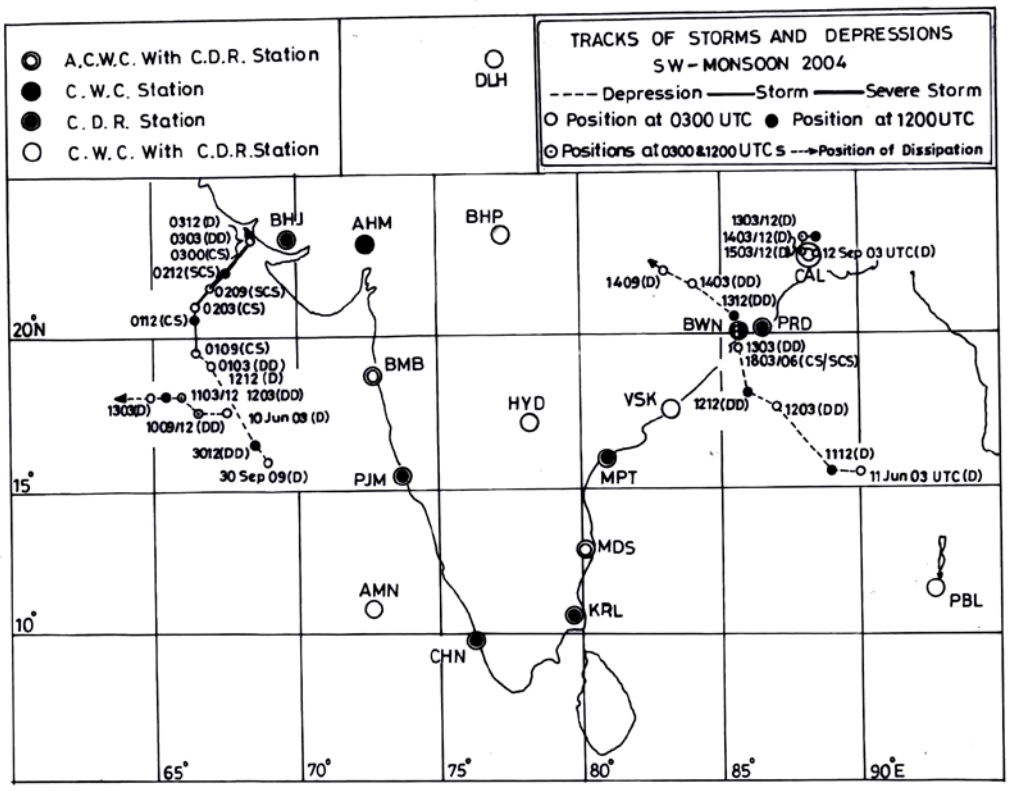


Fig. 8. Isochrones of withdrawal of southwest monsoon



Figs. 9. Tracks of storm and depressions during southwest monsoon 2004

TABLE 7

Details of weather system during August 2004

S. No.	System	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	2-6	Northwest Bay off north Andhra Orissa coasts	West	Central parts of Madhya Pradesh & neighbourhood	Formed under the influence of an upper air cyclonic circulation, became well marked on 3. The associated upper air cyclonic circulation merged with the cyclonic circulation over Gujarat region on 9
2.	Low pressure area	7-10	Jharkhand & adjoining Orissa	West	Northeast Madhya Pradesh & adjoining southeast Uttar Pradesh	Formed under the influence of an upper air cyclonic circulation. Rapidly moved westwards & became less marked. Associated upper air cyclonic circulation merged with the cyclonic circulation associated with the subsequent low pressure area on 14
3.	Low pressure area	11-18	Northern parts of coastal Orissa & neighbouring areas	Westnorthwest	West Uttar Pradesh & neighbourhood	Formed under the influence of an upper air cyclonic circulation. Became less marked on 18 evening
4.	Well marked low pressure area	17-25	North Orissa & adjoining areas of Gangetic West Bengal, Jharkhand & northwest Bay	Westnorthwest	West Uttar Pradesh & neighbourhood	Formed under the influence of an upper air cyclonic circulation. Became well marked on 20. Had been the marginal case of a l & depression
(**B**)	*Upper air cyclonic circulations*					
1.	Between 3.6 & 5.8 km a.s.l.	29-30	South coastal Andhra Pradesh & adjoining areas of Tamil Nadu & west central Bay	Quasi-stationary	Southwest Bay off south Andhra - north Tamil Nadu coasts	Became less marked on 31
2.	Upto 0.9 km a.s.l.	30	Southwest Bay off north Tamil Nadu coast	Stationary	*In situ*	Became less marked on 31
3.	Between 3.1 & 5.8 km a.s.l.	30 Aug – 2 Sep	Gujarat region & adjoining west Madhya Pradesh	Quasi-stationary	Madhya Maharashtra & neighbourhood	Became less marked on 3 September
(**C**)	*Systems in westerlies*					
1.	Upper air cyclonic circulation upto mid tropospheric levels	4-5	North Pakistan & adjoining Jammu & Kashmir	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 6
2.	Do	6- 8	Do	Northeastwards	Jammu & Kashmir & neighbourhood	Moved away on 9
3.	Do	9-13	Do	Do	Do	Moved away on 14
4.	Do	13 eve - 17	Northeast Afghanistan & adjoining Pakistan	Eastnortheast	Do	Moved away on 18
5.	Do	18-19	North Pakistan & adjoining Jammu & Kashmir	Northeast	Do	Moved away on 20
6.	Do	19-22	Do	Do	Do	Moved away on 23
7.	Do	23 eve - 26	Northeast Afghanistan & neighbourhood	Do	Do	Moved away on 27
8.	Do	27 Aug – 1 Sep	North Pakistan & adjoining Jammu & Kashmir	Do	Jammu & Kashmir & neighbourhood	Moved away on 2 September
(**D**)	*Other troughs*					
1.	At sea level	27 Aug	Eastern parts of Bihar to east central Bay	Quasi-stationary	-	Monsoon trough was close to foot hills of Himalayas during 26 August

TABLE 8

Details of weather system during September 2004

S. No.	System	Duration	Place of first location	Direction of movement	Final location	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Depression*					
1.	Land depression	12-15	Gangetic West Bengal, close to Kolkata	Quasi–stationary	Gangetic West Bengal close to Kolkata	Initially formed as an upper air cyclonic circulation. As a depression it did not show much movement and the heavy rainfall remained confined to its northeast sector giving rise to flooding. After weakening into a low pressure area on 16, it moved in a westnorthwesterly direction upto central part of Uttar Pradesh & neighbourhood on 22 and became less marked on 23. However, associated cyclonic circulation persisted over northern parts of the country till 30 September and became less marked on 1 October
2.	Deep depression	30 Sep onwards	East–central Arabian Sea	Northwesterly	Do	A trough of low over southwest Bay moved westwards and organised into a low pressure area over Lakshadweep area and adjoining Arabian Sea on 27 September later on it became a severe cyclonic storm on 2 October and is accounted for in the next season
(**B**)	*Upper air cyclonic circulations*					
1.	Upto mid tropospheric levels	2-9	West–central Bay off Andhra coast	West	Coastal areas of Konkan & Goa and neighbourhood	Became less marked on 10
2.	Between 3.1 & 7.6 km a.s.l.	8-9	Coastal Andhra Pradesh & neighbourhood	Stationary	*In situ*	Became less marked on 10
3.	Between 1.5 & 5.8 km a.s.l.	3-5	South Tamil Nadu & neighbourhood	Quasi–stationary	Southwest Bay off Tamil Nadu coast	Became less marked on 6
4.	Between 3.1 & 5.8 km a.s.l.	12-19	Gujarat region and neighbourhood	Do	South Maharashtra – Goa coasts	Became less marked on 20
5.	Between 3.1 & 4.5 km a.s.l	20-24	West central and adjoining southwest Bay off Andhra – north Tamil Nadu coast	West northwest	East central Arabian Sea	Became less marked on 25
6.	Upto mid tropospheric levels	23-25	Southwest Bay off Tamil Nadu and adjoining Sri Lanka coasts	Quasi–stationary	*In situ*	It was seen as an embedded cyclonic circulation on a trough of low which formed on 25. Merged with the cyclonic circulation associated with the depression on 1 October
7.	Lower tropospheric levels	28-30	Southwest Bay off Tamil Nadu – Sri Lanka coasts	Eastnortheast	Southeast Bay	Merged with the cyclonic circulation associated with the depression on 1 October
(**C**)	*Systems in westerlies*					
1.	Upper air cyclonic circulation upto mid tropospheric levels	2-7	North Pakistan & neighbourhood	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 8

TABLE 8 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
2.	Upper air cyclonic circulation upto mid tropospheric levels	8-12	North Pakistan and adjoining Jammu & Kashmir	Eastnortheast	Eastern parts of Jammu & Kashmir	Moved away on 13
3.	Do	14-19	Do	Northeast	Jammu & Kashmir and neighbourhood	Moved away on 20
4.	Upper air cyclonic circulation upto lower tropospheric levels	16-17	Central Pakistan and adjoining northwest Rajasthan and Punjab	Eastnortheast	West Uttar Pradesh and neighbourhood	Less marked on 18
5.	Upper air cyclonic circulation upto mid tropospheric levels	21-26	North Pakistan and adjoining Jammu & Kashmir	Northeast	Eastern parts of Jammu & Kashmir and neighbourhood	Moved away northeastwards on 27
6.	Do	26-28	Central Pakistan and adjoining western parts of Jammu & Kashmir	Do	Jammu & Kashmir and neighbourhood	Do
7.	Do	29 Sep – 1 Oct	North Pakistan and adjoining Jammu & Kashmir	Eastnortheast	Do	Moved away northeastwards on 4 October
(**D**)	*Other troughs*					
1.	At sea levels	20-22	Northeast Madhya Pradesh to Tamil Nadu	Quasi–stationary	*In situ*	Became less marked on 23

4.1.3. *Deep Depression over the Bay of Bengal (11- 14 June)*

A trough of low organised into a low pressure area over east central Bay and adjoining Andaman Sea on 10 evening. It concentrated into a depression and lay centred at 0300 UTC of 11 near Lat. 15.5° N / Long. 90.0° E and near Lat. 15.5° N / Long. 89.0° E at 1200 UTC of 11. Subsequently, moving in a northwesterly direction, it intensified into a deep depression and lay centred near Lat. 17.5° N / Long. 87.0° E at 0300 UTC of 12; near Lat. 18.0° N / Long. 86.0° E at 1200 UTC of 12 and lay centered near Lat. 19.5° N / Long. 85.5° E at 0300 UTC of 13. Moving northwards, it crossed south Orissa coast between Gopalpur and Puri between 0400 and 0500 UTC of 13. Thereafter, moving in a westnorthwesterly direction, it lay close to Phulbani (about 200 km west of Bhubaneswar) at 1200 UTC of 13 and near Sambalpur at 0300 UTC of 14. Subsequently moving northwestwards, it weakened into a depression and lay close to Raigarh at 0900 UTC of 14 and further weakened into a well marked low pressure area over northwest Chattisgarh and adjoining east Madhya Pradesh on 14 evening.

4.1.4. *Land depression over Gangetic West Bengal (12-15 September)*

Under the influence of an upper air cyclonic circulation, a low pressure area formed over northwest Bay of Bengal in the eastern end of the monsoon trough on 10th September. It moved in a north-northwesterly direction and concentrated into a depression over Gangetic West Bengal on 12th morning and lay centred near Kolkata (42807). The system meandered around Kolkata till 15th evening as it was located under the upper level col region. The system moved slowly northwestwards and subsequently weakened into a low pressure area over Gangetic West Bengal and neighbourhood in the night of 15 September, 2004.

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

Altogether 8 low pressure areas/well marked low pressure areas formed during the season. Most of them originated as upper air cyclonic circulations. Except 3, all of them formed over the oceanic area and subsequently

TABLE 9(a)

Positions of off-shore troughs during the monsoon period 2004

Date	Location	Date	Location
19-20 May	North Maharashtra to Kerala coasts	24-26 July	North Maharashtra to Kerala coasts
21-24 May	South Maharashtra to Kerala coasts	27 July- 2 August	North Maharashtra to Kerala coasts
25-26 May	Karnataka to Kerala coasts	3-4 August	South Gujarat to Karnataka coast
4-5 June	South Maharashtra to Kerala coasts	5-8 August	Gujarat to Karnataka coasts
6-7 June	North Maharashtra to Kerala coasts	9-10 August	Gujarat to Karnataka coasts
12-13 June	Off Karnataka-Kerala coasts	11-20 August	Gujarat to Kerala coasts
14-18 June	South Gujarat to Kerala coasts	21-23 August	Gujarat to Karnataka coasts
19-21 June	South Gujarat to Karnataka coasts	24-25 August	Gujarat to Kerala coasts
22 June	South Gujarat to Maharashtra coasts	26-27 August	Gujarat to Karnataka coasts
25-28 June	North Karnataka to Kerala coasts	28 August	Gujarat to south Maharashtra coasts
29 June-4 July	North Maharashtra to Kerala coasts	8-12 September	Gujarat to Kerala coasts
5 July	South Gujarat to south Karnataka coasts	13-15 September	Maharashtra to Karnataka coasts
6 July	South Gujarat to north Kerala coasts	16 September	Maharashtra to Kerala coasts
7-23 July	North Maharashtra to Kerala coasts		

TABLE 9(b)

Details of off-shore trough from 1999-2004

Year	Details of off – shore trough
2004	Off-shore trough 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	Off-shore trough 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	Off-shore trough 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	Off-shore trough along different parts of west coast (surface and lower levels) noted upto 13 September except during 1-4 June and 11 September.
2000	Off-shore trough 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 and 23-30 August.
1999	From 20 May to 22 September 1999, off-shore trough along different parts of west coast (surface and lower levels), persisted on most of the days except from 12 to 14 and from 16 to 26 August.

moved over to land. Monthwise breakup of the systems is 4 each in July and August. The total number of low pressure areas during the past 5 years, *viz.*, 1999 to 2004 is 11, 13, 10, 10, 12 & 8 respectively.

4.3. *Upper air cyclonic circulations (CYCIR)*

There were 22 upper air cyclonic circulations (in lower and upper tropospheric levels) formed during the season. The monthwise break up of these are 4 in June, 8 in July, 3 in August and 7 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 19 May to 16 September except during 27 May - 3 June, 8 - 11 June, 23 - 24 June, 29 August - 7

TABLE 10

Statistics of mid latitude troughs

Level	June	July	August	September	Total
300 hPa	4	2	0	4	10
500 hPa	4	3	4	5	16

September. The details of the position of the Off-shore trough are given in Table 9(a) and that for 1999-2004 are given in Table 9 (b).

4.5. *Eastward moving cyclonic circulations/western disturbances*

There were 33 eastward moving systems as upper air cyclonic circulations. The monthwise break-up is 6 in June, 12 in July, 8 in August and 7 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 (8-10 kts) by about 10-15 kts during June and nearly normal (8-10 kts) in the month of July. It was more than normal (8-10 kts) by about 5-10 kts in the middle of August and normal during rest of the week in the month. During September the surface wind was more than normal (8-10 kts) by about 5-10 kts.

5.1.2. *Over the Arabian Sea*

It was more than normal (10-12 kts) by about 5 kts during June and less than normal (12-14 kts) by about 5 kts in July. It was nearly normal in the month of August (10-12 kts) and September (8-10 kts).

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 16 & 10 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 22 systems (tropical depression stage and above) in the northwest Pacific Ocean / south China Sea during June – September 2004. The month wise break-up is shown in Table 11.

TABLE 11

Statistics of systems in northwest Pacific Ocean/south China Sea during June to September 2004

Weather systems	June	July	August	September	Total
T.D.	0	0	4	2	6
T.S.	2	2	1	0	5
Typhoon	4	2	3	2	11
Total	6	4	8	4	22

5.4. *Systems in southern hemisphere*

5.4.1. *Tropical storms/depressions*

Only one tropical depression formed during September 2004 in the southwest monsoon season in the south Indian Ocean.

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

There were in all 15 upper air troughs in westerlies (4 in June, 5 in July and 3 each in August & 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 2004. (*Source* : INSAT full disc pictures).

5.4.3. *Mascarene High*

The strength of Mascarene High at 30° S / 60° E was quite high (Dep. + 5.0 hPa) in June and was near normal during July to September. *Source* (Climate Diagnostic Bulletins, NOAA, June to September 2004, Departures are taken from the 1979 – 95 base period monthly means). The intensity of Mascarene High alongwith that for the past 5 years, are given in Table 12.

5.4.4. *Australian High*

The intensity of Australian High pressure area at 30° S / 140° E was normal during June and July. It was below normal during August and above normal during September. *Source* (Climate Diagnostic Bulletins, June, July, August, September 2004, 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 Table 13.

TABLE 12

Intensity of Mascarene High during monsoon season for the years 1999-2004

Year	June		July		August		September	
	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)
1999	1023	-1	1024	1	1024	0	1025	1
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

TABLE 13

Intensity of Austarlian High during monsoon season for the years 1999-2004

Year	June		July		August		September	
	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)
1999	1029	5	1032	8	1032	10	1031	7
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

6. Semi-permanent systems

6.1. *Heat low*

Heat low made its appearance in its near normal position by 15 May and remained more or less in its normal position (though diffused on many days during August & September) until 20 September. The lowest and the second lowest observed pressure values of the heat low were :

June : 990 hPa (on 17) and 992 hPa (on 18)

July : 992 hPa (on 7) and 994 hPa (on 19)

August : 991 hPa (on 2) and 995 (on 7)

September : 998 hPa (on 9 & 10) and 1000 hPa (on 2)

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*

Monsoon trough got established in its near normal position on 18 July. The characteristic heat trough was present over the region, even from the beginning of June, which showed a northward shifting from 17 June and remained close to the foot hills on 22 & 23 June. The western end of it remained there until the first week of July during which the country experienced a lull in rainfall activity. After regaining the normal position, the eastern end once again shifted northwards from 5 July to be back in the normal position on 13 July with the formation of a low pressure area. Even after the establishment of the monsoon trough, its western end shifted close to the foothills during 19 to 27 July and the entire trough axis remained there during 26 August to 8 September. The country experienced break monsoon conditions during the said period. Again with the formation of a low pressure area over northwest Bay, the monsoon trough shifted southwards to its near normal position on 10 September and remained there till 22 September. Thereafter it shifted northwards and subsequently the monsoon started withdrawing from the northwestern parts of the country.

TABLE 14

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

Month	Year				
	1999	2000	2001	2002	2003
June	990.0 (23rd)	989.0 (13th, 14th, 16th & 25th)	987.0 (20th & 21st)	988.0 (21st & 22nd)	986.0 (7th,8th & 27th)
July	988.0 (2nd)	989.0 (7th)	989.0 (12th)	988.0 (2nd)	990.0 (4th, 9th & 30th)
August	988.5 (6th)	990.0 (30th)	990.0 (29th)	998.0 (11th)	991.0 (9th)
September	994.0 (17th)	992.0 (1st)	995.0 (5th &10th)	997.0 (4th)	993.0 (2nd)

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

Year *Axis of monsoon trough*

1999 Established on 10 June. Less marked on 26 September.

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.

6.3. *Tibetan Anticyclone/High*

Tibetan Anticyclone (TA) was established at 500, 300 & 200 hPa levels on 13 June 2004. It remained east of its normal position during the second half of June and was not seen during most of the days in the first half of July. It was present in its normal position during many days in August except at 500 hPa. It remained south of its normal position at all levels until 18 September. The details of Tibetan Anticyclone for the past five years are given below.

Year *Tibetan Anticyclone*

1999 Appeared on 10 June. Seen on most of the days during July, August & September.

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.

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

STWJ was seen over Srinagar upto 23 June and over Ranchi until 20 June. It then shifted northwards and re-appeared over the north Indian stations during the 1st week of October. The days, the Sub tropical Westerly Jet was observed in the past five years are given below.

Year *Sub-Tropical Westerly Jet (STWJ)*

1999 Seen only till 12 June.

2000 Appeared on 5 June, 24 June & 16 July and re-appeared in the last week of September.

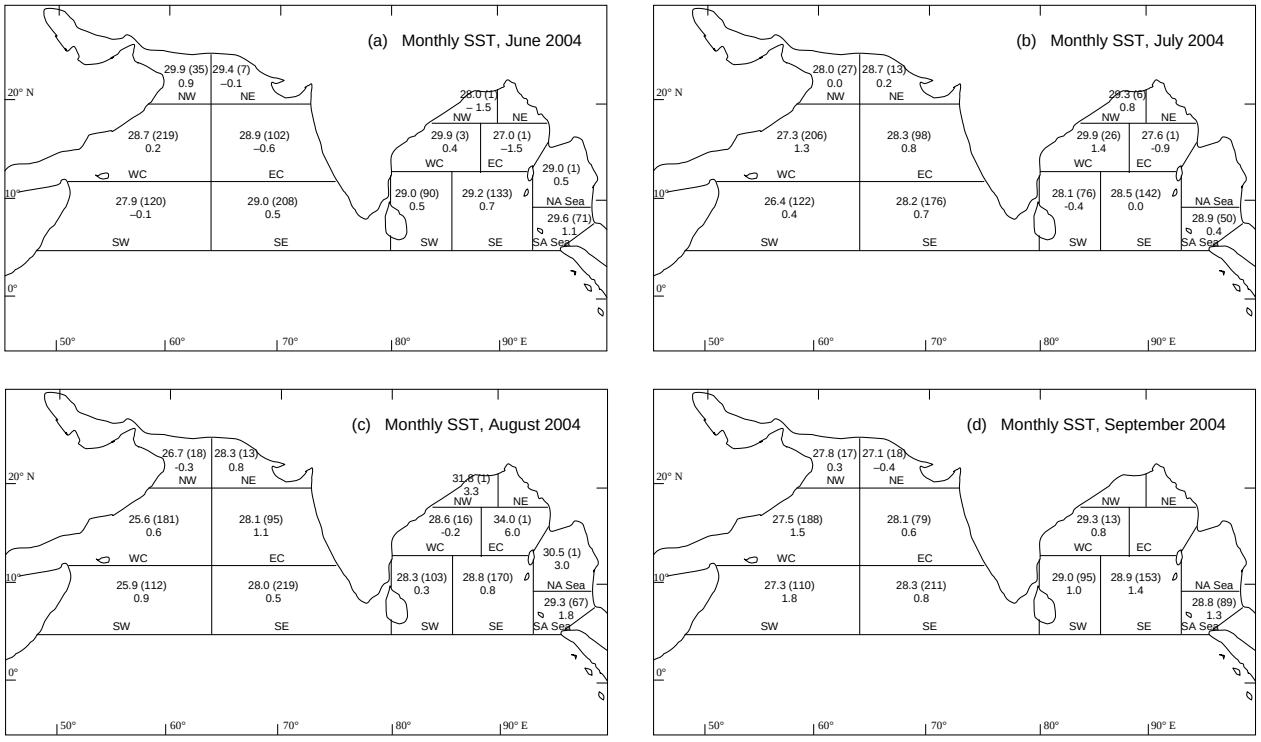
2001 Seen over north India during last week of May and reappeared in the last week of September.

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.

6.5. *Tropical Easterly Jet (TEJ)*

Jet speed winds were observed at Thiruvananthapuram from 10 May to 30 September. The



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

maximum wind reported was 175 kts at 157 hPa at 0000 UTC of 16. It was seen over Chennai from 19 May to 30 September. Maximum wind speed of 100 kts was observed on many occasions like 19 June, 5, 7 & 14 July above 100 hPa. Over Minicoy it appeared from 16 June and was noticed upto 30 September. Here, a maximum wind speed of 180 kts was reported at 118 hPa on 22 June (0000 UTC) over Mumbai and Port Blair, it appeared from 22 June onwards and disappeared in the 3rd week of September. Many a times winds of jet speed were reported over Visakhapatnam, Hyderabad, Nagpur and sometimes even further to the north, stations like Delhi, Lucknow, Guwahati etc reported strong easterlies.

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

Year *Tropical Easterly Jet (TEJ)*

1999 Appeared on 3 June till the end of September Maximum wind 140 kts at 141 hPa on 28 July.

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 knots at 137 hPa over Chennai on 18 June.

2003 Seen from 9 May to 25 September. Maximum wind speed 125 knots at 116 hPa over Minicoy on 25 July.

7. Sea surface temperature (SST)

Monthly mean SST values for June, July, August and September 2004 for Arabian Sea, Bay of Bengal as well as Andaman Seas are discussed below:

The Figs. 10(a-d) show 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. 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

TABLE 15

Zonal wind anomalies

Levels (hPa)	Week ending dates: 1 Jun	8 Jun	15 Jun	22 Jun	29 Jun	6 Jul	13 Jul	20 Jul	27 Jul	3 Aug	10 Aug	17 Aug	24 Aug	31 Aug	7 Sep	14 Sep	21 Sep	28 Sep	5 Oct
Thiruvananthapuram (TRV)																			
850	1.1	7.5	10.3	6	-4.9	-4.4	-7.7	-7	-2.3	-0.3	-2.1	-5.3	3.4	-6.1	-7.9	-2.6	-9.6	-12.7	3.6
500	4.2	-3.7	15.9	3	-0.3	-10.8	-3.5	-2.1	-1.7	-1.7	-2.5	0.4	-0.7	-7.5	-2.2	-1.2	-4.3	-19	5.2
200	-3.5	-8.6	-5.1	-15.5	-2.6	-1.3	-3.2	7.1	-5.6	-4	3.5	-4.7	7.6	-0.4	11.6	-10.1	-0.8	24.3	-7.1
Chennai (MDS)																			
850	-7.8	-2.2	20.4	11	-5.9	-0.8	-13.4	-3.6	0.4	7.6	8.4	11.7	7.8	-2.9	-5.8	4.9	-3.2	-22.7	0.4
500	-9.6	-4.4	21.1	17.9	-3.4	-8.8	-17.2	-9	1.2	10.1	8.7	7.4	0.4	-5.2	-12.1	4.1	1.2	-19.7	-6.2
200	-8.5	-0.3	-3.9	17.7	-15.8	-5.7	-20.4	-0.5	4.1	4.1	9	8.7	0.3	5.5	2.4	-12.5	-0.9	-	-
Mumbai (BMB)																			
850	-0.1	-4.2	-6.2	7.7	-1.1	-4.4	-5.5	-8.8	-6.4	1	3.6	7.6	6.7	2	-7.3	3.1	1.2	-22.3	-6.8
500	-7	-4.8	-0.6	8.1	5.4	-3.9	-1.2	-1.9	-2.7	3.6	2.5	3.5	3.7	1	-7.2	-3.7	-1.1	-7.6	-2.3
200	-4.6	-9	12.2	-0.6	0.7	-2	3.1	8.7	14.3	17.9	8.6	9.7	6.7	-5.1	-5.1	8.9	9.1	7.5	-0.4
Nagpur (NGP)																			
850	-1.5	7.4	-3.9	32.4	13.9	-4.2	-0.7	-0.3	-8.9	0.8	2.4	12.2	9.1	5.7	-9.3	4.9	1.9	-9.1	-0.5
500	-20.9	4.1	-3.9	27.5	21.3	-1.1	6.4	4.9	-0.2	1.5	2.7	9.4	6.6	1.9	-9.7	-2.8	3.4	-8.2	-8.1
200	-11	-3.2	0.2	-38.4	-3.9	-10.6	3.6	11.3	1	2.2	0	6.7	-3	-10.2	-27.9	-31.7	-23.4	-1.8	-17.9

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.

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 NE, EC and SW sectors of Arabian Sea were cooler than normal with highest negative anomaly being 0.6° C in the EC sector. The remaining sectors (NW, WC and SE) were warmer than normal with highest positive anomaly being 0.9° C in the NW sector. The WC, SW and SE sectors of Bay and Andaman Sea region were warmer than normal. Over the remaining sectors (NW, NE and EC) of Bay, the SSTs were below normal.

7.2. *July*

SST_s over all the sectors of Arabian Sea were warmer than normal with highest anomaly being 1.3° C over WC Arabian Sea. Except NE, EC and SW sectors of Bay, the SST_s over NW, WC and South Andaman Sea were above normal with highest positive anomaly being 1.4° C in WC Sector.

7.3. *August*

Except NW, SST_s over all sectors of the Arabian Sea were warmer than normal with highest anomaly being 1.1° C over the EC Arabian Sea. Except WC sector, SST_s over all available sectors of the Bay (NW, EC, SW and SE) and Andaman Sea were also warmer than normal.

7.4. *September*

Except NE Sector of the Arabian Sea, SST_s over all remaining sectors NW, WC, EC, SW and SE) were warmer than normal with highest anomaly being 1.8° C over the SW sector of the Arabian Sea. SST_s over all available sectors of the Bay (WC, SW and SE) were warmer than normal with highest anomaly being 1.4° C over the SE Bay. The south Andaman Sea was warmer than normal by 1.3° C.

From the above discussion it is seen that WC sector of the Arabian Sea was warmer than normal throughout the season. Except during June, the EC, SW and SE

sectors of the Arabian sea were also warmer than normal during July to September whereas the WC sector was warmer than normal during June, July and September. The south Andaman Sea was warmer than normal throughout the season.

8. Other features

8.1. *Weekly upper wind anomalies in southwest monsoon 2004*

The circulation anomaly features during SW Monsoon Season 2004 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 trough was seen at about 23 to 25° N in the 850 and 700 hPa levels and at 200 hPa mostly the easterly winds prevailed over peninsula.

Circulation pattern of the weekly anomalies showed a clear northward movement of anomaly trough week by week. For week ending on 8 June, the anomaly trough was seen at about 10 to 11° N at 850 and 700 hPa level. For the week ending on 15 June the trough was seen over northern parts of peninsula roughly around 17 to 18° N. For the week ending on 22 June the trough was along 25° N and for the week ending on 29 June the anomaly trough was not seen but the ridge appeared near about 25° N at 850 and 700 hPa level and the south peninsula was characterised by easterly anomaly winds showing weak monsoon conditions. At 200 hPa level generally for all weeks the easterly anomaly winds were seen over peninsula.

8.1.2. *July wind anomaly features*

In monthly anomaly pattern at 850 and 700 hPa an anomaly ridge was seen at about 23 to 24° N. An anomaly cyclonic circulation was seen over south Konkan. All the winds south of 20° N were easterly anomalous winds showing weak or bad monsoon conditions.

On weekly scale for weeks ending on 6 July, 13 July and 20 July an anomaly ridge was seen at 850, 700 and even at 500 hPa level over central parts of the country and easterly anomaly winds to the south of it, indicating weak monsoon conditions. For the week ending on 13 July an anomaly cyclonic circulation was seen on the southern most parts of peninsula at 850 hPa level. For the week ending on 27 July a second anomaly trough of the season was seen at 700 and 500 hPa level extending from south Konkan to North Andaman Sea. For the week ending on 3 August again the anomaly trough was more or less on the same place as on week ending on 27 July. At 200 hPa for the first two weeks, the peninsula was having easterly anomalies but in the weeks followed, it does not show any clear easterly or westerly type of anomaly.

8.1.3. *August wind anomaly features*

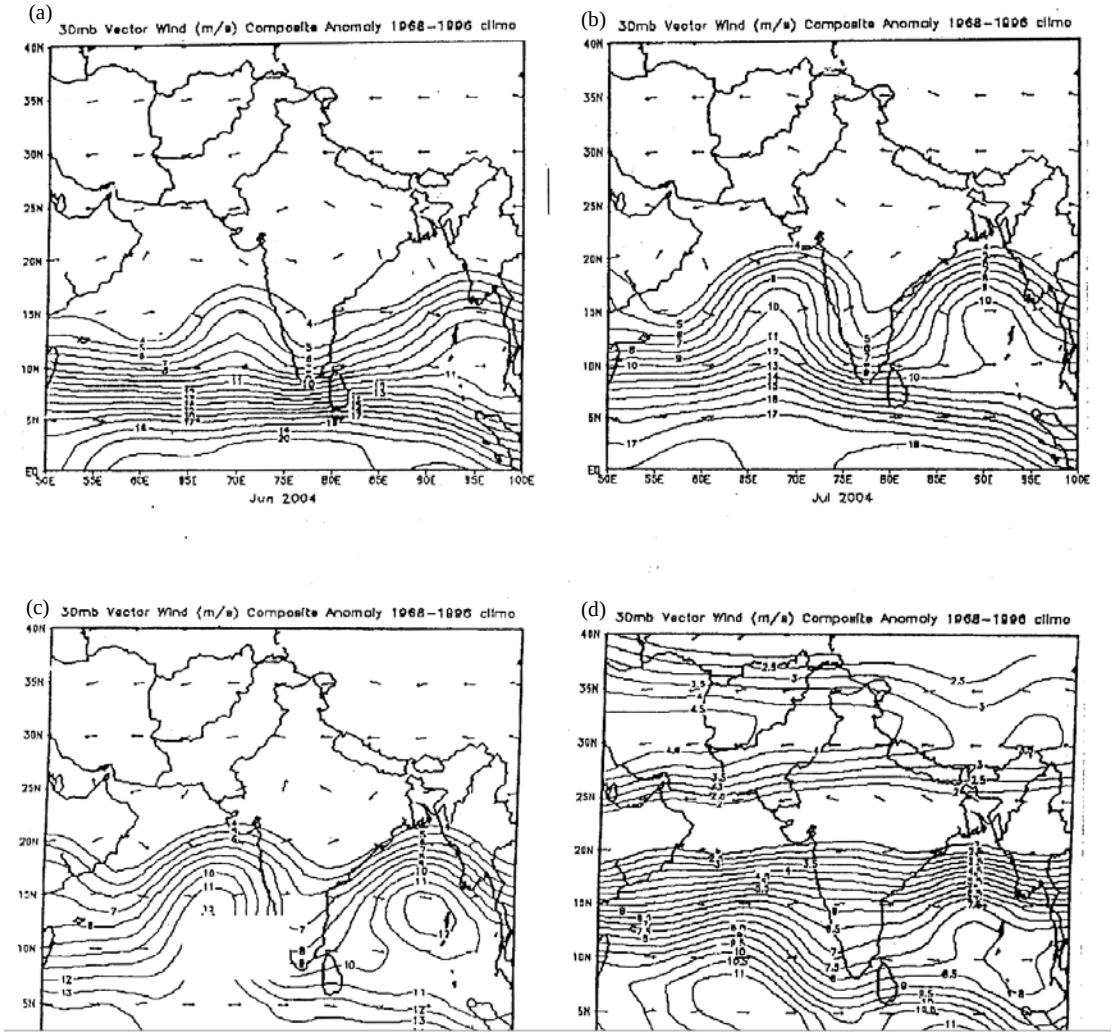
On monthly scale an anomaly trough was seen from 23 to 25° N at 850 and 700 hPa level and at the same time anomaly ridge is also seen on the southern most parts of peninsula.

On weekly scale the anomaly trough which formed in the last week of July continued and was seen for the week ending on 10 August at about 25° N at 850 hPa level. For the week ending on 17 August, the trough was seen at from 23 to 25° N. For the week ending on 24 August the orientation of an anomaly trough was from northwest to southeast and it was running from northwest Rajasthan to Orissa – in the lower tropospheric levels. For the weeks ending on 10, 17 and 24 August at 850 and 700 hPa along with anomaly trough, an anomaly anticyclone was seen over southern most parts of peninsula. For the week ending on 31 August again an anomaly ridge appeared running roughly around 20° N and again all easterly anomaly winds to the south of it indicating weak monsoon conditions.

8.1.4. *September wind anomaly features*

In this month at 850 and 700 hPa level an anomaly ridge was seen roughly from 22 to 23° N and at 200 hPa level, an anomaly trough was seen over southern most parts of peninsula with all easterly anomaly winds to the north of it.

On weekly scale for the week ending on 7 September, an anomaly trough was seen over central and northern parts of country at 850 and 700 hPa level. At 200 hPa level strong easterly anomalies were seen on northern parts of peninsula whereas to the south of it weaker easterly anomalies were present. For the week ending on 14 September at 850 and 700 hPa anomaly anticyclone was seen over Northwestern parts of country but an anomaly cyclonic circulation was seen over northeastern parts and over coastal Andhra Pradesh and neighbourhood. At 200 hPa southernmost peninsula had easterly anomalies. For the week ending on 21 September anomaly trough was seen from 22 to 23° N and anomaly ridge over southern most peninsula at 850 and 700 hPa level. At 200 hPa level anomaly ridge was present near 15° N. In last week of September again an anomaly ridge



Figs. 11(a-d). Monthly anomalous vector winds at 30 hPa during southwest monsoon 2004 for the month (a) June, (b) July, (c) August and (d) September 2004

was seen at 850, 700 hPa and 500 hPa level, also from 22 to 23° N.

8.2. *Stratospheric features*

Analysis of stratospheric winds over the Indian region during the southwest monsoon season 2004 was done using monthly NCEP reanalysis data (www.cdc.noaa.gov.). Figs. 11(a-d) shows the monthly anomalous vector winds at 30 hPa over the Indian region during the Southwest monsoon season 2004. The anomalies were computed using 1968-1996 climatology. As seen in Fig. 11, during all the four months, the anomalous winds south of about 22.5° N were mainly westerly. The core of the anomalous wind speed during the first three months (June to August) was along the equator and that during September was north of equator (3 to 5°). Secondary maximum in the anomalous wind speed was also observed over South-central Bay of Bengal. The secondary maximum was more visible during the month of August. It may be mentioned that climatologically easterly winds are observed all over the Indian region with the core wind speed in the 15° N - 20° N latitudinal range.

Fig. 12 shows the latitude – height diagram of zonal wind anomalies for the monsoon season (June-September) 2004 averaged over longitudinal zone of 70° - 90° E. The anomalies were computed using 1968-96 climatology. This figure indicates that during the monsoon season of

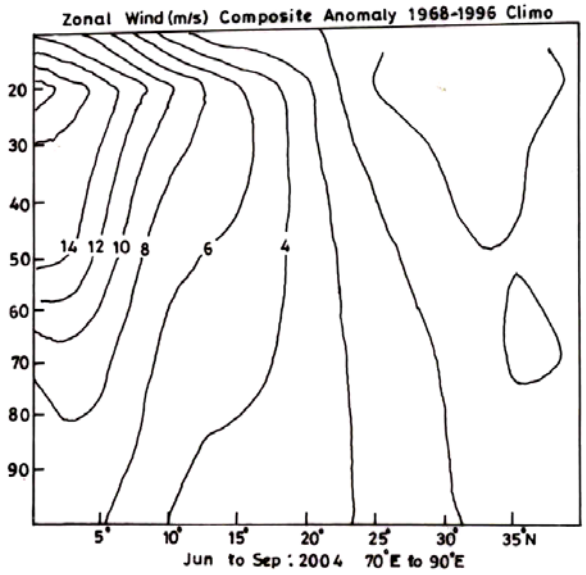


Fig. 12. Latitude height diagram of zonal anomalies for June – September 2004

2004, over the entire stratosphere south of 22.5° N, the zonal wind anomalies were westerly.

8.3. *Aridity conditions during southwest monsoon 2004*

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

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

Where, PE is potential Evapotranspiration, which is nothing but the loss of water vapour to atmosphere in the form of evaporation from soil, and transpiration from the plants, when the supply of water is unlimited. This is the water need of the plants. 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 water balance procedure, which takes into account the water holding capacity of the soil.

The difference between actual Aridity for the month and normal aridity *i.e.*, the aridity anomaly is worked out. 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 is given in Figs. 13(a-d).

Moderate to severe arid conditions were noticed in small northern parts and in west-central and eastern parts of peninsula in June. In July these areas increased over eastern, northwestern and western parts and those over eastern peninsular parts have decreased. In August, the moderate and severe arid areas in the northwestern and western parts have decreased to small areas and those over eastern parts of peninsula have increased. In September, these areas increased over northwestern parts and also existed in small patches in western and central parts over the peninsula.

Severe and moderate arid conditions which prevailed over the country during the monsoon months are given below :

8.3.1. *June*

(a) *Severe arid areas*

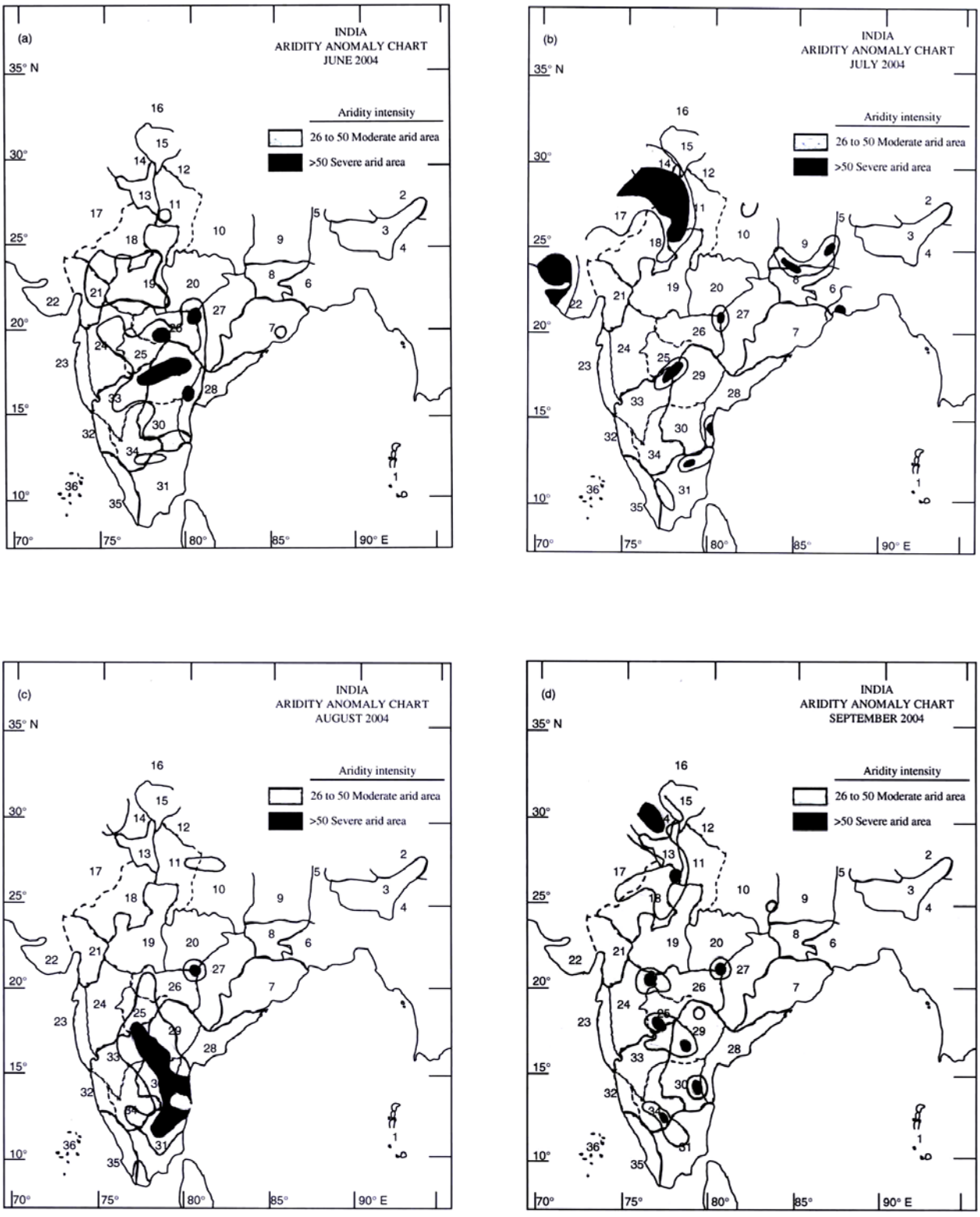
(*i*) Small areas of northwestern parts of Telangana and adjoining northeastern parts of north interior Karnataka.

(*ii*) Isolated areas around Yeotmal and Gondia (Vidarbha) and Khammam (Telangana).

(b) *Moderate arid areas*

(*i*) Large areas of west Madhya Pradesh, Marathwada, Vidarbha, Telangana and north interior Karnataka.

(*ii*) Small areas of eastern parts of Gujarat Region; southern parts of east Rajasthan; northeastern parts of Madhya Maharashtra; southern parts of east Madhya Pradesh; western parts of Chattisgarh; southern parts of coastal Andhra Pradesh; northern parts of Rayalaseema; southern parts of south interior Karnataka and adjoining northwestern parts of Tamil Nadu.



Figs. 13(a-d). Aridity anomaly chart for the month (a) June, (b) July (c) August and (d) September 2004

(*iii*) Isolated areas around Aligarh (west Uttar Pradesh), Ambikapur (Chattisgarh) and Cuttack (coastal Andhra Pradesh).

8.3.2. *July*

(a) *Severe arid areas*

(*i*) Large areas of Punjab and Haryana.

(*ii*) Small areas of northeastern parts of east Rajasthan and adjoining western parts of west Uttar Pradesh; northern parts of west Rajasthan; western parts of Saurashtra & Kutch; southern parts of Bihar and adjoining northern parts of Jharkhand and northern parts of north interior Karnataka.

(*iii*) Isolated areas around Sabour (Bihar), Gondia (Vidarbha), Contai (Gangetic West Bengal); Nellore (coastal Andhra Pradesh) and Tirupattur (Tamil Nadu).

(b) *Moderate arid areas*

(*i*) Large areas of west Rajasthan.

(*ii*) Small areas of northern parts of Punjab; southwestern parts of Himachal Pradesh; western parts of west Uttar Pradesh; northern and northwestern parts of east Rajasthan; central parts of Saurashtra & Kutch; southeastern and southwestern parts of Bihar and adjoining northern parts of Jharkhand; southeastern parts of east Madhya Pradesh and adjoining northeastern parts of Vidarbha; western parts of Chattisgarh; southeastern parts of Gangetic West Bengal and adjoining northeastern parts of Orissa; northern parts of north interior Karnataka and adjoining western parts of Telangana; southern parts of coastal Andhra Pradesh and adjoining northern and western parts of Tamil Nadu.

(*iii*) Isolated areas around Bahraich (east Uttar Pradesh) and Kanyakumari (Tamil Nadu).

8.3.3. *August*

(a) *Severe arid areas*

(*i*) Large areas of Rayalaseema.

(*ii*) Small areas of southern parts of Marathwada; northern parts of north interior Karnataka; southwestern parts of Telangana; south-central parts of coastal Andhra Pradesh; northern and central parts of Tamil Nadu and adjoining eastern parts of south interior Karnataka.

(*iii*) Isolated area around Gondia (Vidarbha).

(b) *Moderate arid areas*

(*i*) Large areas of Tamil Nadu.

(*ii*) Small areas of western parts of Punjab; northern parts of west Rajasthan; northwestern parts of east Uttar Pradesh and adjoining eastern parts of west Uttar Pradesh; western and northeastern parts of Vidarbha and adjoining southern parts of east Madhya Pradesh and western parts of Chattisgarh; central and southern parts of coastal Andhra Pradesh and adjoining southeastern parts of Rayalaseema; western and southeastern parts of Telangana; eastern and central parts of Marathwada; southeastern parts of Madhya Maharashtra; northern and central parts of north interior Karnataka; eastern and central parts of Rayalaseema; eastern and southeastern parts of south interior Karnataka; southern parts of Kerala; northeastern, central and western parts of Tamil Nadu.

8.3.4. *September*

(a) *Severe arid areas*

(*i*) Small areas of northwestern parts of Punjab.

(*ii*) Isolated areas around Bharatpur (east Rajasthan); Jalgaon (Madhya Maharashtra); Gondia (Vidarbha); Osmanabad (Marathwada); Mehboobnagar (Telangana); Cuddapah (Rayalaseema) and Mysore (south interior Karnataka).

(b) *Moderate arid areas*

(*i*) Large areas of Punjab, Haryana and east Rajasthan.

(*ii*) Small areas of northern and east-central parts of west Rajasthan; northwestern parts of west Madhya Pradesh; western parts of west Uttar Pradesh; northeastern parts of Madhya Maharashtra; northern and southern parts of Marathwada; western and northeastern parts of Vidarbha; southern parts of east Madhya Pradesh; western parts of Chattisgarh; northern parts of north interior Karnataka; southern and western parts of Telangana; eastern parts of Rayalaseema and adjoining western parts of coastal Andhra Pradesh; western and southeastern parts of south interior Karnataka and adjoining western parts of Tamil Nadu.

(*iii*) Isolated areas around Varanasi (east Uttar Pradesh); Dwarka and Bhavnagar (Saurashtra & Kutch) and Ramagundam (Telangana).

TABLE 16

Representative heavy to very heavy rainfall amounts during June – September 2004

Date (1)	June (2)	July (3)	August (4)	September (5)
1	Kanakapura 12, Mangalore 10, Sankalan & Quilandy 9 each, Cuddalore 8, Kundagal 7	Haimara 14, Taibpur 13, Jawahar 11, Durg, Bhind & Igatpuri 7 each	Murbad 18, Mangrol 17, Bagidogra & Prantij 15 each, Veraval 14, Danpur, Banswada, Bhatkal & Bhudhni 13 each, Ratlam & Madhuban 12 each, Bhira & Mahabaleshwar 11 each, Chandanpur 10, Maya Bandar, Tantloi, Koida & Dadahu 8 each, Bilara, Khanapura & Pachhad 7 each	Sevoke 22, Bargaon 8, Panagarh, Itanagar, Passighat, Darjeeling, Jalpaiguri & Tiruvarur 7 each
2	Chikkanayakanahalli 11, Hatkanangale & Karwar 8 each, Mundargi & Panjim 7 each	Murbad 22, Ayodhya 9, Jhanjgir & Mhow 8 each, Amraghat, Halwara, Igatpuri & Dundigal 7 each	Bhira 26, Mount Abu 24, Jawhar 23, Mahabaleshwar 21, Mangrol 20, Madhuban 19, Chandigarh 12, Hutin 11, Rajpura 10, Baghpat 9, Golaghat, Tiring, Lalganj, Dabra, Agumbe, Uttarkashi, Palwal, Jaunpur & Agra 7 each	Cherrapunji 15, Bhalukpong 13, Araria 12, Chouldhowaghat 10, Tezu & Dinhata 9 each, Neelamangala 7
3	Chickmagalur 9, Agartala, Ratnagiri, Vita & Lokapura 8 each, Passighat, Karimganj & Belthangaddy 7 each	Agumbe 22, Sonbarsa 18, Gajoldoba 14, Mahad, Satara & Gevrai 12 each, Honavar 11, Dillighat 10, Parala & Khemundi 8 each	Songadh 48, Mahabaleshwar 46, Madhuban 44, Bhira 36, Ambala 34, Koida 24, Ambala 25, Chandigarh & Koida 24 each, Velhe 23, Dharampur 21, Agumbe 19, Valparai 17, Jagalpet 16, Kalka, Solan & Rajpura 15 each, Patiala & Thirthhalli 14 each, Dahanu, Peddapuram & Pachhad 13 each, Munnar & Kinta 12 each, Long Island, Konta & Konavaram 11 each, Gambhiridam, Jhirka, Kharkhoda & Londa 10 each, Delhi Ridge, Kaithal, Samalkha, Rewari, Gohana, Kundaghat & Chittorgarh 9 each, Panipat, Gohar, Theog & Rajgarh 7 each	Mandela 13, Usilampatti 11, Cooch Behar, Naraj & Vaniyambadi 9 each, Karimganj 8, Passighat & Nayakanahalli 7 each
4	Baghdogra 13, Panambur 12, Nalbari 10, Quilandy 9, Kondul, Digha & Raighat 8 each, Miao 7	Roha 26, Sujanpurbira 13, Nasirabad 12, Cherrapunji 11, Hirakud 10, Islampur, Gautampura & Mahabaleshwar 9 each, Medikeri 8	Songadh 58, Ahwa 38, Murbad 30, Mahabaleshwar & Agumbe 28 each, Munnar 27, Ambala & Bhira 24 each, Bhagamandala 20, Subramanya 19, Mangalore & Allathur 18 each, Londa 17, Somwarpet 14, Dummagudem 15, Chandigarh, Guhla & Kashinagar 14 each, Bhiwani & Jhabua 13 each, Khanapur 12, Belgaum 11, Pehowa, Rajpura & Rajura 10 each, Kahu, Harda & Veraval 9 each, Kandaghat, Batala & Patiala 7 each	Gouribidanur & Maddur 11 each, Anantpur & Kanchipuram 9 each, Dhamtari 8
5	Kannur 25, Thrissur 20, Udupi 12, Darbhanga & Kozhikode 7 each	Alibag 24, Chargharia 10, Itanagar & Khanpur 9 each, Guna & Chittur 8 each, Sambalpur & Mirzapur 7 each	Shrivardhan 36, Mandangad 32, Mahabaleshwar 30, Vasai 24, Ashti 22, Munnar 21, Valaparai 20, Piravom 19, Bhira & Bhagamandala 16 each, Warud 15, Hamai, Gaganbavda, Subramanya & Kottighera 14 each, Subramanya 13, Silvassa 10, Chouldowaghat & Mahuva 9 each, Bhalukpong & Haripur 8 each, Paonta 7	Lakhipur 15, Annapurnaghat 13, Singlabazar, Sevoke & Hanamkonda 9 each, Arantangi & Kudligi 8 each, Barrackpur & Adirabad 7 each
6	Bhatkal & Kudulu 21 each, Pandharpur 11, Nancowry 9	Cherrapunji 22, Mathabhanga 17, Jowai 16, Uran 13, Sikandarpur 10, Daltonganj 9, Rayagadda & Uttarkashi 8 each, Harda & Milambur 7 each	Baijnath 30, Javad 21, Biora & Munnar 17 each, Valaparai 13, Gandwani 14, Mumbai, Dohad, Mahabaleshwar, Gaganbavada & Agumbe 13 each, Katol & Durgachak 11 each, Dharamsala & Gandhinagar 10 each, Veraval 9, Honavar & Kangra 8 each, Thalaguppa & Thodupuzha 7 each	Gajoldoba 13, Sindhanur 12, Alipurduar 11, Bhalukpong, Srisailam & Malur 10 each, Lanjigarh & Setharamapuram 9 each, Vellore & Turuvekere 8 each, Nanded & Perur 7 each, Motala 4

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
7	Khandapura 12, Rajghat 10, Nancowry 9, Kudulu & Vadakancherry 8 each, Mainapore & Dindori 7 each	Cherrapunji 37, Sevoke 20, Passighat 17, Sonbarsa 14, Bansi 13, Dehra Dun 9, Mettapatti & Neyyatinkara 8 each, Dharamsala 7	Laikera 31, Sundergarh 19, Purihansa 14, Katra 13, Jamnagar 12, Durgachak, Mount Abu, Pratapgarh & Khamba 11 each, Dharamsala & Subramanya 10 each, Jhabua, Tezpur, Bhagamandala, Bhograi, Solopet & Munnar 9 each, Chanlang 8, Betul & Kangra 7 each	Hasimara 13, Dhollabazar 12, Itanagar & Chitturl 9 each, Chikkodi & Thruvanathapuram 8 each, Tirupathi 7
8	Sevoke 24, Bhatkal 18, Shirali 17, Kankanna 10, Port Blair & Repalle 7 each	Cherrapunji 37, Tarabganj 20, Chepan 17, Jhanjharpur & Birpur 15 each, Passighat 14, Tiruvannamalai 13, Dholpur 11, Hardwar & Mulki 9 each	Hemgiri 20, Champa 19, Mount Abu & Raigarh 17 each, Ambabhona 15, Bichhia & Kalyanpur 14 each, Ropar & Roing 13 each, Sawai Madhopur, Deogaon, Shahjina & Jamnagar 12 each, Sawai Madhopur 11, Kankrej 10, Sundergarh, Nahan, Gaganbavda & Hosdurg 9 each, Balachaur, Hindol & Katra 8 each, Mayabandar, Jamshedpur, Mahabaleshwar & Bhira 7 each	Chepan 47, Alipurduar 35, Barobhisa 29, Beki Mathanguri 17, Kokrajhar 14, Murud 13, Roing 12
9	Pemem 17, Jalpaiguri, Car Nicobar & Bhatkal 12 each, NH–31 10, Dhubri & Kotraguda 9 each, Akbarpur, Nandigama, Hosanagara & Munnar 7 each	Passighat 25, Mother 24, Sonbarsa 22, Aie NH Xing 21, Chintamani 16, Jalpaiguri 14, Nargund & Gorakhpur 11 each, Kasol & Kotdwar 10 each	Katni 16, Lanji, Ambabhona & Garotha 11 each, Karear, Meerut, Kangra & Phillaur 10 each, Maya Bandar, Mussoorie, Delhi, Dohad, Dausa, Sujangarh, Sarangarh & Dadahu 9 each, Mahabaleshwar & Pachhad 8 each, Ludhiana 7	Chepan 34, Mathabhanga 28, Karmala 14, Chargharia & Thodupuzha 11 each, Lakhipur 10, Miao, Dharmanagar & Ketti 9 each
10	Bhatkal 37, Shirali 21, Agumbe 20, Vadakara 13, Honavar & Valpoi 12 each, Vengurla & Panjim 10 each, Malvan 9, Port Blair 8, Barobhisa & Darbhanga 7 each	Cherrapunji 43, Tezu 34, Chepan 27, Pakala 13, Birpur & Subramanya 11 each, Haripad & Kunigal 9 each, Daspalla 8, Kudal & Dhenkanikottai 7 each	Mount Abu & Songadh 13 each, Kanpur 12, Mohana & Sangod 10 each, Kotri & Katghora 9 each, Canning Town, New Kandla, Gwalior, Sikohabad, Kuchinda & Uluberia 8 each, Mohana, Satna, Khaga, Mahabaleshwar, Kaleswaram & Koika 7 each	Khajuri 17, Gaganbavada & Covelong 10 each, Yellandu 9, Aurangabad 8
11	Agumbe & Puttur 14 each, Ratnagiri 10, Valparai 9, Munnar 8, Harnai & Maya Bandar 7 each	Cherrapunji 39, Chepan 24, Birpur 20, Taibpur 16, Passighat & Barur 12 each, Mhasala & Thodupuzha 7 each	Kotri & Pardi 18 each, Sarwar 16, Dabohi 14, Jawhar 13, Halvad, Baroda, Jhazpur & Bhander 12 each, Banda & Chhatnag 10 each, Naharkatia, Dibrugarh, Shahpura & Gwalior 9 each, Cuttack, Pachpadra, Mahabaleshwar, Diamond Harbour, Chhendipada & Pechpadra 7 each	Purna 11, Bhawanipatna & Dharamsala 11 each, Banbasa 8, Ramgarh & Nizamabad 7 each
12	Munnar 14, Bhagamandala 12, Kottighera & Port Blair 11 each, Rajkanika 10, Guddalur Bazar 9, Dowleswaram & Pariakhemundi 8 each, Madanpur 7	Cherrapunji 26, Motihari & Deoband 11 each, Bapatla & Udupi 10 each, Hasimara, Chiplun & Banth 19 each, Kailashahar & Khagaria 8 each	Korba 36, Bhira & Banswara 25 each, Mahabaleshwar 29, Murbad 27, Katghora 22, Pallahara, Hirakund & Ahwa 13 each, Bansda & Agumbe 12 each, Javad 11, Yellapura 10, Uttarkashi 8	Kotdwar 12, Jhalda 9, Kolkata 7
13	Mandanpur & Rampur 32 each, Chintapalli 29, Junagarh 28, Lanjigarh 20, Munnar 17, Paderu 16, Kalingapatnam 11, Digha 15, Guddalur Bazar 14	Mahabaleshwar & Motihari 14 each, Honavar 13, Kollur 12, Akbarpur 11, Matijuri & Agumbe 10 each, Owk & Yelburga 9 each	Baruipur 27, Mahabaleshwar 23, Sagwara 22, Banswara & Tusuma 21 each, Kansabati Dam 20, Agumbe 17, Siddapura 15, Karwar & Banswara 14 each, Tensa 13, Thrissur 11, Concona 12, Linkheda 10, Tuni 7, Rampur Bushahar & Ratnagiri 9 each, Patan 8	Sonamura 25, Agartala 22, Cherrapunji 16, Canning Town 9, Sundergarh 7
14	Titlagarh 31, Ratnagiri 23, Gaganbavada 21, Khed & Komna 18 each, Daspatta 16, Shrivardhan 15, Kalaikunda, Jagdalpur & Navranapur 13 each	Sevoke 14, Yellandu 11, Suri 9, Galgalia 8, Dhantiwada & Agra 7 each	Broach 11, K. B. Dam, Subramanya & Agumbe 10 each, Naurangpur, Arnod, Kashipur & Rajapur 9 each, Namsai, Pallahara, Panchet & Jhabua 8 each, Pendra, Sapatra & Didwana 7 each	Bahraich 11, Agartala & Chettikulam 10 each, Krishnanagar 9, Nawarangpur 7

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
15	Mahabaleshwar 37, Durg 34, Mandangad 25, Poladpur 24, Chiplur, Bhira & Gaganbavada 21 each, Raipur 16, Hosanagara 14, Medikeri 13	Tikarpara 13, Korba & Vasai 12 each, Pali & Kota 11 each, Panvel, Banbasa, Tanakpur, Pen, Roha & Mhasala 10 each, Thane 9, Guwahati, Udupi, Khalapur & Mangaon 8 each, Bageswar, Koida, Peermade, Murbad, Vengurla, Murud, Matheran, Harnai, Koida, Mani & Agumbe 7 each	Limkheda 30, Peint 26, Madhuban 22, Jawahar 18, Galiakot & Khurai 17 each, Maharajgunj 15, Dohad 14, Agumbe 12, Narsingarh 10, Jhalwar 9, Khajuraho 8, Chouldhowaghat & Bhira 7 each	Raibareilly 25, Kashipur 17, Ambha 16, Rajakhera 15, Naraingarh 12, Krishnanagar 10, Bishalpur 9, Dharampur & Shivaganga 8 each, Khajuraho 7
16	Maihar 22, Mahabaleshwar 20, Sakaleshpura 17, Mandangad & Pendra 13 each, Khalapurwada, Yellapura & Satna 12 each, Alibagh, Durgachak & Murbad 10 each	Rajapur 20, Harnai 17, Rajnandgaon 15, Ambabhona & Mulki 13 each, Khonsa 12, Bantwal & Bajpe 11 each, Dharavi 10, Aie NH Xing & Karkala 9 each, Sevoke, Puthimari, Valparai, Mudibidre & Belthangaddy 8 each, Thalassery, Chepan, Malabar Hills, Mani, Panambur, Mangalore, Puttur & Kundapura 7 each	Garoth 34, Sunel 33, Rawat Bhata 31, Uttarkashi 14, Ambala, Nahan & Paonta 12 each, Bhund 11, Dharampur 9, Kalaikunda 8, Nawan City, Bhopal, Malad, Mahabaleshwar & Kasol 7 each	Bangana 20, Krishnanagar 16, Port Blair & Valparai 9 each, Nangal, Karaikal & Jammu 8 each, Deori & Jagdalpur 7 each
17	Mumbai & Ballupet 15 each, Gorakhpur & Panna 13 each, Passighat 12, Kokrajhar & Valsad 11 each, Kamtaul 10, Sarkaghat 9, Champasarai, Dehra Dun & Dhittur 8 each	Jowai 22, Tezu & Dondilohara 14 each, Sevoke & Uttarkashi 13 each, Agumbe & Ashti 11 each, Simulia, Satna, Passighat & Bagidora 9 each, Miao, Dhollabazar, Gajoldoba, Hasimara, Umedsagar, Ghadola & Jagalpet 8 each, Chatia, Basua, Daruali, Varanasi, Raighat, Dillighat, Baghdogra, Kotri & Chhoti Sadri 7 each	Pallahara 28, Paradip & Uttarkashi 19 each, Rawat Bhata 12, Mukhlispur & Agumbe 10 each, Daltonganj, Basti & Kota 9 each, Nangal, Dabhoi, Subramanya & Nawanshahar 8 each, Taoru, Dharamsala, Guler, Nagroiasurian, Sangrahu & Murbad 7 each	Maharo 23, Tantloi 17, Sivaganga 10, Port Blair 7
18	Mahabaleshwar 21, Mumbai 16, Neora 13, Goalpara, Dehra Dun & Garhakota 12 each, Linganamakki 10, Maya Bandar & Guddalur Bazar 9 each	Passighat 45, Jowai 35, Tezu 18, Bhal Purwoighat FM 14, Cooch Behar, Benibad & Cooch Behar 15 each, Bhatpurwaghat 14, Banbasa, Goalpara & Kapasan 13 each, Domohani & Bhansroad Garh 12 each, Gajoldoba, AIE NH Xing, Lengpui & Washim 11 each, Dhubri, Jalpaiguri & Champasarai 10 each, Baghdogra, Alipurduar & Railmaghra 9 each, Beki Mathanguri, Diana, Kakrahi, Marwari Junction & Surat 8 each, Bilara, Mathabhanga, Hasimara, Munger, Bhinga, Bilara, Meja Dam, Bijolia, Bhadesar & Mangrol 7 each	Ghumarwin 18, Tibri 17, Nangal, Balachaur & Tajewala 16 each, Paonta 15, Gohar & Dehragopipur 14 each, Dabra & Pathankot 13 each, Dadupur & Ranchi 11 each, Diana, Kangra & Mukerian 10 each, Sheopur Kalan 9, Sujanpurtira, Hamirpur, Guler, Bangana, Jhirka, Berthin, Nahan & Nadboi 8 each, Uchana, Bhiranj, Dadahu, Khanna, Lalganj & Thakurmunda 7 each	Barkisurya 33, Talaiya 23, Kulithalai 13, Dillighat 12, Kodavasai 10, Haripad 9, Idukki 8, Harinkhola & Roing 7 each
19	L. B. Ghat 14, Diana, Saulighat & Bareilly 13 each, Baran 11, Radhanagari 10, Amraghat 9, Barkisurya, Ayodhya, Banbasa & Yellapur 7 each	Passighat 42, Jowai 40, Daporijo 21, Sevoke 19, Roing & Shillong 14 each, Nagrakata, Diana, Basua & Surat 12 each, Thiruvananthapuram & Maruti 11 each, Gajoldoba 10, Naktidevi, Jhanjharpur, Kakrahi, Balarampur & Neyyatinkara 9 each, Bansi, Karimganj, Champasarai, NH 31, Saulighat, W. Champaran & Bansi 8 each, Maharo, Cuddapah, Minicoy, Annapurnaghat, Alipurduar, Mamarao & Saharsa 7 each	Jhanjarpur 12, Annapurnaghat 11, Hapur, Agumbe & Murbad 9 each, Silchar, Agartala, Kahu, Jamnagar & Kundapura 8 each, Kasargode, Kendrapara & Katghora 7 each	Jashpurnagar 15, Chandbali 12, Sobong 10, Etawah 8, Diana & Lakhipur 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
20	Cherapunji 27, Gajoldoba 12, Belonia 9, Kolkata 7	Jowai 40, Badatighat 22, Diana 19, Dharamanagar 16, Kailashahar 15, Goalpara 14, Karimganj 13, Manas NH Xing & Beki Road Bridge 12 each, Dholai, Silchar, Matizuri & Amini Divi 10 each, Agartala 9, Amraghat, AIE NH Xing & Cooch Behar 8 each, Ghat, Malvan, Mulki, Numaligarh & Darjeeling 7 each	Mirzapur 11, K. B. Dam, Neemsar & Talab Sahi 9 each, Panchet & Dindori 8 each, Bankura, Jowai, Tensa, Barora, Bhatkal, Shirali & Gaganbavada 7 each	Jaipur 17, Alibag 12, Surajpur 10, Allagadda & Red Hills 9 each, Aizwal, Lengpui & Kavali 8 each, Jeur 7
21	Gaya 21, Cherrapunji 19, Maharo 18, Chepan 12, Kataula 10, Rampurhat & Bhalukpong 7 each	Kokrajhar 13, Hasimara 11, Neora 10, Dhubri & Mathabhanga 9 each, Gossaigaon & Murti 8 each, Manas NH Xing, AIE NH Xing, Sonbarsa, Valpoi, Athagarh & Araria 7 each	Navarangpur 19, Mirzapur 18, Pantnagar & Ajaigarh 16 each, Tangla 13, Shantipuri 11, Goalpara & Rajghat 10 each, Bahraich, Kanker & Perur 9 each, Murbad 8, Matunga & Borsad 7 each	Khajuraho 18, Fatehgarh, Hamirpur & Shahjina 12 each, Naraingarh 10, Port Blair 8, Machilipatnam, Suryapet, Panvel & Annigeri 7 each
22	Khusiary 20, Basua 13, N. H. Xing 11, Sonamura 10, Itanagar 9, Rampurhat 8	Bankura & Songadh 9 each, Valparai 8, Bardoli 7	Paikmal & Dewas 13 each, Jabalpur & Narsinghpur 11 each, Hoshangabad 10, Sibsagar, Masani, Barrage, Sibsagar, Agumbe & Khalapur 9 each, Goalaghat & Mohana 8 each, Bhira & Garautha 7 each	Sharadanagar 48, Neemsar 27, Palliakalan 20, Mohana & Kalpi 16 each, Cancona & Valpoi Patoda 10 each, Soro & Aurangabad 9 each, Shirali & Bidar 8 each
23	Diana 40, Mellabazar 15, Roing 9, Kailashahar & Guler 8 each	Kondul 16, Nancowry, Dahanu & Agumbe 7 each	Budhni 29, Hoshangabad 25, Sikohabad 16, Bhungra & Dug 11 each, Kondul, Suri & Banswara 9 each, Dadahu 8, Kharkhoda, Marwar & Jaspurnagar 7 each	Kashipur 23, Gajoldoba 12, Nagina 11, Kokrajhar & Palliakalan 7 each
24	Agartala 23, Mellabazar 11, Sankalan 8, Passighat & Aizawal 7 each	Kailashshahar 11, Nayagarh, Agumbe Linganamakki & Madikere 9 each, Alipurduar, Udala & Khanapur 8 each, Matizuri & Bhagamandala 7 each	Sunel 25, Rajpura, 18, Dug 17, Pirawa & Hindon 15 each, Gaziabad 14, Tauru, Mandsaur & Agar 13 each, Khalapur 12, Ambala & Sonepat 10 each, Ambala, Gannaur & Mahabaleshwar 9 each, Delhi Ridge, Jagadhari, Bharwain, Dharamsala & Agumbe 8 each, Sohana, Uchana, Rohtak, Gohana, Kharkhida & Diana 7 each	Kokrajhar 16, Cooch Behar 11, Beki Mathanguri 10, Tilaiya 9, Bhalukpong, Taibpur & Erode 8 each, Peermade, Kanakapura & Harapanhalli 7 each
25	Sevoke 10, Purnea & Honavar 7 each	Mudibidre 20, Puttur, Kota & Karkala 15 each, Banbasa 14, Chouldhowaghat & Kundapur 12 each, Dibrugarh, Gangtok & Hoshangabad 9 each, Bajpe & Agumbe 8 each, Neamatighat, Alibag, Simga, Metapalli, Karwar & Medikeri 7 each	Govindgarh & Sawar 15 each, North Lakhipur 14, Bhalukpong, Harinkhola & Bharatpur 11 each, Moradabad, Basti & Roorkee 9 each, Nawashahar, Hasimara, Patna & Mahabaleshwar 8 each	Coonoor 12, Neora 11, Wada 10, Vyara & Jhanjgir 8 each, Itanagar, Galgalia, Daund & Aryankavu 7 each
26	Kumta 12, Vengurla 11, Agumbe 9, Khowang 7	Navsari 21, Kudulu 15, Udupi 13, Kasargode, Bosan, Dindigul & Karkala 11 each, Mumbai & Hosdurg 10 each, Malabar Hill, Dharavi, Bantwal & Agumbe 9 each, Mussoorie, Dehra Dun, Kota, Shirali & Sulya 8 each, Kondul, Kashinagar, Umargaon, Daman, Bandra Hill, Bhandup, Madhira, Mani. Puttur, Mangalore, Kundapura, Honavar & Kannur 7 each	Hasanpur 25, Tanakpur 17, Moradabad 14, Dharmanagar, Kashipur, Pantnagar & Mukteshwar 11 each, Narora, Ramgarh & Barsar 10 each, Bhiwani 8, Nainital, Kotdwar & Kathumar 9 each, Bhalukpong, Cherrapunji & Bhiwani 8 each, Bangana & Kondul 7 each	Chalakudy 11, Jagdalpur 9, Bhalukpong, Kunda Bridge & Nayakanahalli 8 each, Baliguda, Songadh & Shevgaon 7 each
27	Mahabaleshwar, Gajoldoba & Bhatkal 16 each, Asti & Bhalukpong 11 each, Murbad 9, Kalladgi 8	Narsingarh 20, Pardi 16, Uttarkashi 15, Guler & Rajakhera 14 each, Dehra Dun 12, Biora & Umargaon 11 each, Nagrota Surian 10, Dahanu 9, Mussoorie, Sarangpur, Valia, Bansda, Kamrej & Vapi 8 each, Malakpur, Pandoh, Mandrial, Shajapur, Sarengar, Bardoli, Songadh, Daman, Gogha, Bhira & Mahabaleshwar 7 each	Cherrapunji 28, Neora 19, Murti 14, Cooch Behar 13, Galgalia 11, Khonsa 10, Amraghat 7	Akola & Pullambadi 9 each, Hindigir 8, Joida, Karjat, Nagapattinam, Kottayam & Shirali 7 each

TABLE 16 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
28	Kozhikode 12, Murti & Agumbe 11 each, Ponnani 9	Palliakalan 16, Pottangi & Bosan 15 each, Haripur 12, Tikavali & Mussoorie 11 each, Madanpur & Deori 10 each, Didihat, Sujanpur, Tira, Dharamsala, Mungali & Parvathipuram 9 each, Phulbani & Satna 8 each, Khandapara 8, Umerkote, Karanprayag, Almora, Pathankot, Vidisha, Mahabaleshwar & Sriramsagar 7 each	Diana 24, Gorakhpur 22, Gajoldoba & Murti 15 each, Kakrahi 11, Panagarh 8, Birpur 7	Vadakara 16, Myladi 11, Chalakudy 8, Rengali 7
29	Sulya 12, Alapuzha, Jintoor & Bihubar 9 each, Mahanpur & Agumbe 8 each, Barrackpur & Haripad 7 each	Agumbe 16, Shriwardhan & Kashipur 14 each, Jalpatna & Ratnagiri 12 each, Bilari, Sardarnagar & Chouldhowaghat 11 each, Dewas, Nizamsagar, Kairi & Harnai 10 each, Bankura, Itanagar, Uttarkashi, Mussoorie, Srinagar, Dharamsala, Basholi, Jabalpur, Mumbai & Alibag 9 each, Moradabad, Bangana, Bhira, Medak & Shringeri 8 each, Port Blair, Rudraprayag & Bhuntar 7 each	Rewa Ghat 12, Kolkata 10, Rairangpur 9	Kondul 18, Naharkatia 14, Neora 9, Chakur 8, Suri, Tezu, Joshipur, Mahabaleshwar, Cuddalore, Munnar & Panchanahalli 7 each
30	Chouldhowaghat 12, Maya Bandar & Mokhada 10 each, Agumbe 9, Mathabhanga, Passighat & Eturnagaram 7 each	Navsari 46, Pardi 30, Gandevi 26, Vapi 25, Madhuban 22, Valsad 21, Silvasa 19, Dharamsala 17, Mumbai, Umrer, Chikhli & Ratnagiri 13 each, Umergaon, Bansda, Broach Kotdwar & Agumbe 12 each, Surat, Dahanu, Harnai & Udgir 11 each, Dholka, Lanji, Banswada, Bhira, Mahabaleshwar & Nagpur 10 each, Kohima, Telkoi, Pallahara, Bhungra, Palsana, Dharampur, Dediapada, Mahuva & Palitana 9 each, Bihubar, Vyara, Ahwa, Sagbara & Piravom 8 each, Port Blair, Sagar, Parambikulam, Kashinagar, Galiakot. Rajpipla, Bhavnagar, Gondal, Alibag & Valparai 7 each	Hayaghat 20, Champasarai & Cherrapunji 12 each, Khadda 10, Gajoldoba 9, Magra & Bijepur 8 each	Champasarai & Beki Mathanguri 9 each, Udaipur 8, Itanagar 7
31	–	Pardi 30, Gandevi 26, Vapi 25, Madhuban 22, Dabok, Udaipur & Dabhoi 21 each, Murbad 20, Silvasa 19, Baroda 18, Kadi 17, Bansda 15, Ratnagiri, Hoshangabad, Jambughoda & Tilakwada 14 each, Gandhinagar, Palsana, Navsari, Songadh & Sankheda 13 each, Lunawada, Umergaon, Jodia & Kodinar 12 each, Sanand, Surat, Karian, Wagodia, Agumbe & Morvi 11 each, Ahuwa, Bardoli, Bhira & Mahabaleshwar 10 each, Mehamadabad, Mahuva, Mandvi, Dharampur & Chhota Udaipur 9 each, Karkala, Jhalwar, Motisagar Bandh, Dholka, Anand, Gandhinagar, Chikhli, Rajpipla, Ahmedabad, Amreli, Sihor, Jasdan, Mumbai & Jawahar 8 each, Tikabali, Godhara, Valod, Veraval, Wankaner, Ratnagiri, Alibag, Bhandup & Thane Belapur 7 each	Chepan 12, Gheropara 10, Chouldhowaghat, Jhawa & Pondicherry 7 each	–

TABLE 17

Characteristics of monsoon rainfall

S. No.	Sub – division	(No. of days)			
		Vig.	Act.	V. Heavy	Heavy
1.	Andaman & Nicobar Island	–	–	2	21
2.	Arunachal Pradesh	4	29	8	33
3.	Assam & Meghalaya	1	21	23	45
4.	Naga., Mani., Mizo. & Trip.	4	23	3	15
5.	S.H.W.B. & Sikkim	8	29	27	30
6.	Gangetic West Bengal	4	21	6	37
7.	Orissa	2	24	18	42
8.	Jharkhand	3	22	5	17
9.	Bihar	6	13	12	23
10.	East Uttar Pradesh	1	8	10	22
11.	West Uttar Pradesh	–	7	3	15
12.	Uttaranchal	6	11	9	20
13.	Haryana	3	7	3	6
14.	Punjab	1	3	4	9
15.	Himachal Pradesh	3	10	7	25
16.	Jammu & Kashmir	–	–	–	–
17.	West Rajasthan	–	1	–	5
18.	East Rajasthan	–	–	9	13
19.	West Madhya Pradesh	1	14	9	20
20.	East Madhya Pradesh	3	8	6	13
21.	Gujarat Region	9	7	1	3
22.	Saurashtra & Kutch	7	5	1	3
23.	Konkan & Goa	3	12	26	34
24.	Madhya Maharashtra	5	11	11	36
25.	Marathwada	2	11	–	8
26.	Vidarbha	–	–	2	2
27.	Chattisgarh	–	6	5	21
28.	Coastal Andhra Pradesh	6	14	4	7
29.	Telangana	1	19	–	17
30.	Rayalaseema	4	10	–	7
31.	Tamil Nadu & Pondicherry	1	4	4	28
32.	Coastal Karnataka	1	14	14	35
33.	North interior Karnataka	4	8	3	21
34.	South interior Karnataka	7	14	13	44
35.	Kerala	–	11	10	37
36.	Lakshadweep	–	–	–	2

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 5 to 7 days in Sub-Himalayan West Bengal & Sikkim, Konkan & Goa, coastal & south interior Karnataka and Kerala; on 2 to 4 days in Assam & Meghalaya, Gangetic West Bengal, Orissa, Jharkhand, Bihar and Madhya Maharashtra and on 1 day each in Nagaland-Manipur-Mizoram-Tripura, east Uttar Pradesh, east Madhya Pradesh, Chattisgarh, coastal Andhra Pradesh and Tamil Nadu. Also *Heavy* rainfall occurred on 10 to 14 days in Andaman & Nicobar Islands, Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, coastal & south interior Karnataka and Kerala; on 6 to 9 days in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Konkan & Goa and north interior Karnataka and on 1 to 5 days in Orissa, Jharkhand, Bihar, Uttar Pradesh, Uttaranchal, Himachal Pradesh, west Rajasthan, east Madhya Pradesh, Marathwada, Chattisgarh and Tamil Nadu.

9.2. *Heavy rainfall during July*

During the month, *very heavy rain* occurred on 11 to 13 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim and Konkan & Goa, on 4 to 7 days in Arunachal Pradesh, Orissa, Bihar, east Uttar Pradesh and Uttaranchal and on 1 to 3 days in Andaman & Nicobar Islands, Nagaland-Manipur-Mizoram-Tripura, Jharkhand, Himachal Pradesh, east Rajasthan, west Madhya Pradesh, Vidarbha, Chattisgarh, coastal Andhra Pradesh, Tamil Nadu, Karnataka and Kerala. Also *heavy rain* occurred on 10 to 15 days in Assam & Meghalaya, Orissa, Konkan & Goa, Madhya Maharashtra, Chattisgarh, Telangana, coastal and south interior Karnataka and Kerala, on 5 to 9 days in West Bengal & Sikkim, Jharkhand, Bihar, Uttar Pradesh, Uttaranchal, Himachal Pradesh, Madhya Pradesh and north interior Karnataka and on 1 to 4 days in Andaman & Nicobar Islands, Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, Punjab, east Rajasthan, Marathwada, Vidarbha, coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, north interior Karnataka and Lakshadweep.

9.3. *Heavy rainfall during August*

During the month, *very heavy rain* occurred on 6 to 9 days in Orissa, east Rajasthan, west Madhya Pradesh, Konkan & Goa, Madhya Maharashtra, on 3 to 5 days in Assam & Meghalaya, west Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, east Madhya Pradesh, coastal and south interior Karnataka and Kerala and on 1 to 2 days in West Bengal & Sikkim, Bihar, east Uttar Pradesh, Gujarat state, Vidarbha, Chattisgarh, coastal Andhra Pradesh, Tamil Nadu and north interior Karnataka. Also *heavy rain* occurred on 10 to 14 days in Assam & Meghalaya, Gangetic West Bengal, Orissa, Himachal Pradesh, West Madhya Pradesh, Konkan & Goa, Madhya Maharashtra and south interior Karnataka, on 5 to 9 days in Andaman & Nicobar Islands, Arunachal Pradesh, Jharkhand, Bihar, Uttar Pradesh, Uttaranchal, Punjab, east Rajasthan, Saurashtra & Kutch, Chattisgarh, coastal Karnataka and Kerala and on 1 to 4 days in Nagaland-Manipur-Mizoram-Tripura, Sub-Himalayan West Bengal & Sikkim, Haryana, west Rajasthan, east Madhya Pradesh, Gujarat region, Marathwada, Vidarbha, Coastal Andhra Pradesh, Telangana, Tamil Nadu and north interior Karnataka.

9.4. *Heavy rainfall during September*

During the month, *very heavy rain* occurred on 5 days in Sub-Himalayan West Bengal & Sikkim, on 4 days in Assam & Meghalaya and on 1 to 2 days in Andaman & Nicobar Islands, Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Orissa, Jharkhand, Bihar, east Uttar Pradesh, Uttaranchal, Himachal Pradesh, east Rajasthan, Madhya Pradesh, Konkan & Goa, Madhya Maharashtra, Chattisgarh, Tamil Nadu, north interior Karnataka and Kerala. *Heavy rain* also occurred on 18 days in Tamil Nadu, 7 to 10 days in Arunachal Pradesh, Assam & Meghalaya, West Bengal & Sikkim, Orissa, Madhya Maharashtra, south interior Karnataka and Kerala and on 1 to 5 days in Andaman & Nicobar Islands, Nagaland-Manipur-Mizoram-Tripura, Jharkhand, Bihar, Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, east Madhya Pradesh, Konkan & Goa, Marathwada, Chattisgarh, coastal Andhra Pradesh, Telangana, Rayalaseema and coastal and north interior Karnataka.

10. Significant temperature during the season

Unlike the previous year in which *Severe heat wave* conditions continued till mid June, the early onset and the comparatively normal flow patterns which prevailed during June 2004 prevented any anomalous temperature field to get established over the country.

Heat wave conditions prevailed on 5 days each in West Rajasthan, east Madhya Pradesh and Vidarbha, 4 days in west Madhya Pradesh, 3 days in east Rajasthan and 1 day each in Jharkhand and Uttar Pradesh during June. Also day temperatures were *appreciably to markedly above normal* on 3 to 4 days in Orissa, Madhya Pradesh, Saurashtra & Kutch, Madhya Maharashtra, Marathwada and Chattisgarh and on one day each in Jharkhand, west Rajasthan, Gujarat region, coastal Andhra Pradesh, Telangana and north interior Karnataka during the month. 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.

11. Disastrous weather events and damage during monsoon months

11.1. *June*

Flood in river Bramhaputra, took a toll of 14 lives in Assam and Meghalaya, damaged standing crops of 22,502 hectares of paddy field and affected a population of 8, 63, 445. Also flood situations disrupted normal life in Nagaland, Manipur, Mizoram and Tripura. Lightning caused the death of 1 in Assam, 23 in West Bengal and 5 in Vidarbha and 2 in Karnataka. Heavy rains, flood and landslides took the lives of 30 in Bihar, 136 in Gujarat, 5 in Karnataka and 32 in Kerala. Also many Bridges, huts, factories and other buildings were damaged and massive loss of Agriculture occurred in Bihar, Kerala and Karnataka. Capsising of a boat due to northwester caused the death of 31 people in Bihar. In Uttar Pradesh, 25 people lost their lives in a thundershower. Rough seas and strong winds claimed the lives of 3 fishermen in Tamil Nadu, 4 in Karnataka and 6 in Kerala.

11.2. *July*

Flood in river Bramhaputra and its tributaries continued to be grim, claiming 212 lives in Assam and Meghalaya. Flood affected more than 60 % of the standing crops and also 11 Rhinos in Kaziranga National Park were reported to be died. Heavy rain and flood took a toll of 6 in West Bengal, 69 in Bihar, 9 in Karnataka, 3 in Kerala, 5 in Maharashtra and 56 in Nagaland. It also damaged properties worth lakhs of rupees and rendered many people homeless in these regions. Landslides caused

the death of 44 in Assam and 17 pilgrims in Uttaranchal. It also damaged 5 houses, 50 acres of Agriculture, 5 bridges and 7 roads in Kerala. Lightning claimed the lives of 1 in Nagpur, 7 in Bhopal, 31 in Orissa and 7 in West Bengal. Three fishermen in Kerala lost their lives due to rough sea conditions.

11.3. *August*

Heavy rains and floods claimed the lives of 184 people in Gujarat, 36 in Assam, 3 in Karnataka and 2 in Madhya Pradesh. Due to land slides, flash floods, strong winds and heavy rain 40 people lost their lives in Kerala. It also caused large scale destruction of property including houses, roads and crops. Collapse of a tunnel triggered by heavy rains took a toll of 27 workers in Tehri Dam. Also 11 labourers lost their lives due landslides in Jammu and Kashmir, 2 in Himachal Pradesh and 2 on the Mumbai – Pune express highway. Flash floods and incessant rains affected the normal life in many parts of Uttaranchal, Himachal Pradesh, Punjab, Haryana and Maharashtra states. Lightning claimed the lives of 7 in Assam, 5 in West Bengal and 3 in Orissa. Ten fishermen in Kerala lost their lives in rough seas.

11.4. *September*

Lightning and heavy rains took a toll of 47 people in Maharashtra, 17 in West Bengal and 10 in Bihar. Heavy rains and floods also claimed 50 lives in Uttar Pradesh, 7 in Assam, 4 in Karnataka, 1 in Madhya Pradesh and 4 in Gangetic West Bengal. Lightning caused the death of 14 in West Bengal and 3 in Kerala and strong winds and rough seas claimed the lives of 2 fishermen in Kerala. .

12. Damage due to floods etc. during monsoon season

According to press reports and other disaster reports, weather related natural hazards took a toll of 1261 people in different parts of the country. Gujarat state and Assam & Meghalaya were the most affected sub-divisions where respectively 320 & 318 people lost their lives mainly due to floods, followed by Bihar (140). Apart from heavy rain, flash floods, landslides, lightning also had been major causes for death toll during the season.

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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	- 75% or more stations of a meteorological sub-division reporting at least 2.5 mm rainfall.
Fairly widespread	- 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.

Monsoon activity

Active	- average rainfall of a sub-division is more than 1½ 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, when the rainfall is fairly western disturbance to western disturbance.
Vigorous	- average rainfall of a sub-division is more than 4 times or more the normal with minimum 8 cm along the west coast and 5 cm elsewhere in atleast two stations in the sub-division, when the rainfall is western disturbance to western disturbance.

Maximum/day temperatures

Severe heat wave conditions	- departure of maximum temperature from normal is + 6.0° C or more for the regions where the normal maximum temperature is more then 40° C and + 7° C or more for regions where the normal maximum temperature is 40° C or less.

Heat wave conditions - departure of + 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 - departure of maximum temperature from normal is between +3° C to +4° C for the regions where the normal maximum temperature is 40° C or less.