MAUSAM, **54**, 3 (July 2003), 775-810

Weather in India

MONSOON SEASON (June to September 2002)†

1. Introduction

The rainfall during the southwest monsoon season over the country as a whole was deficient by –19% of the long period normal. There had been large intra-seasonal variability during the season. The July rainfall was the lowest (–51%) during the past 100 years. However, the rainfall in remaining 3 months was near normal. The rainfall was *excess** in 1, *normal* in 14, *deficient* in 19 and *scanty* in the remaining 2 meteorological subdivisions. The onset of monsoon over Kerala, the southern tip of main land, was near to the normal date. Further advance also took place in near normal dates, until the first hiatus in its northern limit during 13 to 19 June. Thereafter, the progress was rather sluggish, and it took nearly 2 months for the monsoon current to cover the northern parts of central India and northwest India. The coverage of the entire country by 15 August, with a delay of 1 month from normal, has been the longest delay in the recorded history of the monsoon. Withdrawal took place as per the normal dates initially and later on it was delayed by almost a week's time. During the season, no intense low pressure systems, *viz*., monsoon Depressions / Cyclonic Storms formed over the Indian seas.

2. Characteristic features of southwest monsoon 2002

2.1. Total seasonal monsoon rainfall over the country as a whole was 81% of its long period average, thus it has been a deficient year, preceded by 13 successive normal monsoon years.

2.2. The southwest monsoon set in over Kerala on 29 May, 3 days earlier than its normal date of 1 June. No intense low pressure systems were present as onset vortex, other than an off-shore trough present along west coast.

2.3. Southwest monsoon covered the entire country on 15 August with a delay of 1 month, which is the longest delay ever recorded in covering the entire country.

There were 3 hiatuses in its northern limit, the first one which was of rather shorter duration from 13 to 19 June, the second one from 5 to 18 July and the third from 20 July to 14 August. The Isochrones of advance are shown in Fig. 2.

2.4. The southwest monsoon withdrew from most parts of west Rajasthan, some parts of Gujarat state and of north Arabian Sea on 16 September as against the normal date of 15 September.

Further it withdrew from the central parts of the country by 3 October (more or less in the normal date), northeastern states by 17 Oct, (4-5 days delay over the extreme northeast). The withdrawal completed from most of the regions north of Lat. 15° N by 21 October (6-7 days delay). It withdrew from the entire country on 25 October (10 days delay) with the simultaneous commencement of northeast monsoon rains over Tamil Nadu, Kerala and adjoining states of Karnataka and Andhra Pradesh. Fig. 8 gives the Isochrones of withdrawal.

2.5. Not a single intense low pressure system, like, Depression/ Cyclonic Storm formed during the season. The lack of monsoon Depressions was an unusual feature of the season, as no similar case had been found in the recorded account of past 130 years.

2.6. Rainfall during the monsoon 2002 was *excess* in 1 and *normal* in 14 meteorological subdivisions. Rainfall activity was normal in June (27- E/N), extremely subdued in July (6-E/N), normal in August (25-E/N) and nearly normal in September (17-E/N)

2.7. Seasonal rainfall was *excess* only in Jammu & Kashmir, and it was *excess* there all through the months except July. Cumulative rainfall was *excess* or *normal* throughout the monsoon season in Sub Himalayan West Bengal & Sikkim and Gangetic West Bengal.

2.8. As seen in the week by week progress of rainfall, [Fig. 1(a)], extremely subdued rainfall activity was observed during the entire July over the country except the northeastern parts including Jharkhand and Bihar. Similar situation was also observed towards the end of the season.

2.9. Monsoon trough got established on 15 August (in accordance with the late coverage of monsoon over the country) and Tibetan anticyclone on 11 July. The off-shore trough persisted on most of the days (though quite weak on many occasions) from 20 May to 17 September along different parts of west coast.

*Definition of words in italics are given in Appendix

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Progress of the monsoon week by week

1 June – 30 September 2002

Fig. 1(a)

Progress of the monsoon week by week (cumulative)

1 June – 30 September 2002

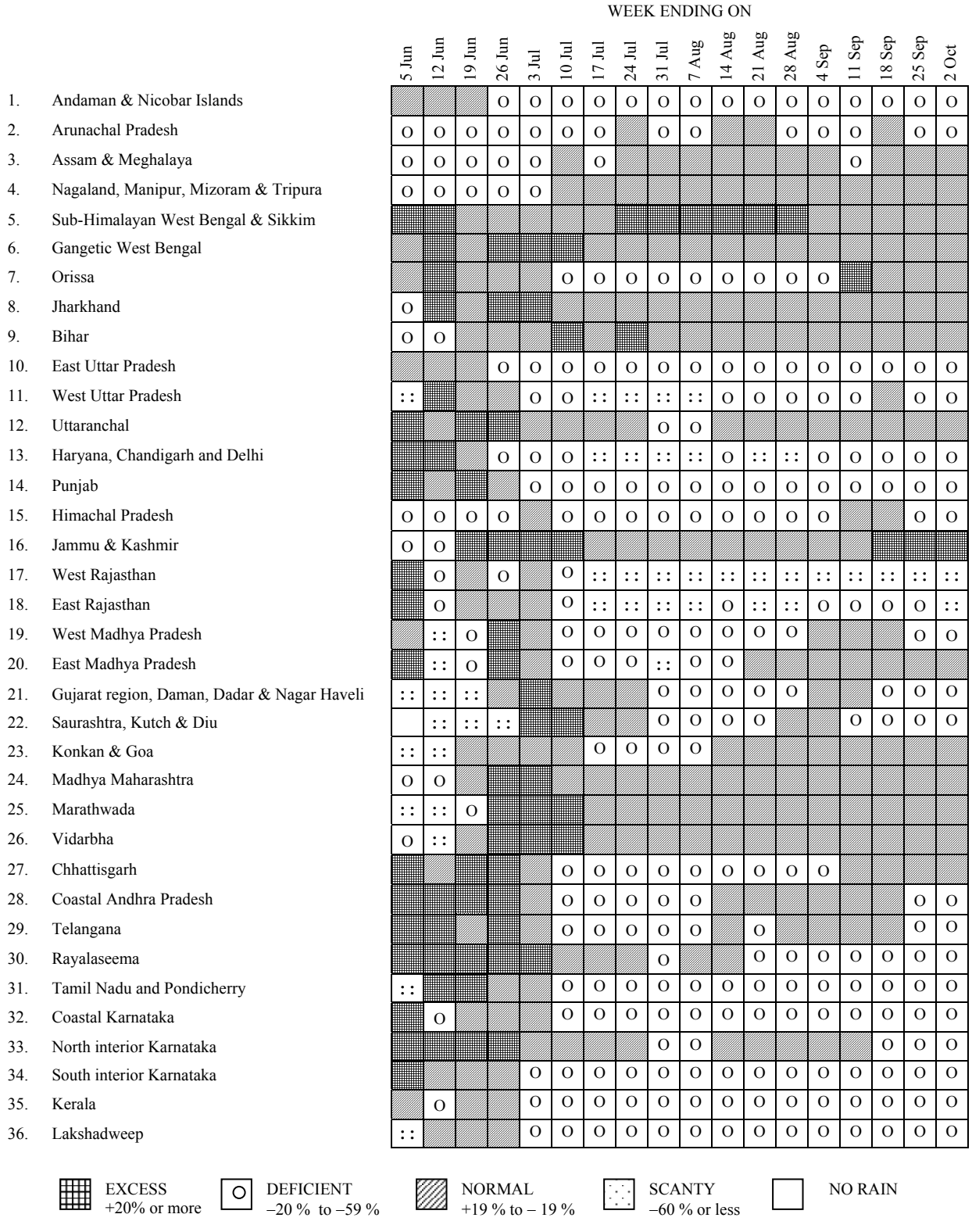


Fig. 1(b)

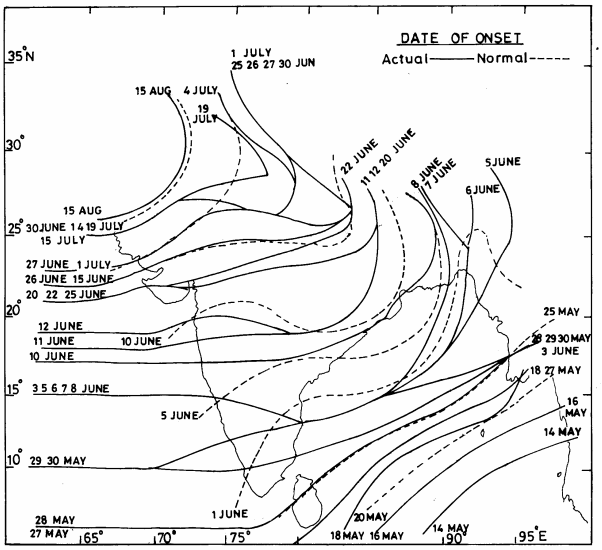


Fig. 2. Advance of southwest monsoon 2002

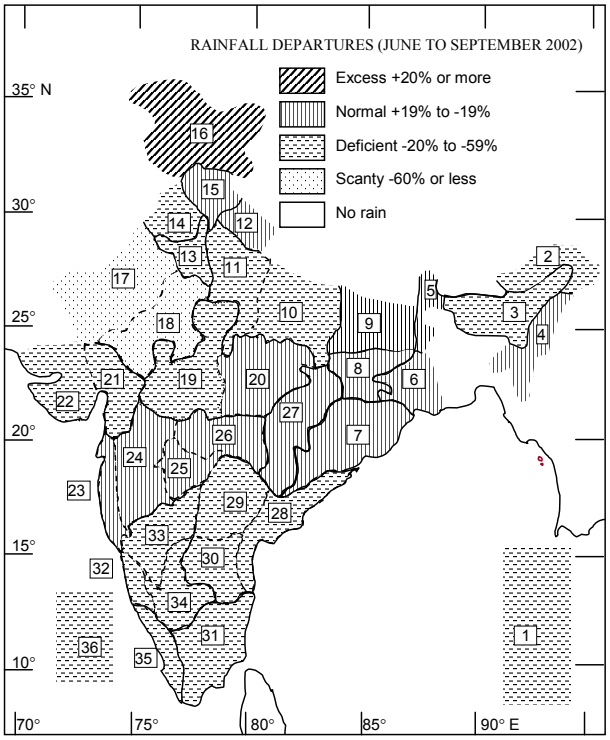


Fig. 3. Rainfall for the season June to September 2002 departure from normal (%). Sub-divisions are indicated by number on the map & bold letters in legend. The rainfall anomaly values for these 36 sub-divisions are indicated below

1	–23	**7**	–19	**13**	–38	**19**	–22	**25**	–3	**31**	–46
2	–24	**8**	6	**14**	–27	**20**	–15	**26**	1	**32**	–30
3	–20	**9**	0	**15**	–16	**21**	–26	**27**	–18	**33**	–31
4	–4	**10**	–24	**16**	23	**22**	–25	**28**	–25	**34**	–44
5	12	**11**	–21	**17**	–71	**23**	–18	**29**	–22	**35**	–33
6	5	**12**	–4	**18**	–60	**24**	–13	**30**	–33	**36**	–45

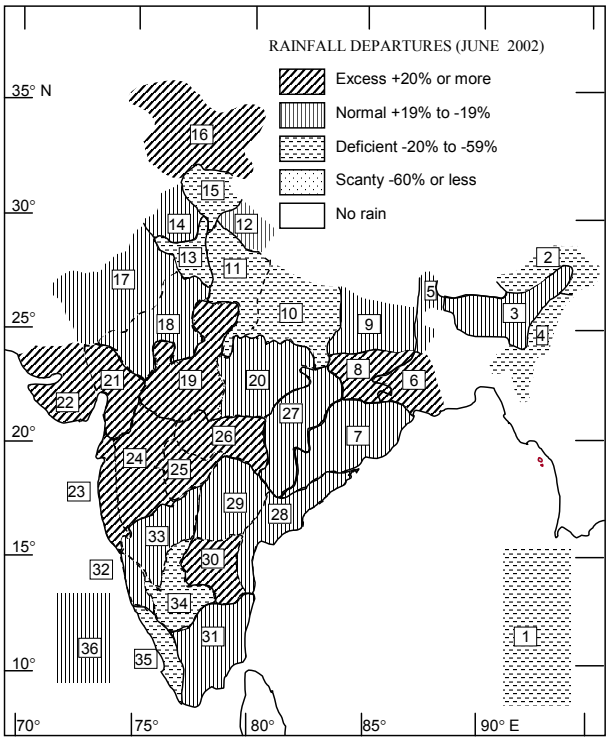


Fig. 4. Sub-divisionwise seasonal rainfall departure from normal (%) for the June 2002. Sub-divisions are indicated by number on the map & bold letters in legend. The rainfall anomaly values for these 36 sub-divisions are indicated below :

1	–31	**7**	–5	**13**	–33	**19**	49	**25**	67	**31**	7
2	–29	**8**	22	**14**	–7	**20**	–11	**26**	107	**32**	–8
3	–18	**9**	–9	**15**	–23	**21**	111	**27**	8	**33**	18
4	–33	**10**	–41	**16**	80	**22**	120	**28**	7	**34**	–22
5	–9	**11**	–28	**17**	15	**23**	25	**29**	2	**35**	–25
6	33	**12**	9	**18**	15	**24**	74	**30**	31	**36**	–19

2.10. Cross equatorial flow was quite weak in general, during the entire season over the Arabian Sea and Bay of Bengal except during August, when it gathered a little momentum.

2.11. Northeast monsoon rains commenced over Tamil Nadu, Kerala and adjoining areas of Karnataka and Andhra Pradesh States on 25 October, 5 days later than the normal date *i.e.* 20 October. It ceased in these regions on 27 December, as against the normal date of 15 December.

3. Features of monsoon

3.1. *Advance of southwest monsoon*

The southwest monsoon set in over Kerala on 29 May, 3 days earlier than its normal date of 1 June. No

intense low pressure systems were present as onset vortex, other than an off-shore trough present along west coast, as had been noticed in 1999, 1997, 1996, 1995, 1994, 1990 and 1989.

The southwest monsoon covered the entire country on 15 August, with a delay of 1 month, the longest delay ever recorded, in covering the entire country. The second longest delay in the past occurred in 1987, when the southwest monsoon covered the entire country on 27 July.

During the onset phase of this monsoon, there were 3 hiatuses in its northern limit, the first one which was of rather shorter duration from 13 to 19 June, the second one from 5 to 18 July and the third from 20 July to 14 August.

Date wise onset of southwest monsoon 2002 over different areas is given below :

Onset / progress over	*Date*	*Dep. from normal*
▪ Most parts of Tamil Nadu, some more parts of central Bay of Bengal.	30 May	2 days prior
▪ Entire Lakshadweep area, some more parts of Kerala and some parts of south interior Karnataka.	30 May	6 days prior
▪ Southern parts of central Arabian Sea, most parts of coastal Karnataka, some parts of south interior Karnataka and Rayalaseema.	3 Jun	2 days prior
▪ Some more parts of central Bay, some parts of northeast Bay, some parts Nagaland, Manipur, Assam and Arunachal Pradesh.	5 Jun	Normal
▪ Entire Nagaland, Manipur and Meghalaya, some more parts of Assam and Arunachal Pradesh.	6 Jun	1 day late
▪ Some more parts of northeast Bay, entire Mizoram and most parts of Tripura.	6 Jun	5 days late
▪ Most parts of Assam and some parts of Sub-Himalayan West Bengal & Sikkim.	7 Jun	2 days late
▪ Some more parts of Sub-Himalayan West Bengal & Sikkim.	8 Jun	3 days late
▪ Some more parts of central Arabian Sea, southern parts of Konkan & Goa and of Madhya Maharashtra, most parts of north interior Karnataka, entire Rayalaseema and some parts of Telangana, entire coastal Andhra Pradesh and of Bay, some parts of coastal Orissa and of coastal Gangetic West Bengal, and some more parts of Sub-Himalayan West Bengal & Sikkim.	10 Jun	5days delayed in most of these regions. Whereas a small portion of the region received on normal date
▪ Some more parts of central Arabian Sea, Konkan & Goa and of Madhya Maharashtra, some parts of Marathwada, most parts of Telangana, some parts of Chattisgarh, remaining parts of Gangetic West Bengal.	11 Jun	1 day delayed
▪ Some more parts of Orissa, Jharkhand and of Bihar.	11 Jun	4 days early
▪ Most parts of central Arabian Sea, remaining parts of Konkan & Goa, some more parts of Madhya Maharashtra, most parts of Marathwada, some more parts of Telangana.	12 Jun	2 days delayed
▪ Remaining parts of Madhya Maharashtra, Marathwada and of west Vidarbha.	20 Jun	10 days delayed
▪ Remaining parts of central Arabian Sea, some parts of north Arabian Sea, Saurashtra & Kutch and of Gujarat Region, some parts of east Madhya Pradesh, most parts of Chattisgarh and of Jharkhand, some more parts of Bihar and entire east Vidarbha.	20 Jun	5 days delayed
▪ Some more parts of Gujarat Region and of west Madhya Pradesh, most parts of east Madhya Pradesh, some parts of east Uttar Pradesh, remaining parts of Chattisgarh, Jharkhand and of Bihar.	22 Jun	7 days delayed
▪ Some more parts of west Madhya Pradesh, east Madhya Pradesh and of east Uttar Pradesh, most parts of Uttaranchal, Himachal Pradesh and of Jammu & Kashmir.	25 Jun	6 days prior
▪ Some more parts of north Arabian Sea and of Saurashtra & Kutch, remaining parts of Gujarat Region, southern parts of east Rajasthan, some more parts of west and east Madhya Pradesh, some more parts of east Uttar Pradesh.	26 Jun	11 days delayed (a small part of east Uttar Pradesh received 5 days prior)
▪ Some more parts of north Arabian Sea, most parts of Saurashtra & Kutch, some parts of west Rajasthan, some more parts of east Rajasthan, most parts of west Madhya Pradesh, remaining parts of east Madhya Pradesh and some more parts of east Uttar Pradesh.	27 Jun	4 days prior
▪ Entire Arabian Sea, remaining parts of Saurashtra & Kutch and of Gujarat Region and in some more parts of Rajasthan.	30 Jun	15 days prior
▪ Some more parts of west Madhya Pradesh, remaining parts of east Uttar Pradesh and of Uttaranchal and some more parts of west Uttar Pradesh.	1 Jul	Normal
▪ Remaining parts of Himachal Pradesh and of Jammu & Kashmir.	4 Jul	3 days delayed
▪ Some more parts of west Rajasthan.	19 Jul	4 days delayed
▪ Remaining parts of east Rajasthan, entire west Uttar Pradesh and some parts of Haryana and of Punjab.	19 Jul	18 days delayed
▪ Remaining parts of west Rajasthan, Haryana and of Punjab and thus the entire country. (some parts of Haryana and Punjab received monsoon rain more than one and a half months delayed)	15 Aug	1 month delayed

TABLE 1

Rainfall figures (mm) for each month and season as a whole (June – September 2002)

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	293	422	-31	226	369	-39	340	365	-7	335	404	-17	1194	1560	-23
2.	Arunachal Pradesh	423	596	-29	655	791	-17	379	483	-22	268	394	-32	1725	2263	-24
3.	Assam & Meghalaya	541	661	-18	605	639	-5	343	490	-30	235	359	-34	1724	2149	-20
4.	Naga., Mani., Mizo. and Tripura	282	424	-33	443	379	17	331	333	0	266	243	9	1323	1379	-4
5.	S. H. W. B. & Sikkim	441	483	-9	970	577	68	411	492	-16	336	377	-11	2159	1929	12
6.	Gangetic West Bengal	329	248	33	271	325	-17	302	320	-6	311	265	18	1214	1158	5
7.	Orissa	194	204	-5	143	335	-57	346	351	-1	237	242	-2	920	1132	-19
8.	Jharkhand	230	189	22	243	333	-27	344	317	8	325	237	37	1142	1076	6
9.	Bihar	149	164	-9	406	331	23	256	291	-12	193	221	-13	1004	1006	0
10.	East Uttar Pradesh	58	97	-41	121	303	-60	229	297	-23	265	195	36	673	892	-24
11.	West Uttar Pradesh	48	67	-28	36	265	-86	267	285	-7	258	150	72	609	767	-21
12.	Uttaranchal	176	161	+9	263	449	-42	474	453	+5	292	213	37	1205	1259	-4
13.	Haryana, Chandigarh & Delhi	33	49	-33	28	186	-85	119	183	-35	140	97	44	321	515	-38
14.	Punjab	39	42	-7	72	189	-62	120	168	-29	133	100	33	364	499	-27
15.	Himachal Pradesh	81	106	-23	143	329	-56	335	301	11	177	142	24	737	879	-16
16.	Jammu & Kashmir	78	43	80	70	116	-39	173	111	55	89	64	39	410	335	23
17.	West Rajasthan	34	29	15	6	114	-95	27	105	-74	20	46	-56	87	294	-71
18.	East Rajasthan	70	60	15	15	237	-94	130	242	-46	45	108	-58	260	647	-60
19.	West Madhya Pradesh	159	107	49	53	306	-83	322	317	2	169	178	-5	704	908	-22
20.	East Madhya Pradesh	131	147	-11	81	383	-79	554	390	42	184	202	-9	950	1122	-15
21.	Gujarat region	268	127	111	51	370	-86	267	296	-10	118	164	-28	705	957	-26
22.	Saurashtra & Kutch	219	100	120	13	209	-94	149	145	3	19	80	-77	401	534	-25
23.	Konkan & Goa	827	661	25	402	1068	-62	837	711	18	223	353	-37	2289	2794	-18
24.	Madhya Maharashtra	245	141	74	89	272	-67	231	201	15	106	159	-33	670	772	-13
25.	Marathwada	233	139	67	53	182	-71	232	183	27	134	169	-21	652	673	-3
26.	Vidarbha	332	160	107	75	318	-76	416	292	43	132	177	-25	955	947	1
27.	Chattisgarh	195	181	8	135	380	-65	387	373	4	229	225	2	946	1159	-18
28.	Coastal Andhra Pradesh	109	101	7	79	163	-52	173	156	11	76	162	-53	436	582	-25
29.	Telangana	137	134	2	89	240	-63	290	223	30	87	176	-51	602	773	-22
30.	Rayalaseema	80	61	31	38	93	-59	69	99	-30	72	134	-46	259	386	-33
31.	Tamil Nadu	47	44	7	22	72	-69	47	90	-47	55	113	-51	172	318	-46
32.	Coastal Karnataka	812	884	-8	526	1127	-53	676	803	-16	174	314	-45	2188	3128	-30
33.	North interior Karnataka	115	97	18	51	129	-61	113	109	4	51	143	-64	329	478	-31
34.	South interior Karnataka	157	201	-22	115	336	-66	174	245	-29	75	152	-50	522	933	-44
35.	Kerala	491	653	-25	319	687	-54	422	405	4	90	242	-63	1322	1965	-33
36.	Lakshadweep	262	325	-19	81	282	-71	144	212	-32	50	164	-70	537	983	-45

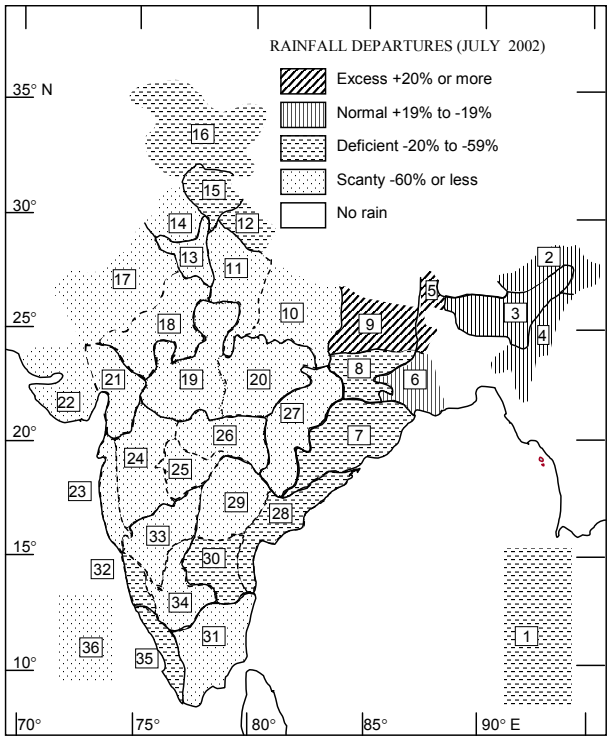


Fig. 5. Sub-division wise seasonal rainfall departure from normal (%) for the July 2002. Sub-divisions are indicated by number on the map & bold letters in legend. The rainfall anomaly values for these 36 sub-divisions are indicated below :

1	–39	**7**	–57	**13**	85	**19**	–83	**25**	–71	**31**	–69
2	–17	**8**	–27	**14**	–62	**20**	–79	**26**	–76	**32**	–53
3	–5	**9**	23	**15**	–56	**21**	–86	**27**	–65	**33**	–61
4	17	**10**	–60	**16**	–39	**22**	–94	**28**	–52	**34**	–66
5	68	**11**	–86	**17**	–95	**23**	–62	**29**	–63	**35**	–54
6	–17	**12**	–42	**18**	–94	**24**	–67	**30**	–59	**36**	–71

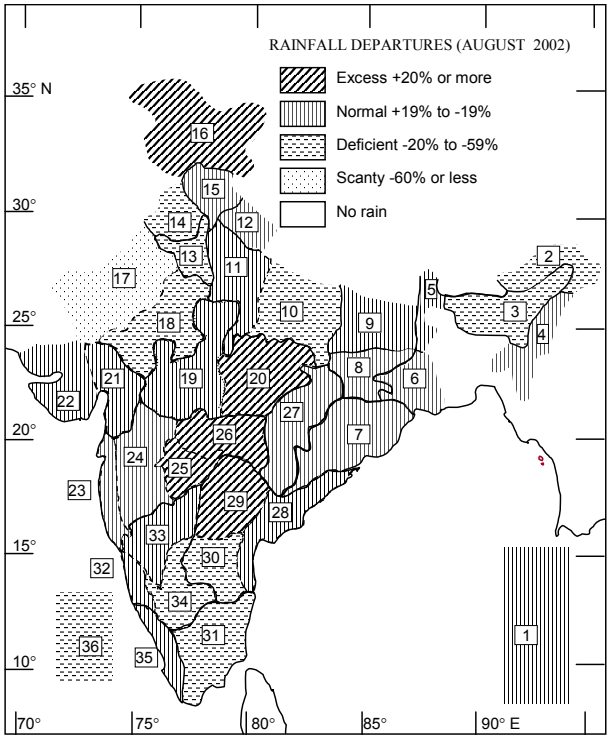


Fig. 6. Sub-division wise seasonal rainfall departure from normal (%) for the August 2002. Sub-divisions are indicated by number on the map & bold letters in legend. The rainfall anomaly values for these 36 sub-divisions are indicated below :

1	–7	**7**	–1	**13**	–35	**19**	2	**25**	27	**31**	–47
2	–22	**8**	8	**14**	–29	**20**	42	**26**	43	**32**	–16
3	–30	**9**	–12	**15**	11	**21**	–10	**27**	4	**33**	4
4	0	**10**	–23	**16**	55	**22**	3	**28**	11	**34**	–29
5	–16	**11**	–7	**17**	–74	**23**	18	**29**	30	**35**	4
6	–6	**12**	5	**18**	–46	**24**	15	**30**	–30	**36**	–32

3.2. *Weekly rainfall distribution*

3.2.1. *Week by week rainfall*

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

Rainfall activity over Peninsular India was quite good (with most of the sub-divisions reporting normal/excess rainfall) in the first 4 weeks and was generally subdued for the next 5 weeks. It was good except over the extreme south peninsula during entire August and also during the first week of September. Over northeast India, it was rather good in the first 3 weeks, generally subdued in the 4th week, again picked up towards the third week of July and remained so in the first fortnight of August. Subsequently it was subdued till the week ending on 18 September, and was extremely good during the last two weeks thereafter. Over northwest India, generally good rainfall received in the first 4 weeks, especially during the first fortnight of June. During the entire July and till the first week of August there was a general dry spell prevailing over the region with most of the sub-divisions receiving scanty rainfall during the period. Second week of August received good rainfall which was again followed by subdued rainfall during the subsequent 3 weeks. There was good rainfall during September over most parts of this region. Over central India, rainfall activity picked up towards the end of June and remained subdued during the entire July. It was rather good during most of the weeks in August and again subdued in September.

3.2.2. *Weekly cumulative rainfall distribution*

Meteorological sub-division wise cumulative rainfall departures (percentage departure from normal) during the

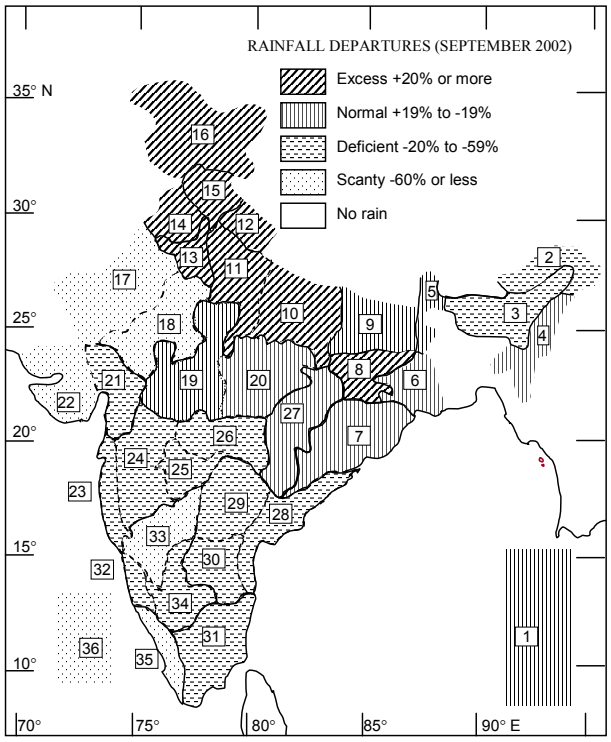


Fig. 7. Sub-division wise seasonal rainfall departure from normal (%) for the September 2002. Sub-divisions are indicated by number on the map & bold letters in legend. The rainfall anomaly values for these 36 sub-divisions are indicated below :

1	–17	**7**	–2	**13**	44	**19**	–5	**25**	–21	**31**	–51
2	–32	**8**	37	**14**	33	**20**	–9	**26**	–25	**32**	–45
3	–34	**9**	–13	**15**	24	**21**	–28	**27**	2	**33**	–64
4	9	**10**	36	**16**	39	**22**	–77	**28**	–53	**34**	–50
5	–11	**11**	72	**17**	–56	**23**	–37	**29**	–51	**35**	–63
6	18	**12**	37	**18**	–58	**24**	–33	**30**	–46	**36**	–70

southwest monsoon season from 1 June to 30 September comprising of 18 weeks are given in Fig. 1(b).

During the weeks ending on 19 and 26 June, 75% of sub-divisions received *excess/normal* rainfall. But the weak monsoon conditions in July reduced it to 28% by the week ending on 31 July. The good rainfall activity in August and in the first fortnight of September brought this percentage to 56 by the week ending on 18 September. Thereafter, 42% sub-divisions received *excess/normal* rainfall.

Cumulative rainfall was *excess/normal* throughout the monsoon season in the sub-divisions Sub-Himalayan West Bengal & Sikkim and Gangetic West Bengal. Rainfall was also *excess/normal* during most of the period in Jharkhand (except for week ending on 5 June), Bihar (except for weeks ending on 5 and 12 June), Uttaranchal

TABLE 2

District wise distribution of monsoon rainfall for the years 1997 to 2002

Years	Excess/Normal (%)	Deficient/Scanty (%)
1997	81	19
1998	83	17
1999	67	33
2000	65	35
2001	68	32
2002	37	63

(except for the weeks ending on 31 July and 7 August), Jammu & Kashmir (except for the weeks ending on 5 and 12 June), Madhya Maharashtra (except for the weeks ending on 5 and 12 June) Marathwada (except for the weeks ending on 5, 12 and 19 June) and Vidarbha (except for the weeks ending on 5 and 12 June)

Rainfall was *deficient/scanty* during most of the period in Andaman & Nicobar Islands (except for the weeks ending on 5, 12 and 19 June), Arunachal Pradesh (except for the weeks ending on 24 July, 14 and 21 August), east Uttar Pradesh (except for the weeks ending on 5, 12 and 19 June), west Uttar Pradesh (except for the weeks ending on 12, 19 and 26 June and 18 September), Haryana (except for the weeks ending on 5, 6 and 19 June), Punjab (except for the weeks ending on 5, 6, 19 and 26 June), Himachal Pradesh (except for the weeks ending on 3 July, 11 and 18 September), west Rajasthan (except for the weeks ending on 5 and 19 June and 3 July), east Rajasthan (except for the weeks ending on 5, 19 and 26 June and 3 July), Tamil Nadu (except for weeks ending on 12, 19 and 26 June and 3 July), coastal Karnataka (except for the weeks ending on 5, 19 and 26 June and 3 July), south interior Karnataka (except for the weeks ending on 5, 12, 19 and 26 June), Kerala (except for the weeks ending on 5, 19 and 26 June) and Lakshadweep (except for the weeks ending on 12, 19 and 26 June).

3.3. *Monthly rainfall distribution*

Figs. 4 – 7 show month wise distribution of monsoon rainfall. Rainfall figures and departures for each month and season as a whole, sub-division wise, are given in Table 1 and the heavy to very heavy daily rainfall amounts are given in Table 11.

3.4. *Seasonal rainfall distribution*

Meteorological sub-division wise seasonal rainfall distribution in terms of percentage departures from normal is given in Fig. 3 and in Table 1. The seasonal rainfall

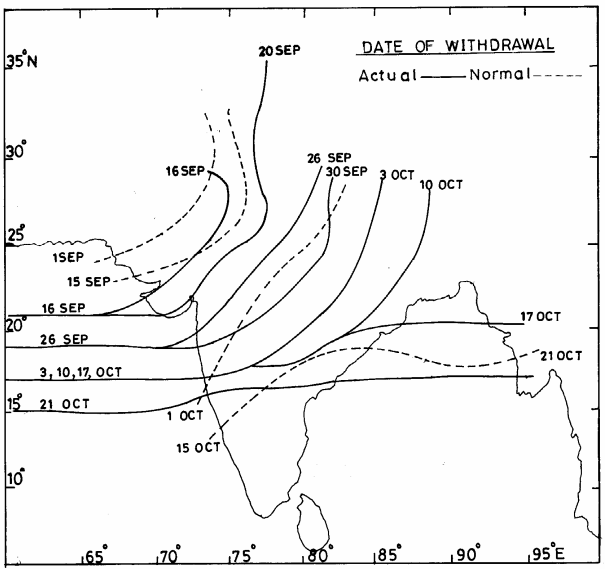


Fig. 8. Withdrawal of southwest monsoon 2002

was *excess* in 1, *normal* in 14, *deficient* in 19 and *scanty* in 2 meteorological sub-divisions. Seasonal total rainfall for the country as a whole was below normal and country received 81% of its long period average rainfall.

3.5. *Districts wise distribution of monsoon rainfall*

Only 39% of districts received *normal/ excess* rainfall and the rest 61% districts received either *deficient* or *scanty* rainfall during the period 1 June-30 September 2002.

This is a reverse pattern to that observed during the past 3 years (Table 2).

3.6. *Withdrawal of southwest monsoon*

The southwest monsoon withdrew from most parts of west Rajasthan, some parts of Gujarat state and of north Arabian Sea on 16 September as against the normal date of 15 September. Further it withdrew from the central parts of the country by 3 October (more or less in the normal date), northeastern states by 17 Oct, (4-5 days delay over the extreme northeast). The withdrawal was completed from most of the regions north of Lat. 15° N by 21 October (6-7 days delay). It withdrew from the entire country on 25 October (10 days delay) with the simultaneous commencement of northeast monsoon rains over Tamil Nadu, Kerala and adjoining states of Karnataka and Andhra Pradesh (Fig. 8).

Date wise withdrawal of southwest monsoon over different regions until 30 September is given below:

Withdrawal from	*Date*	*Dep. from normal*
▪ Some part of west Rajasthan	16 Sep	15 days delayed
▪ Most parts of west Rajasthan, some parts of north Arabian Sea	16 Sep	1 day delayed
▪ Some parts of Gujarat State and of north Arabian Sea	16 Sep	14 days prior
▪ Most parts of Jammu & Kashmir, Punjab, Haryana, some parts of Himachal Pradesh, most parts of Rajasthan and Saurashtra & Kutch and some more parts of Gujarat Region.	20 Sep	11 days prior
▪ Remaining parts of Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, entire Uttaranchal, most parts of west Uttar Pradesh, some parts of east Uttar Pradesh, west Madhya Pradesh, remaining parts of Rajasthan, Gujarat State and of north Arabian Sea and some parts of central Arabian Sea.	26 Sep	5 days prior
▪ Some parts of north Madhya Maharashtra and some more parts of east-central Arabian Sea, remaining parts of west Uttar Pradesh, some parts of east Uttar Pradesh, some parts of Madhya Pradesh	30 Sep	1 day prior
▪ Some parts of north Madhya Maharashtra, Vidarbha, Madhya Pradesh and of east Uttar Pradesh.	30 Sep	16 days prior

3.7. *El-Nino phenomenon*

The planetary-scale tropical SLP anomalies associated with the SO generally occur in conjunction with episodes of El Nino/La Nina in the tropical Pacific, indicating "El-Nino Southern Oscillation" phenomena. The phase and magnitude of the ENSO can be indicated either by the SST anomalies over the Pacific or by Southern Oscillation Index (SOI). The SOI, generally expressed as a measure of the strength of the Walker Circulation across the Pacific, is taken as the difference between the SLP at Tahiti, an island station in the Southeast Pacific Ocean and Darwin, Australia. The intensities of El-Nino/La Nina events are generally assessed on the basis of the average SSTs over three regions in the Pacific Ocean, widely known as Nino 1+2, Nino 3 and Nino 4. On about 60% cases, an inverse relationship between ENSO and Indian summer monsoon rainfall has been noted in the past.

Table 12 depicts the monthly values of SST anomaly indices at various geographical regions of tropical Pacific and SOI for the period October 2001 to September 2002. Weak warm episode (El Nino) conditions were observed in the tropical Pacific with SST anomalies exceeding 0.5° C over Nino 3, and Nino 4 regions for the first time since the end of the 1997-98 El Nino episode. All the SST

TABLE 3

Details of the weather systems during June 2002

S. No.	System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	*Low pressure areas*					
1.	Well-marked low pressure area	20-28	Northwest Bay off Orissa-Gangetic West Bengal coasts	Westnorthwesterly	Southeast Rajasthan and adjoining northwest Madhya Pradesh	Associated cyclonic circulation extended upto mid tropospheric levels tilting southwestwards with height, became less marked on 30
(**B**)	*Cyclonic circulation*					
1.	Between 2.1 and 5.8 km a.s.l.	1-4	Southeast and adjoining east-central Arabian Sea off Karnataka coast	Quasi-stationary	Interior Karnataka and neighbourhood	Became less marked on 5
2.	Lower tropospheric levels	4-5	East Uttar Pradesh and neighbourhood	Stationary	*In situ*	Lay embedded in the east-west trough
3.	Between 1.5 and 4.5 km a.s.l.	10-11	Northeast Arabian Sea and adjoining Gujarat State	Stationary	*In situ*	
4.	Between 2.1 and 4.5 km a.s.l.	12-24	Konkan-Goa coasts and neighbourhood	Northnorthwesterly	Saurashtra & Kutch and neighbourhood	Might have influenced the well marked low pressure area to move westwards
5.	Mid tropospheric levels	10-13	Orissa and neighbourhood	Northnorthwesterly	Gangetic West Bengal and neighbourhood	Became less marked on 14
6.	Lower tropospheric levels	16-17	Jharkhand and neighbourhood	Westerly	Bihar	Became less marked on 18
7.	Between 2.1 and 5.8 km a.s.l.	30 Jun-1 Jul	West Uttar Pradesh and neighbourhood	Easterly	East Uttar Pradesh	Became less marked on 2 July
(**C**)	*Eastward moving systems/ western disturbances*					
1.	Induced cyclonic circulation	1-4	North Rajasthan and neighbourhood	Northeasterly	–	Moved away northeastwards on 5
2.	Do	5	Central Pakistan and adjoining west Rajasthan	Stationary	*In situ*	
3.	Cyclonic circulation	6-8	Punjab and adjoining Haryana			Moved away northeastwards on 9
4.	Induced cyclonic circulation	7-14	Central Pakistan and adjoining west Rajasthan	Northeasterly		Moved away northeastwards on 15
5.	Cyclonic circulation	15-19	North Pakistan and adjoining Jammu & Kashmir	Northeasterly		Moved away northeastwards on 20
6.	Do	18-22	Do	Do		Moved away northeastwards on 23
7.	Do	23-25	Do	Easterly		Moved away eastwards on 26
8.	Do	25-30	Do	Eastnortheasterly		Moved away northeastwards on 1 July
(**D**)	*Troughs in westerlies*					
1.	Lower tropospheric levels	14-15	Along Long. 88° E, north of Lat. 20° N	Stationary	*In situ*	Less marked on 16
(**E**)	*Other troughs*					
1.	At 0.9 km a.s.l.	2-11	East Madhya Pradesh to north Karnataka coast	Quasi-stationary	Chattisgarh to Kerala	Less marked on 12

TABLE 4

Details of the weather systems during July 2002

S. No. (1)	System (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(**A**)	*Low pressure areas*					
1.	Low pressure area	15-19	Northwest Bay off West Bengal-Orissa coasts	Westerly	Northern parts of Chattisgarh and adjoining areas of Orissa and Jharkhand	Associated cyclonic circulation extended upto mid tropospheric levels
2.	Low pressure area	31 Jul-1 Aug	Northwest Bay and adjoining areas of Orissa, coastal Andhra Pradesh and west-central Bay	Do	Chattisgarh and adjoining areas of Orissa, Vidarbha and east Madhya Pradesh	Associated cyclonic circulation extending upto mid tropospheric levels moved in a westnorthwesterly direction upto north Madhya Pradesh and neighbourhood and became less marked on 9 August
(**B**)	*Cyclonic circulations*					
1.	Mid tropospheric levels	2-8	Gangetic West Bengal and adjoining areas of Jharkhand and Bihar	Northerly to northeasterly	Bangladesh and neighbourhood	Became less marked on 9
2.	Between 1.5 and 5.8 km a.s.l.	13-16	Southeast Rajasthan and adjoining areas of north Gujarat State	Quasi-stationary	Gujarat State and neighbourhood	Became less marked on 17
3.	Between 3.1 and 7.6 km a.s.l.	16	West-central Bay off coastal Andhra Pradesh	Stationary		Merged with the cyclonic circulation associated with the low pressure area on 17
(**C**)	*Eastward moving systems/ western disturbances*					
1.	Cyclonic circulation	6-10	North Pakistan and adjoining Jammu & Kashmir	Eastnortheasterly		Moved away eastnortheastwards on 11
2.	Do	8-14	North Pakistan	Do		Moved away eastnortheastwards on 15
3.	Do	15-21	North Pakistan and neighbourhood	Do		Moved away eastnortheastwards on 22
4.	Do	21-25	Do	Do		Moved away eastnortheastwards on 26
5.	Induced cyclonic circulation	23 Jul-3 Aug	South Pakistan	Stationary	*In situ*	
6.	Cyclonic circulation	29 Jul-1 Aug	North Pakistan and adjoining Jammu & Kashmir	Northeasterly		Moved away northeastwards on 2 August
7.	Do	31 Jul-3 Aug	North Pakistan	Eastnortheasterly		Moved away eastnortheastwards on 4 August

indices in the table show either negative or 0 (zero) values until January 2002. After January 2002, the Nino 3 and Nino 4 regions show similar features with decreasing negative anomaly and consequently increasing positive anomaly during subsequent months. The Nino 3 index after becoming positive in March 2002 increased to 0.7 in September 2002. The Nino 4 index, on the other hand after reaching to 0 (zero) in January 2002 increased to 1.2 in September 2002. The Nino 1+2 index, on the other hand, after reaching to 0 (zero) in February 2002 remained positive and more than 0.5° C till May 2002. During the monsoon season from June to September 2002 the Nino 1+2 index again became negative when the Nino 3 and Nino 4 index were positive with values > 0.5° C. This

TABLE 5

Details of the weather systems during August 2002

S. No. (1)	System (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(**A**)	*Low pressure areas*					
1.	Low pressure area	7-9	Northwest Bay and neighbourhood	Westnorthwesterly	Jharkhand and neighbourhood	Associated cyclonic circulation extending upto mid tropospheric levels moved further in a westnorthwesterly direction and became less marked on 20
2.	Low pressure area	15-18	Jharkhand and adjoining areas of Orissa and Gangetic West Bengal	Westnorthwesterly	North Madhya Pradesh and adjoining south Uttar Pradesh	Associated cyclonic circulation extended upto mid tropospheric levels
3.	Low pressure area	22-27	Northwest Bay off coastal areas of Orissa and Gangetic West Bengal	Westerly	Northeast Arabian Sea and adjoining areas	Do
4.	Low pressure area	29 Aug-3 Sep	Northwest Bay off coastal areas of Orissa	Westerly	West Madhya Pradesh and neighbouring areas	Associated cyclonic circulation extending upto mid tropospheric levels became less marked on 12
(**B**)	*Cyclonic circulations*					
1.	Between 2.1 and 4.5 km a.s.l.	2-3	Off coasts of Karnataka-Goa	Stationary	*In situ*	Became less marked on 4
2.	Between 1.5 and 5.8 km a.s.l.	6-11	Saurashtra & Kutch and neighbourhood	Quasi-stationary	Do	Became less marked on 12
3.	Do	16-18	South Pakistan and adjoining west Rajasthan	Do	Saurashtra & Kutch and neighbourhood	Became less marked on 19
4.	Lower tropospheric levels	19-20	South Pakistan and neighbourhood	Stationary	*In situ*	Became less marked on 21
5.	Mid tropospheric levels	21-24	Saurashtra & Kutch and neighbourhood	Do		Merged with the cyclonic circulation associated with the low pressure area on 25
6.	Lower tropospheric levels	29	West Uttar Pradesh and neighbourhood	Do	*In situ*	Became less marked on 30
7.	Do	31 Aug-1 Sep	North Bay	Westerly	Orissa and neighbourhood	Merged with the monsoon trough on 2 September
(**C**)	*Eastward moving systems/ western disturbances*					
1.	Induced cyclonic circulation	3-9	Central Pakistan	Northeasterly	Northwest Rajasthan and neighbourhood	Became less marked on 10
2.	Cyclonic circulation	8-10	North Pakistan and adjoining Jammu & Kashmir	Do		Moved away northeastwards on 11
3.	Do	11-13	Do	Eastnortheasterly		Moved away eastnortheastwards on 14
4.	Induced cyclonic circulation	14-15	Central Pakistan and adjoining areas of Punjab and Haryana	Northeasterly	Haryana and neighbourhood	Became less marked on 16
5.	Cyclonic circulation	15-19	North Pakistan	Eastnortheasterly		Moved away eastnortheastwards on 20
6.	Do	18-22	North Pakistan	Do		Moved away eastwards on 23
7.	Induced cyclonic circulation	22-24	Central Pakistan and adjoining west Rajasthan	Northeasterly	Northwest Rajasthan and neighbourhood	Became less marked on 2 September
8.	Cyclonic circulation	27-29	North Pakistan and adjoining Jammu & Kashmir	Northeasterly		Moved away northeastwards on 30
9.	Do	30 Aug-1 Sep	Jammu & Kashmir and adjoining Pakistan	Easterly	Punjab and neighbourhood	Became less marked on 2 September

TABLE 6

Details of the weather systems during September 2002

S. No. (1)	System (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(**A**)	*Low pressure areas*					
1.	Low pressure area	8-12	Northwest Bay and adjoining coastal areas of Gangetic West Bengal and Orissa	Westnorthwesterly	Northeast Madhya Pradesh and adjoining south Uttar Pradesh	Associated cyclonic circulation extending upto mid tropospheric levels became less marked on 17
2.	Well marked low pressure area	19-26	East-central and adjoining northeast Bay	Northwesterly	Southern parts of Jharkhand and adjoining areas of Gangetic West Bengal and north Orissa	Associated cyclonic circulation extending upto mid tropospheric levels became less marked on 27
3.	Low pressure area	27-28	Northwest Bay and adjoining west-central Bay off Orissa coast	Northwesterly	Jharkhand and neighbourhood	Associated cyclonic circulation extended upto mid tropospheric levels
(**B**)	*Cyclonic circulations*					
1.	Lower tropospheric levels	6-8	West Uttar Pradesh and neighbourhood	Quasi-stationary	Uttaranchal and neighbourhood	–
2.	Between 2.1 and 5.8 km a.s.l.	18-27	North Maharashtra-south Gujarat coast and adjoining east-central Arabian Sea	Do		Became less marked on 28
3.	At 1.5 km a.s.l.	29	Lakshadweep-Maldives areas off south Karnataka-Kerala coasts	Stationary	*In situ*	Became less marked on 30
4.	At 0.9 km a.s.l.	28 Sep-1 Oct	Tamil Nadu and neighbourhood	Westerly	East-central Arabian Sea	Became less marked on 2 October
(**C**)	*Eastward moving systems/ western disturbances*					
1.	Cyclonic circulation	2-5	North Pakistan and adjoining Jammu & Kashmir and Punjab	Easterly		Moved away northeastwards on 6
2.	Do	4-8	North Pakistan and adjoining Jammu & Kashmir	Eastnortheasterly		Moved away eastnortheastwards on 9
3.	Do	9-12	North Pakistan and adjoining Jammu & Kashmir	Do		Moved away northeastwards on 13
4.	Do	12-15	North Pakistan	Do		Moved away northeastwards on 16
5.	Do	13-21	North Pakistan and adjoining Jammu & Kashmir and Punjab	Easterly		Moved away eastwards on 22
6.	Induced cyclonic circulation	22-24	Central Pakistan and adjoining northwest Rajasthan	Eastnortheasterly	Uttaranchal and neighbourhood	Became less marked on 25

TABLE 6 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
7.	Cyclonic circulation	22-23	North Pakistan and adjoining Jammu & Kashmir	Northeasterly		Moved away northeastwards on 24
8.	Do	24-25	North Pakistan and neighbourhood	Easterly	Northwest Rajasthan and neighbourhood	Became less marked on 26
9.	Do	26 Sep-1 Oct	North Pakistan and adjoining Jammu & Kashmir	Eastnortheasterly		Moved away eastnortheastwards on 2 October
(**D**)	*Trough in westerlies*					
1.	At 0.9 km a.s.l.	28 Sep-1 Oct	Assam & Meghalaya to south Tamil Nadu coast	Easterly		Moved away eastwards on 2 October
(**E**)	*Trough in easterlies*					
1.	At 0.9 km a.s.l.	30 Sep-7 Oct	Lakshadweep area to Chattisgarh	Quasi-stationary		Became less marked on 8 October

was an unusual situation compared to the past several years. Thus the El Nino signals were mixed up from June 2002 onwards. The El Nino built up in the Nino 3 and Nino 4 regions and abated in Nino 1+2 region. The SOI has been consistently negative since March 2002. (*Ref*. : Climate Diagnostics Bulletin, Climate Prediction Centre, USA).

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 3, 4, 5 and 6 respectively.

4.1. *Cyclonic storms/depressions*

No Cyclonic Storms or Depressions formed during the season. As mentioned in the chief features this had been a rare event having no simile in the past 130 years, for which records are available.

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

During the season, 10 low pressure areas/ well marked low pressure areas formed. Most of them originated as upper air cyclonic circulations. Month wise break up of the systems are 1 in June, 2 in July, 4 in August and 3 in September. Details are given below.

4.2.1. *Well marked low pressure area during 20-28 June*

Under the influence of an upper air cyclonic circulation a low pressure area formed over northwest Bay off Orissa-Gangetic West Bengal coasts on 20. Associated cyclonic circulation extended upto mid-tropospheric levels, tilting southwestwards with height. It persisted there on 21 and became well marked over northeast Bay off Bangladesh-Gangetic West Bengal coasts on 22. Following a westnorthwesterly track, it traversed upto southeast Rajasthan and adjoining northwest Madhya Pradesh (as a low pressure area) and dissipated on 29.

4.2.2. *Low pressure area during 15-19 July*

Under the influence of an upper air cyclonic circulation, a low pressure area formed over northwest Bay off West Bengal-Orissa coasts on 15. It moved over to Gangetic West Bengal and adjoining northwest Bay, Jharkhand and Orissa on 16. On 17, it reorganised over northwest Bay off Orissa coast. Associated cyclonic circulation extended upto mid-tropospheric levels tilting slightly southwestwards with height. It lay over northwest Bay and adjoining areas of Orissa on 18, moved over to northern parts of Chattisgarh and adjoining areas of Orissa and Jharkhand on 19 and became less marked on 20.

4.2.3. *Low pressure area during 31 July-1 August*

Under the influence of an upper air cyclonic circulation a feeble low pressure area formed over northwest Bay and adjoining areas of Orissa, north Andhra Pradesh and west-central Bay on 31 July. It rapidly moved inland and became less marked on 2 August.

4.2.4. *Low pressure area during 7-9 August*

Under the influence of an upper air cyclonic circulation a low pressure area formed over northwest Bay

TABLE 7(a)

Positions of off-shore troughs during the monsoon period 2002

Date	Position
20 – 24 May	South Karnataka coast to Kerala coast
27 – 30 May	Karnataka to Kerala coasts
1 – 3 June	Karnataka coast to Kerala coast
12 – 13 June	Maharashtra coast to Kerala coast
14 – 16 June	South Gujarat coast to Kerala coast
17 – 18 June	North Gujarat coast to Kerala coast
19 June	North Gujarat coast to north Kerala coast
20 – 24 June	Gujarat coast to Kerala coast
25 – 26 June	North Arabian Sea to Karnataka coast
27 June - 8 July	South Gujarat coast to Karnataka coast
9 – 13 July	Maharashtra coast to Kerala coast
14 – 17 July	Maharashtra coast to Karnataka coast
18 – 24 July	Maharashtra coast to Kerala coast
1 – 2 August	Karnataka coast to Kerala coast
3 – 21 August	Maharashtra coast to Kerala coast
22 – 25 August	South Gujarat coast to Karnataka coast
26 – 27 August	South Gujarat coast to Karnataka coast
1 – 4 September	South Gujarat coast to Konkan-Goa, Karnataka coasts
5 – 6 September	Gujarat coast to north Kerala coast
7 – 9 September	South Maharashtra coast to Kerala coast
12 September	South Maharashtra coast to north Kerala coast
13 September	North Maharashtra coast to Karnataka coast
17 September	South Maharashtra coast to Kerala coast

TABLE 7(b)

Details of off-shore trough from 1997– 2002

Year	Details of off – shore trough
2002	Offshore trough along different parts of west coast (surface and lower levels) persisted on most of the days from 20 May to 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 4 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
1998	From 16 June to 30 September, off-shore trough along different parts of west coast (surface and lower levels) persisted on most of the days except on 11-15 June, 18-19 July and 9-10 September
1997	During 8 June to 1 October 97, the off-shore trough along different parts of the west coast (surface and in lower levels) persisted on most of the days

and neighbourhood on 7. It persisted there on 8, lay over Jharkhand and neighbourhood on 9 and became less marked on 10. But the associated cyclonic circulation persisted for a rather long period, which traversed upto west Uttar Pradesh and adjoining Haryana and became less marked on 20.

4.2.5. *Low pressure area during 15-18 August*

Under the influence of an upper air cyclonic circulation, a low pressure area formed over coastal areas of north Orissa and adjoining northwest Bay on 15. It moved in a westnorthwesterly direction upto north Madhya Pradesh and adjoining south Uttar Pradesh and became less marked on 19.

4.2.6. *Low pressure area during 22-27 August*

Under the influence of an upper air cyclonic circulation, a low pressure area formed over northwest Bay off the coastal areas of Orissa and Gangetic West Bengal on 22. Moving inland, it lay over Orissa and adjoining areas of Chattisgarh and north Andhra Pradesh on 23, over Vidarbha and neighbourhood on 24, over west Madhya Pradesh and adjoining areas of Maharashtra and Gujarat on 25. Over Saurashtra & Kutch and adjoining areas on 26, over northeast Arabian Sea and neighbourhood on 27 and became less marked on 28.

4.2.7. *Low pressure area during 29 August-3 September*

Under the influence of an upper air cyclonic circulation, a low pressure area formed over northwest Bay off the coastal areas of Orissa on 29 August. Moving inland, it lay over Orissa and neighbourhood, with associated cyclonic circulation extending upto mid tropospheric levels, tilting southwestwards with height on 30. It moved westwards upto west Madhya Pradesh and became less marked on 4 September.

4.2.8. *Low pressure area during 8-12 September*

Under the influence of an upper air cyclonic circulation a feeble low pressure area formed over northwest Bay and adjoining coastal areas of Gangetic West Bengal and Orissa on 8. It persisted there on 9. It moved in a westnorthwesterly direction inland, reached upto northeast Madhya Pradesh and adjoining south Uttar Pradesh and became less marked on 13.

4.2.9. *Well marked low pressure area during 19-26 September*

Under the influence of an upper air cyclonic circulation a low pressure area formed over east-central and adjoining northeast Bay on 19. It Moved over to northern parts of central Bay and adjoining north Bay and became well marked over there on 20 evening. It persisted over the oceanic area till 24. Moving inland, it lay as a low pressure area over Bihar and adjoining areas of Jharkhand and Gangetic West Bengal on 25 and became less marked on 26 evening.

4.2.10. *Low pressure area during 27-28 September*

A low pressure area lay over northwest and adjoining west-central Bay off Orissa coast on 27. Moving inland, it lay as a feeble low pressure area over Jharkhand and neighbourhood on 28 and became less marked on 29.

4.3. *Cyclonic circulations (CYCIR)*

Altogether 21 cyclonic circulations (in lower and upper tropospheric levels) formed in the season.

The month wise breakup of cyclonic circulations is 7 in June, 3 in July, 7 in August and 4 in September.

4.4. *Off-shore trough*

Off shore trough along different parts of west coast (surface and lower levels) persisted on most of the days from 20 May to 17 September except during 4-11 June, 25-31 July, 28-31 August and 14-16 September.

The details of the position of the Off-shore trough for 2002 are given in Table 7(a) and that for 1997-2002 are given in Table 7 (b).

4.5. *Low level troughs*

During the season, altogether there were 4 troughs in the lower levels. Details are given in Tables 3 and 6.

4.6. *Eastward moving cyclonic circulations/western disturbances*

There were 8 eastward moving cyclonic circulations in June, 7 in July, 9 in August and another 9 in September (last 21 year average for June is 4, July and August is 2 each and that for September is 3).

TABLE 8

Main features of weekly wind anomalies (during June to September 2002)

Week ending	850 hPa	500 hPa	200 hPa	Remarks (lower level anomalous features)
			June	
4 Jun	NE-SW trough over northwest part of the country	Anticyclonic circulation over Tamil Nadu coast	Ridge from Northern part of Bay to Karnataka coast	Anomalous flow was mainly cyclonic over peninsular India
11 Jun	NE-SW trough from north Bihar to Tamil Nadu region	E-W trough at extreme southern peninsula	E-W ridge from west Rajasthan to north Bay	Anomalous flow was mainly cyclonic over northeastern past of the country
18 Jun	E-W trough at northeastern part of the country	E-W ridge along 19°N and E-W trough at extreme south	E-W ridge along 23°N	Anomalous flow was mainly cyclonic at extreme south and anticyclonic over central India
25 Jun	Cyclonic circulation over Bihar and adjoining area	Cyclonic circulation over North Bay	E-W ridge along 25°N	Anomalous flow was cyclonic over NE part of the country
			July	
2 Jul	Cyclonic circulation over eastern part of UP and neighbourhood	E-W trough along 23° N	Ridge from 22° N/70° E to 27°N/ 95° E	Anomalous flow was anticyclonic over peninsular India and cyclonic over northern part of the country
9 Jul	N-S ridge roughly along 75° E	Trough from 18° N/73° E to 23° N/78° E	E-W ridge roughly along 29°N	Anomalous flow was mainly anticyclonic over central part of the country
16 Jul	N-S ridge roughly along 75° E	E-W ridge along northern part of the country	E-W ridge roughly along 28°N.	Anomalous flow was anticyclonic over northern and central part of the country and cyclonic over Tamil Nadu coast
23 Jul	N-S ridge roughly along 75° E and N-S trough over NE part of the country	E-W ridge along 25°N	Ridge from 26° N / 70° E to 29° N / 80° E	Anomalous flow was anticyclonic over central India
30 Jul	N-S trough along 90° E	Cyclonic circulation over north Bay and neighbourhood	E-W ridge along 28° N	Anomalous flow was mainly anticyclonic over central India
			August	
6 Aug	E-W trough over northern part of the country	Cyclonic circulation over Orissa and adjoining area.	E-W ridge along 30° N	Anomalous flow was cyclonic over southern part of the country
13 Aug	Cyclonic circulation over West Bengal coast and neighbourhood	E-W trough along 23° N through the cyclonic circulation	E-W ridge along 31° N	Anomalous flow was cyclonic at lower level over NE part of the country
20 Aug	Cyclonic circulation over NE part of the country	Cyclonic circulation over Orissa, WB and adjoining area	E-W ridge along 28° N	Anomalous flow was cyclonic over northeastern part of the country
27 Aug	Cyclonic circulation over Orissa coast and adjoining area	E-W trough along 21° N through the cyclonic circulation	E-W ridge roughly along 30° N	Anomalous flow was cyclonic
			September	
3 Sep	Cyclonic circulation over Orissa and adjoining West Bengal area	E-W trough along 21° N through the cyclonic circulation	E-W ridge roughly along 30° N	Anomalous flow was cyclonic at northern part of the country
10 Sep	E-W trough from north Bay to Punjab and Haryana region.	E-W trough through the cyclonic circulation over Orissa and West Bengal area	Ridge from 23° N/70° E to 30° N/95° E	Anomalous flow was cyclonic over north Bay and adjoining area
17 Sep	Cyclonic circulation over north Bay and adjoining Orissa and WB area	E-W trough through cyclonic circulation over Orissa and WB area along 20° N	Ridge from 22° N/68° E to 34° N/85° E	Anomalous flow was cyclonic over northern part of the country
24 Sep	Cyclonic circulation over north Bay and adjoining Orissa and WB area	Cyclonic circulation over north Bay and adjoining central Bay	E-W ridge along 22° N	Anomalous flow was cyclonic over Bay area
1Oct	N-S trough roughly along 86° E	E-W ridge along 17° N	E-W ridge along 23° N	Anomalous flow was cyclonic over northeast part of the country and anticyclonic over NW India

TABLE 9

Zonal wind anomaly (June to September 2002)

Week ending dates	4 Jun	11 Jun	18 Jun	25 Jun	2 Jul	9 Jul	16 Jul	23 Jul	30 Jul	6 Aug	13 Aug	20 Aug	27 Aug	3 Sep	10 Sep	17 Sep	24 Sep
Thiruvananthapuram (TRV)																	
850	0.7	–0.5	9.0	10.6	–7.2	–6.6	0.7	–5.7	–2.8	1.7	5.7	3.7	15.1	–6.4	1.0	–3.6	–2.4
500	–2.7	–3.1	–5.7	2.3	–7.1	3.9	–2.4	–4.3	0.1	–5.9	3.3	8.3	10.0	–1.5	–0.4	4.5	–0.4
200	0.4	0.2	–4.8	3.4	10.5	0.0	7.7	–15.7	3.9	1.6	–6.2	–4.1	–33.4	6.0	7.5	–5.2	–5.8
Chennai (MDS)																	
850	–0.2	–3.1	–1.2	13.2	–6.3	–6.7	–5.8	–4.3	–5.1	–3.0	16.4	12.2	15.1	0.6	4.0	–2.8	–1.5
500	1.8	–6.0	–13.8	19.7	–7.6	2.7	–0.4	–4.2	0.7	–4.1	7.0	14.4	5.2	–2.8	11.3	–2.5	–1.0
200	12.4	–3.9	–0.6	0.1	–5.1	–6.4	5.2	–3.1	18.3	–4.2	17.8	1.0	–39.5	7.7	5.7	–3.1	0.9
Mumbai (BMB)																	
850	–0.5	–4.0	–7.5	1.6	4.5	–1.8	–0.5	2.1	0.3	–7.4	13.5	4.0	12.7	1.2	1.8	–1.6	–1.0
500	1.5	–3.4	–1.4	–2.3	12.3	0.1	–0.9	–4.2	–3.8	–1.5	0.8	4.4	–4.4	–0.1	2.9	11.2	10.2
200	21.5	–0.2	10.4	–3.0	–1.3	10.7	11.1	–0.1	6.0	4.6	–1.7	9.5	–57.2	1.6	8.9	11.4	12.2
Nagpur (NGP)																	
850	0.2	–1.7	1.3	7.7	8.3	6.3	2.7	1.5	0.9	7.9	3.8	11.1	–4.9	4.6	8.0	5.8	0.7
500	8.0	1.5	2.7	–1.8	16.7	–10.1	–1.9	–2.6	4.3	–5.4	0.0	16.8	–4.1	99.9	1.7	14.0	13.4
200	13.8	4.5	–20.9	14.0	1.8	–14.8	3.4	3.0	12.7	15.2	–0.8	9.1	–62.1	99.9	7.1	–26.3	–16.9

Details are given in Tables 3 to 6.

5. Extra Indian systems

5.1. *Cross equatorial flow*

5.1.1. *Along the equator*

In general the cross equatorial flow was weaker than normal (5-10 kts) by 5 kts or less along the equator over the Arabian Sea, *i.e*. within $\pm$ 5^{o} Latitude of the equator during June to September.

Over Bay of Bengal, the cross equatorial flow was less than normal (5-10 kts) by 5 kts or less since last week of June till August. It was more than normal (5-10 kts) during last three weeks of September by about 5 knots and nearly normal (5-10 kts) during rest period.

5.1.2. *Over the Arabian Sea*

The surface winds were nearly normal (15-20 kts) in June. It was less than normal (20-25 kts) by about 5 kts to the north of 15° N and nearly normal (20-25 kts) to the south of 15^{o} N during July. It was below normal (20-25 kts) by 5 kts or so over Arabian Sea during August. In September it was above normal (5-10 kts) to the north of 15^{o} N by about 5 kts, during first three weeks and normal (5-10 kts) over rest area during remaining period.

5.1.3. *Over the Bay of Bengal*

The surface winds were nearly normal (10-15 kts) for the first three weeks in June. It was less than normal (10-15 kts) during 4th week of June, entire July and August by about 5 to 10 kts. In September, the surface winds were above normal (5-10 kts) by 5 kts during last three weeks of the month and nearly normal (5-10 kts) during the remaining period.

5.2. *Mid-Latitude troughs*

Month wise break-up of troughs in westerlies found between 60° E – 90° E, reaching upto or south of 30° N is given in Table 13.

There were a total of 29 mid and upper tropospheric troughs during the season.

As a comparison, there were 21, 13, 29, 17 and 31 mid and upper tropospheric troughs in 2001, 2000, 1999, 1998 and 1997 respectively.

TABLE 10

Rainfall characteristics in terms of number of days for June-September 2002

S. No.	Sub – division	Vig.	Act.	V. Heavy	Heavy	W/Fw
1.	Andaman & Nicobar Islands	-	-	1	10	48
2.	Arunachal Pradesh	4	9	9	23	48
3.	Assam & Meghalaya	-	6	11	34	53
4.	Naga., Mani., Mizo. & Trip.	-	6	2	11	64
5.	S.H.W.B. & Sikkim	3	28	25	25	38
6.	Gangetic West Bengal	3	19	8	22	24
7.	Orissa	1	12	3	37	25
8.	Jharkhand	2	11	5	14	29
9.	Bihar	3	4	10	12	29
10.	East Uttar Pradesh	-	-	6	24	21
11.	West Uttar Pradesh	-	-	9	8	17
12.	Uttaranchal	-	-	6	13	40
13.	Haryana	-	2	5	9	14
14.	Punjab	3	5	5	7	19
15.	Himachal Pradesh	4	10	10	14	31
16.	Jammu & Kashmir	3	2	-	10	6
17.	West Rajasthan	-	-	-	-	1
18.	East Rajasthan	-	-	2	8	1
19.	West Madhya Pradesh	-	-	3	16	24
20.	East Madhya Pradesh	-	-	6	13	28
21	Gujarat Region	1	-	5	14	11
22.	Saurashtra & Kutch	1	-	1	2	6
23.	Konkan & Goa	2	19	15	33	48
24.	Madhya Maharashtra	3	11	9	31	22
25.	Marathwada	5	8	2	3	12
26.	Vidarbha	7	11	6	10	16
27.	Chattisgarh	-	1	5	11	42
28.	Coastal Andhra Pradesh	-	11	1	8	6
29.	Telangana	3	11	3	10	12
30.	Rayalaseema	-	3	-	6	4
31.	Tamil Nadu & Pondicherry	-	-	-	21	-
32.	Coastal Karnataka	-	13	11	18	71
33.	North interior Karnataka	1	4	-	15	3
34.	South interior Karnataka	-	5	7	20	5
35.	Kerala	2	11	7	26	52
36.	Lakshadweep	-	-	-	1	26

Vig. = Vigorous (Rainfall in the sub-division is fairly widespread or widespread and the average rainfall received in a sub-division is more than 4 times the normal with atleast 2 stations reporting 8 cm in the west coast and 5 cm elsewhere)

Act. = Active(Rainfall in the sub-division is fairly widespread or widespread and the average rainfall received in a sub-division is 1.5 to 4 times the normal with atleast 2 stations reporting 5 cm in the west coast and 3 cm elsewhere)

V. Heavy = Very heavy rainfall (rainfall recorded more than 12.5 cm)

Heavy = Heavy rainfall (rainfall recorded more than 6.5 cm)

W/Fw = At most places (more than 75% stations of a sub-division reporting rainfall atleast 2.5 mm) and or at many places (51% to 75% stations of a sub-division reporting rainfall atleast 2.5 mm).

TABLE 11

Principle amounts of rainfall during June – September 2002

Date (1)	June (2)	July (3)	August (4)	September (5)
1.	Khonsa, Kolkata & Mathabhanga 10 each, Kalaghatagi 8, Mohana, Kumta & Anandpur 7 each	Gajoldoba 29, Murty 22, Ayodhya 10, Matheran & Daporijo 8 each, Gaganbavada 7	Thanjavur & Bhalukpong 13 each, Kondul 12, Barabanki 10, Rairakhol 9, Gopalpur, Alwar, Perur & Muksar 8 each, Munnar, Balaghat, Srungavarappukotta & Padampur 7 each	Ashta & Bangana 12 each, Sahore 11, Lanji 10, Ludhiana & Matheran 9 each, Mohadi, Khalapur & Burdhwan 8 each, Balaghat & Panposh 7 each
2.	Hosdurg 9, Mayabandar, Mudibedere & Arani 7 each	Nandadih 14, Canning Town 13, Domohani 12, Sujanpur 11, Seppa, Triveni & Arki 9 each, Kendrapada 7	Taibpur 16, Sibsagar 13, Jalpaiguri & Sangola 12 each, Domohani 11, Diana & Tikabali 10 each, Gadag & Dundigal 9 each, Belgaon 8, Malakpur, Baheri, Miao & Hirakud 7 each	Raipur 15, Dharmanagar 13, Pen & Ahwa 12 each, Chiplun 10, Jintoor & Sedhwa 9 each, Gaganbavada & Tarana 8 each, Aurad, Naraingarh, Hazaribagh & Matijuri 7 each
3.	Kannur & Tadong 14 each, Gangtok & Panjim 13 each, Panambur 9, Kokrajhar, Sangola & Jagdalpur 7 each	Passighat 22, Palmerganj 17, Indrapuri 15, Banbasa 11, Durgapur & Khusiary 10 each, Khanapura 8, Gazipur, Dharamsala, Agumbe & Jajpur 7 each	Mangalvedha 20, Patna 16, Japla 14, Ashti & Mancherial 11 each, Haldibari & Bangana 10 each, Bhalukpong, Murti, Agumbe & Manthani 9 each, Bhilwara & Raisen 8 each, Ghamroor & Bharwain 7 each	Ahwa 29, Poondi 17, Surgana 15, Dohad 14, Chennai 11, Nandurbar 10, Mohad 9, Naraingarh, Domohani, Khandwa & Mehsana 8 each
4.	Gangtok 19, Gangavati 9	Indrapuri 17, Dehri 14, Turtipar 13, Hardwar & Tilaiya 12 each, Sarif 11, Koderma 10, Chanpatia 9, Nagina, Williamnagar, Dharampur & Bhoranj 8 each	Sarkaghat 16, Sehore & Ranikhet 13 each, Ratlam, Dharamsala & Tilaiya 12 each, Khajuraho, Kotdwar & Tezpur 11 each, Panjim & Jammu 9 each, Ranibandh 8, Bhoranj & Sujanpur Tira 12 each, Nagrota & Surian 11 each, Ghumarwin & Nahan 10 each, Barsar & Bangana 9 each	Chottaudaipur & Karjan 11 each, Dabhol, Nangal & Broach 16 each, Dediapada & Tilakwada 15 each, Ankleshwar 14, Lohari, Nadiad, Rajpipla, Tagewada & Baroda 13 each
5.	Kokrajhar 15, Hasimara 14	Hayaghat & Rewaghat 15 each, Samastipur 14, Ahirwalia & Ferozepur 10 each, Ambala 9, Hut Bay, Darjeeling, Bansdih & Tajewala 8 each, Kotdwar & Nabha 7 each	Balchaur 17, Maya Bandar 16, Bihubar 15, Mumbai 14, Jalaun & Kangra 13 each, Mangalagiri 12, Kalyan 11, Bhiwani & Khonsa 10 each, Cannur & Tikabali 9 each, Kanti 8, Nilokheri, Thanesar, Chhachhrauli, Jagadhari & Tajewala 7 each	Paonta 16, Banbasa 15, Triveni & Songadh 13 each, Wada & Bansdih 12 each, Tirupathi 10, Ahwa, Sandwa & Chikhali 9 each, Lengpui 8, Bareilly, Rewaghat & Igatpuri 7 each
6.	Sagar & Barobisha 12 each, Maya Bandar, Dhubri & Mahendragarh 9 each, Hanasagi & Tekkali 8 each, Daltonganj & Bharmaur 7 each	Jhanjharpur 23, Bansdih & Khonsa 8 each, Deogarh & Basua 7 each	Chapra 16, Siddapura, Balaghat & Maya Bandar 11 each, Uttarkashi, Kailashahar & Dharmanagar 10 each, Koppa 9, Gaya 8, Baheri & Balasinor 7 each	Bareilly 20, Banbasa 19, Paliakala 17, Poladpur 14, Betul 13, Mahabaleshwar 12, Khandwa & Dharmanagar 10 each, Tendukheda 9, Kunnavaram 8
7.	Daporijo 10, Mancherial 9, Nilambur & Madurai 7 each	Bhalukpong 9	Matheran 33, Gaganbavada 12, Uran & Pallahara 11 each, Jenapur, Daman & Valasad 9 each, Landa, Hoshangabad & Tensa 8 each, Chittorgarh, Mudigere, Dharmanagar & Gharmure 7 each	Kanpur 15, Kashipur 14, Najibabad & Jabalpur 13 each, Bilaspur & Dhanpur 11 each, Bhograi & Banda 9 each, Banbasa & Balimundali 8 each, Agumbe 7
8.	Gajoldoba 29, Nagarakata 19, Murty 17, Agartala 11, Paikamal 8, Cooch Behar 7	Sonamura 10, Chepan 9, Champasarai 8	Kalyan 29, Poladpur 15, Bhira 14, Perur & Sihor 12 each, Deogaon 11, Jharsuguda & Satna 10 each, Sevoke & Gadchiroli 8 each, Gangtok, Hoshangabad, Kollur & Chendipada 7 each	Bangana 21, Naraingarh 13, Phulbani 11, Khajuraho & Munnar 10 each, Kundapura, Pendra, Sahib, Najibabad & Banda 7 each

TABLE 11 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
9.	Palamner 12, Cochi & Cherthala 9 each, Gajoldoba & Punganur 8 each, Mangalore & Bukkapatna 7 each	Kokrajhar 12, Mellabazar 11, Sibsagar 8	Hindolia 20, Nilkund 19, Perur 18, Talcher & Baidhgarh 14 each, Athmalik 13, Ratnagiri & Nayagarh 12 each, Agartala, Gadchiroli, Guddalur Bazar & Paradeep 10 each, Guna & Munnar 8 each	Fateshpur & Sakoli 8 each, Sultanpur, Jaypore & Dasuya 7 each
10.	Canning town 11, Krishnagiri 10, Alapuzha & Mandasa 9 each, Lahunipara 8	Murti 21, Nilkund 13, Beki Road Bridge 11, Jammu, Nagrakata & Honavar 10 each, Agumbe 9, Shirali & Golaghat 7 each	Nilkund 19, Naduvattam 12, Naharkatia, Roing, Jharsuguda & Rajganjpur 10 each, Maihar, Munnar, Guddalur Bazar, Laikera & Panposh 9 each, Tantloi & Lohunipada 8 each, Peswa 7	Rajghat 25, Jhalwar 17, Kharagpur 14, Midnapore 13, Munnar 10, Kanpur, Varkala & Maya Bandar 7 each
11.	Kollur 21, Chettikulam 12, Sevoke & Kamakhyanagar 11 each, Ratnagiri & Kudulu 10 each, Dibrugarh 9, Chennagiri, Kundapura & Sankeshwar 8 each, Kakinada & Kagal 7 each	Shirali Dabolim 15, Karwar 14, Kota 13, Kundapura & Gajoldoba 12 each, Mudibidere & Vengurla 11 each, Ankola & Sevoke 10 each, Mangalore & Champasarai 9 each	Kakardharighat 48, Lakhimpur, Imphal & Bijapur 15 each, Bangana 14, Kangra 12, North Deogaon & Japepalli 11 each, Hasimara & Bharwain 10 each, Jagdhari & Kanksai 9 each, Sohela, Naraingarh & Barsar 8 each, Katra, Munnar, Chandigarh & Nadan 7 each	Hazaribagh, Rajghat & Tusama 9 each, Ranikhet 7
12.	Panambur 12, Pullanbadi 11, Bankura & Gajoldoba 10 each, Tirakoilur & Asansol 9 each, Kozhikode & Minicoy 8 each	Thodupuzha 16, Belthangady 13, Bhagamandala, Kodungallur, Hasimara & Dharamsala 12 each, Munnar & Agumbe 11 each, Medikeri & Nagrakata 10 each	Kolkata 23, Dibrugarh & Nilkund 13 each, Passighat 11, Imphal 9, Udhampur & Yellandu 8 each, Sevoke 7	Digha 24, Kiroli & Najibabad 14 each, Ranchi 13, Kotdwar & Lansdown 12 each, Bhograi 8, Pali, Hardoi, Titlagarh & Nandigram 7 each
13.	Ashti 20, Basirhat, Alapuzha & Thalassery 9 each, Junagarh 7	Sringeri 22, Dharamsala 20, Jayapura 14, Belthangady 13, Kamardi & Beki Mathanguri 12 each, Somwarpet 10, Ottapalam, Nilambur & Silchar 9 each	Pachhad 18, Malda 15, Dadritaya 14, Amritsar 13, Kathua 11, Jammu, Sriniketan & Hunchatkatte 10 each, Passighat, Rohtak, Malakpur & Raimal 9 each, Port Blair, Dhubri, Sambalpur & Dadahu 8 each, Naraingarh, Jhajjar & Kharkhad 8 each, New Delhi, Sunibhajji & Fatehgarh Sahib 7 each	Sardhana 21, Safipur 17, Delhi Bridge 16, Buldhana 16, Palwal 15, New Delhi, Ambad, Khair & Ghumarwin 13 each, Satna, Bindki, Rajkheda, Faridabad, Nilokheri, Sonepat & Nabha 11 each, Dillighat & Nangal 10 each, Kanpur, Naraingarh & Ghamroor 9 each
14.	Goalpara 42, Karwar 30, Ankola 24, Thrissur 20, Cochi 17, Shillong 15, Agartala 14, Beki Road Bridge 13, Vellore & Washim 8 each	Diana 21, Nagrakata 15, Karimganj & Agumbe 10 each, Gajoldoba 8, Rajnandgaon, Bhalukpong, Idukki & Dharamsala 7 each	Ambala & Chandigarh 23 each, Dharampur 18, Pachhad 16, Naraingarh, Daduhu & Solan 15 each, Batote 14, Nahan 12, Shimla & Kandaghat 10 each, Sunibhajji 9, Kahu, gohar, Karsog & Rohru 8 each, Perinthalmanna, Guhla, Kalka & Tajewala 7 each	Halwara 16, Amroha & Haldibari 14 each, Hasanpur 13, Chepan 10, Doda, Udhampur, Bilari, Nagrakata & Uklana 9 each, Diana & Thanesar 8 each, Rohtak & Kotdwar 7 each
15.	Gaganbavada 29, Guhagar 26, Ratnagiri 22, Panjim 18, Agumbe 16, Kamtaul 13, Kota & Hosdurg 12 each, Benibad & Karkala 11 each, Port Blair 7	Gaganbavada 14, Midnapore 11, Rajapur 9, Katraj & Paikamal 7 each	Derabassi 13, Rajghat & Khajuraho 11 each, Diamond Harbour 10, Moth 9, Gwalior, Singhbhum, Rajkishorenagar & Pattangi 7 each	Haldibari 14, Shrimushnam 11, Shirgaon & Chepan 10 each, Williamnagar, Metupatti & Avinasi 7 each
16.	Kumta 18, Agumbe & Ratnagiri 16 each, Kudulu 15, Mandangad 14, Dhubri 10, Gaganbavada 9	Malwan 16, Gaganbavada 14, Panjim 11, Kankavali & Junagarh 9 each, Vythiri, Devgad, Baijnath & Kharior 8 each, Radhanagari 7	Lanji 24, Kodungallur 13, Mathroji, Agumbe & Subramanya 11 each, Simulia & Paradeep 9 each, Bhopal 8, Gondia & Raipur 7 each	AIE NH Xing 13, Chettikulan 12, Sandur 11, Mahendragarh 9, Narsapur, Purushottampur, Krishnagiri & Sangola 8 each, NH 31 7

TABLE 11 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
17	Arkuralley & Shrivardhan 12 each, Mohendragarh & Mandangarh 11 each, Dhenkanal & Panjim 10 each, Kotdwar 9, Kollur 8, Khairamal, Bargarh & Hirakud 9 each, Rajghat & Kuchinda 8 each, Jenapur 7	Jharsuguda 20, Phulbani 18, Port Blair & Khed 12 each, Dabolim 10, Langpui & Karimganj 9 each, Valpoi & Sundergad 8 each, Agumbe & Sambalpur 7 each	Munnar 18, Lanji 15, Dharmasthala 13, Nilgiri 11, Dibrugarh & Gariaband 10 each, Gaganbavada 9, Nakshirpara & Sitapur 8 each, Akiera & Chickmagalur 7 each	Bhalukpong, Nagrakata & Srinivaspura 9 each, Chouldhowaghat, Diana, Kolar & Krishnagiri 8 each, Gubbi & Handupur 7 each
18	Khed 14, Siddapura 13, Mandi & Ashti 11 each, Dapoli 10, Ahirwalia 9, Kuddalore & Gaganbavada 8 each	Namsai 10, Dibrugarh 9, Nagrakata, Parvathipuram, Jagdalpur & Bhubaneswar 8 each, Nalhati & Ambhona 7 each	Ghansore 30, Keolari 27, Bhalukpong 15, Sitapur 13, Gaganbavada & Munnar 11 each, Mellabazar 8, Multai & Subramanya 7 each	Gajoldoba 13, Champaran 9, Sevoke 8
19	Ankola & Karwar 13 each, Kudulu 10, Agumbe & Kasargod 9 each, Maya Bandar & Cuddalore 8 each, Munnar 7	Passighat 16, Bhadravati 15, Gajoldoba 14, Baghdogra 13, Chandrapur & Hasimara 12 each, Roing 11, Rajura & Murbad 10 each, Jogindernagar 8, Dharamsala & Sambalpur 7 each	Jalpaiguri, Tendulkheda & Hoshangabad 13 each, Nilakunda 11, Mouranipur 10, Badatigaht 8, Radhanagari 7, Naraigarh & Ghumarwin 9 each, Chhachhrauli, Dadupur & Jagadhari 7 each	Bharmour 8, Dataganj & Rajkot 7 each
20	Gossaigaon 21, Cherrapunji 20, Barobhisa 16, Chepan 13, Malvan 11, Rajapur & Kumta 10 each, Khonsa & Shrivardhan 9 each, Madnoor & Gaganbavada 8 each	Chepan 31, Alipurduar 29, Barobhisa 28, Mathabhanga 24, Cooch Behar & Gossaigaon 20 each, Jogindernagar 18, Roing 17, Tezu 12, Sendwa, Bhadravati & Satna 10 each, Dharamsala 11, Baijnath 9	Gajoldoba 17, Sevoke 11, Berhampore & Agumbe 8 each	Maya Bandar 8, Jayamakandam 7
21	Honavar 14, Bhalukpong & Agumbe 11 each, Kalagi & Vengurla 10 each, Ahirwalia 9, Umargaon & Rajapur 8 each, Cherrapunji, Rewaghat & Shirali 7 each	Sonbarsa 26, Chepan 25, Gossaigaon 24, Barobhisa 22, passigaht 20, Cooch Behar 17, Roing 14, Tezu 13, Jhanjharpur 12, Ahirwalia 11, Paradip 8	Tikabali 24, Phulbani 11, Pendra 8, Darjeeling, Subramanya & Agumbe 7 each	Kolkata & Durgachak 10 each, Balasore 8, Malda, Khesiary & Mayiladuthurai 7 each
22	Umargaon & Kollur 12 each, Harnai, Kheruniaghat & Bomdila 9 each, Agumbe, Gondia, Alibag & Gaganbavada 8 each, Nilagiri & Gondia 7 each	Sevoke 25, Gajoldoba 21, Sonbarsa 20, Chapra 18, Champasarai 17, Galgalia 14, Choudhowaghat & Tantloi 13 each, Jalpaiguri 12, Arambagh 11	Lanji 19, Sakoli 18, Dehra Dun 14, Palmerganj 13, Tagewala & Malakpur 11 each, Phulbani & Chatnag 9 each, Baligada & Tikbali 8 each, Agumbe 7	Nil
23	Navrangpur 21, Bankura 20, Burdhwan 18, Goalpara 12, Valpoi 11, Gaganbavada & Navapara 9 each, Talcher 8, Siddapura, Junagarh & Guwahati 7 each	Birpur 16, Mellabazar 12, Galgalia & Taibpur 10 each, Cooch Behar 9, Khed & Dinhata 8 each, Bhira & Roing 7 each	Una 23, Nimapada 19, Sironcha 15, Perur 14, Maihar 13, Belgaon, Darinbali & Kotagarh 10 each, Nangal 8, Jammu, Bihaur, Gaganbavada, Kanakavali, Pachhad, Bolangir, Tikabali & Kotraguda 7 each	Mirzapur 14, Balimundali & Contai 10 each, Titlagarh 8, Hindol, Balasore, Dholai & Silchar 7 each
24	Agumbe 14, Radhanagari, Shahapur & Uluberia 13 each, Poladpur & Peermade 12 each, Midnapur, Munnar & Navapara 10 each, Pardi & Bolangir 8 each, Silvasa & Ambabhona 7 each	Chepan 17, Alipurduar 15, Cooch Behar & Barobhisa 14 each, Choudhowaghat 13, Mathanguri 12, Poladpur 10, Roing 8	Baijnath 24, Nagpur & Medak 15 each, Kathua & Nagbhir 14 each, Kanker 13, Bidar & Dharamsala 12 each, Udgir 11, Siddapura & Jogindernagar 9 each, Jammu, Jorhat & Baripada 8 each, Bhubaneswar 7	Darauli 12, Contai, Passighat & Palmerganj 11 each, Rayaganj 10, D. P. Ghat, Durapur & Kurkela 9 each, Miao 8, Panposh & Jaipur 7 each
25	Chandrapur 19, Yeotmal 17, Adilabad, Somwarpet, Munnar & Dashapalla 13 each, Bansda 12, Vythiri & Contai 10 each, Bhograi, Parbhani & Subramanya 9 each, Tikabali 7	Galgalia 14, Birpur 13, Gaganbavda & Mathabhanga 12 each, Khed, Cooch Behar & Baghdogra 10 each, Yellandu & Domohani 9 each, Bharwain 8, Ghamroor & Bangana 7 each	Washim & Malegaon 25 each, Parola 21, Patur 20, Chikhli 18, Talakwada 12, Wada & Bansdih 11 each, Khowang 8	Malda 18, Burdhwan 14, Messanjor & Tantloi 13 each, Contai 11, Varanasi 8, Maharo, Dhubri & Junapur 7 each

TABLE 11 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
26	Vada 38, Ahwa 25, Mokheda 20, Parbhani 19, Karjan 17, Nanded 14, Songadh 13, Chandrapur 8, Thakurmunda 7	Birpur 11, Peint 10, Dundigal & Jalpaiguri 9 each, Mahad, Madhuban, Chanpatia, Goalpara, Surgana & Mathabhanga 7 each	Kokrajhar 29, Jafrabad 22, Barobhisa 21, Mehsana 12, New Kandla 10, Katra & Murbad 9 each	Dengraghat & Changharia 21 each, Rayaganj 18, Araria 15, Purnea 13, Port Blair 12, Chopra & Beki Mathanguri 10 each, Goalpara & Mohana 8 each
27	Murbad 34, Igatpuri & Akola 17 each, Surat 15, Mahuva 14, Lalganj 11, Passighat 10, Londa & Raya 7 each	Sankalan 26, Baghdogra 21, Gajoldoba 15, Sevoke 14, Champasarai 12, Galgalia 9, Sibsagar 8, Gaganbavada 7	Kalyanpur 16, Bangana & Barsar 13 each, Krishnagiri 10, Kotdwar, Dharamsala & Kangra 8 each, Dengraghat & Gajoldoba 7 each	Kailashshahar & A. D. Nagara 10 each, Lalbegiaghat & Chaibasa 9 each, Perambur 8, Bhubaneswar 7
28	Bhavnagar 42, Peint 14, Mahuva & Broach 12 each, Shahapur 10, Sakoli 9, Kasargode 8	Bhalukpong 29, Agumbe 18, Uppinangaddy 13, Sringeri & Puttur 12 each, Mani 11, Siddapura 10, Amraghat 9, Gajoldoba 8, Keonjhargarh 7	Bijepur 15, Nagrath, Surian, Dehra Gopipur & Nagrata Surian 11 each, Bangana & Tikabali 10 each, Tangi & Kharior 9 each, Chalora & Guler 8 each, Alipingal & Bharwain 7 each	Pasndavpura & K. R. Sagara 11 each, Harur & Jamshedpur 10 each, Diana 9, Dengraghat & T. P. Barrage 7 each
29	Amreli 21, Chopra 14, Kalyan & Bhalukpong 12 each, Pachhad 11, Mount Abu & Rajkot 10 each, Veraval & Igatpuri 9 each, Triveni & Kasol 8 each, Taibpur & Shimla 7 each	Murti 15, Tikabali 12, Arundhatinagar & Hasimara 10 each, Baghdogra & Gajoldoba 9 each, Silchar 8, Bhalukpong, Thanjavur & Bhagamandala 7 each	Jashpurnagar & Bharwain 18 each, Chattarpur 13, Deoni 12, Begumganj, Hoshangabad & Ghamroor 11 each, Jenapur 10, Dadri Taya & Malakpur 9 each, Dehragopipur, Chandbali & Pattangi 7 each	Aiexing 17, Barobhisa 13, Manas NH Xing 11, Konner & Miao 7 each
30	Murbad 15, Bhalukpong 13, Sevoke 12, Peint, Gossaigaon, Delhi Bridge & Rajghat 9 each, Jaleswar 8, Nilagiri 7	Naharkatia 14, Madhabarida 13, Maharajganj 10, Margherita 9, Dillighat & Sulurpet 8 each, Jalpaiguri & Mohana 7 each	Banbasa 39, Songadh & Kotagarh 12 each, Mandul & Sarkaghat 11 each, Jammu & Dadupur 10 each, Chhachhrauli & Paikamal 9 each, Goalghat, Kantamal, Bareilly, Kharkhada, Bolangir, Madanpur & Rampur 8 each, Tikarpara, Amraghat & Kahu 7 each	Passighat 21, Jalpaiguri 13, Miao & Punalur 7 each
31	–	Rayagadda 11, Passighat 10, Gopalpur & Munnar 9 each, Gunupur & Lucknow 8 each, Thanjavur & Amraghat 7 each	Bilaspur 16, Pen 11, Kantamal & Songadh 10 each, Sakti, Jhanjgir & Dashapalla 9 each, Tilakwada, Bhopal, Indore & Uran 8 each, Visakhapatnam, Khed & Khairamal 7 each	

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

There were 16 systems (Tropical Depression stage and above) in the northwest Pacific Ocean/ South China Sea during June – September 2002. The month wise break-up is shown in Table 14.

5.4. *Systems in southern hemisphere*

5.4.1. *Tropical Storms*

No weather systems (TD, TS or Typhoon) were reported during June to September 2002.

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

During June to September 2002 there were a total of 13 (4 in June and 3 each in July, August and September) upper air troughs in westerlies which moved across Indian Ocean from west to east to the north of Lat.30° S. (*Source* : INSAT full disc pictures)

There were 14 troughs in mid and upper tropospheric westerlies in 2001, 17 in 2000, 13 in 1999, 23 in 1998 and 9 in 1997 which moved across Indian Ocean, north of 30° S in Southern Hemisphere, during the same period.

5.4.3. *Mascarene High*

The intensity of Mascarene High at 30° S / 60° E was above normal in all the months and a highest of +4.0 hPa was noticed during August. Source (Climate Diagnostic Bulletins, Climate Prediction Centre, USA, June, July, August, September 2002, Departures are taken from the 1979-95 base period monthly means). The intensity of Mascarene High along with that for the past 5 years are given in Table 15.

TABLE 12

Monthly values of SST anomalies for the period from October 2001 to September 2002

Month	Pacific SSTA (°C)			SOI
	Nino 1+2 0°-10°S 90°-80°W	Nino 3 5°N-5°S 150°-90°W	Nino 4 5°N-5°S 160°E-150°W	
Oct 2001	-1.4	-0.5	0.0	-0.4
Nov 2001	-1.2	-0.6	-0.1	0.7
Dec 2001	-0.9	-0.5	-0.3	-1.2
Jan 2002	-0.9	-0.5	0.0	0.4
Feb 2002	0.0	-0.2	0.3	0.9
Mar 2002	1.1	0.1	0.2	-0.9
Apr 2002	1.1	0.2	0.3	-0.4
May 2002	0.5	0.2	0.4	-1.2
Jun 2002	-0.4	0.7	0.9	-0.7
Jul 2002	-0.8	0.5	0.9	-0.7
Aug 2002	-0.9	0.5	1.1	-1.6
Sep 2002	-0.6	0.7	1.2	-0.7

TABLE 13

Statistics of mid latitude troughs, monsoon 2002

Levels	June	July	August	September	Total
300 hPa	5	3	2	4	14
500 hPa	4	4	2	5	15

TABLE 14

Statistics of systems in west Pacific Ocean/ South China Sea, monsoon 2002

Weather systems	June	July	August	September	Total
TD	1	0	0	0	1
TS	0	1	3	2	6
Typhoons	1	4	2	2	9
Total	2	5	5	4	16

5.4.4. *Australian High*

The intensity of Australian high pressure area at 30° S / 140° E was normal during June and July, above normal during August (+1.5) and below normal in September (−1.0). *Source* : (Climate Diagnostic Bulletins, Climate Prediction Centre, USA June, July, August, September 2002, Departures are taken from the 1979-95 base period monthly means). Details of the intensity of Australian High for the last five years are given in Table 16.

6. Semi-permanent systems

6.1. *Heat low*

The heat low over west Rajasthan and adjoining Pakistan on the sea level chart formed on 29 May and remained more or less over the same area till 30 September. The lowest and second lowest observed pressure values of the heat low were

June : 988 on 21, 22, 989 on 13, 14 and 21.

July : 988 on 2 and 989 on 4, 17.

August : 988 on 11, 990 on 10.

September : 997 on 4, 998 on 7, 8, 9 and 17.

Details of the lowest observed isobaric values of the Heat low during past five years are given in Table 17.

6.2. *Axis of the monsoon trough*

Monsoon trough was established, unusually late and occupied almost it's normal position on 15 August. The normal position is from Ganganagar to Kolkata through Allahabad. Western end of Monsoon Trough was north of normal position by about 1° and eastern end was south of normal position by 1° to 1.5° from 16 to 22 August. During 23 to 25 August it was south of normal position by 3° to 5° in association with the low pressure area over north Bay of Bengal. On 26 August, only eastern end shifted north of its normal position by about 3° and on 27 August the entire Monsoon Trough shifted close to the foothills of Himalayas. From 28 to 30 August, only eastern end shifted southwards in association with a low pressure area over north Bay of Bengal and was south of its normal position by 1° to 3°. During 1 to 8 September, the entire axis of Monsoon trough was lying south of its normal position by 1° to 4°. On 9 and 10, only western end was in its normal position. However, from 11 to 13 September, again axis of the Monsoon Trough was south of its normal position by about 1° to 5°. On 14 September it was seen in normal position and on 15, it was shifted to the foothills of the Himalayas. It was not seen near its normal position from 16 September onwards.

TABLE 15

Intensity of Mascarene High during monsoon season for the years 1997-2002

Year	June		July		August		September	
	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)
1997	1028	4	1027	3	1027	3	1025	1
1998	1023	-1	1026	3	1023	-1	1024	0
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

TABLE 16

Intensity of Australian High during monsoon season for the years 1997-2002

Year	June		July		August		September	
	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)
1997	1031	7	1034	10	1028	4	1022	4
1998	1024	0	1024	0	1024	0	1023	- 1
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

TABLE 17

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

Month/Year	1997	1998	1999	2000	2001
June	986 hPa (25)	987.5 hPa (21)	990 hPa (23)	989.0 (13, 14, 16 & 25)	987.0 (20 & 21)
July	986.8 hPa (6)	985.6 hPa (12)	988.0 hPa (2)	989.0 (7)	989.0 (12)
August	990.5 hPa (4)	990.7 hPa (4)	988.5 hPa (6)	990.0 (30)	990.0 (29)
September	996.8 hPa (2)	993.9 hPa (3)	994.0 (17)	992.0 (1)	995.0 (5 & 10)

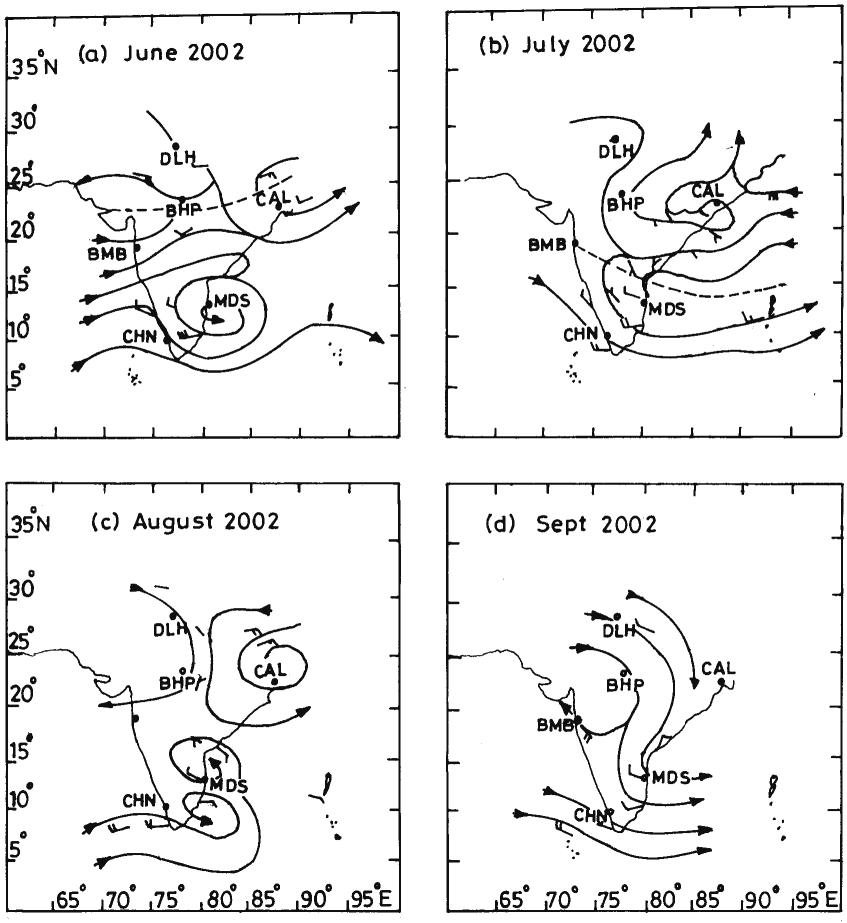
For ready comparison, the positions of monsoon trough in the past five years are given below.

Year	*Axis of Monsoon Trough*
1997	Established on 25 June. Less marked on 6 September. Breaks on 10 July, 9 and 15 August.
1998	Established on 21 June. Less marked on 23 September. Break from 16 to 26 July and 20 to 26 August.
1999	Established on 10 June. Less marked on 26 September.
2000	Established on 2 July. Less marked on 22 September. Break from 1-4 August.
2001	Established on 3 July. Less marked on 20 September.

6.3. *Tibetan Anticyclone/High*

Tibetan Anticyclone (TA) was established at 500, 300 and 200 hPa levels on 11 July 2002. It was not seen in June. In last seven years, there was no similar case. In July also it was not seen regularly at all the three levels. In July at 500 hPa, it was not seen on most of the days. It was seen north of normal position from 11 to 19 July and 30 and 31 July. From 22 to 25 July, it was seen south of normal position at 300 hPa. At 200 hPa it was almost in normal position from 20 to 28 July.

In August, it was seen north of normal position from 1 to 10 August. From 11 to 23 August it was seen south



Figs. 9(a-d). Anomalous wind flow during monsoon 2002 at 30 hPa

of normal position. It was seen north of normal position from 24 to 31 August.

In September, TA was north of normal position during 1-12 September. Thereafter it started moving southsoutheastwards. The details of Tibetan Anticyclone for the past five years are given below :

Year	*Tibetan Anticyclone*
1997	Appeared in the last week of June. Less marked on 17 September.
1998	Appeared on 13 June. Less marked on 27 September.
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 last week of August. Less marked on 13 September.

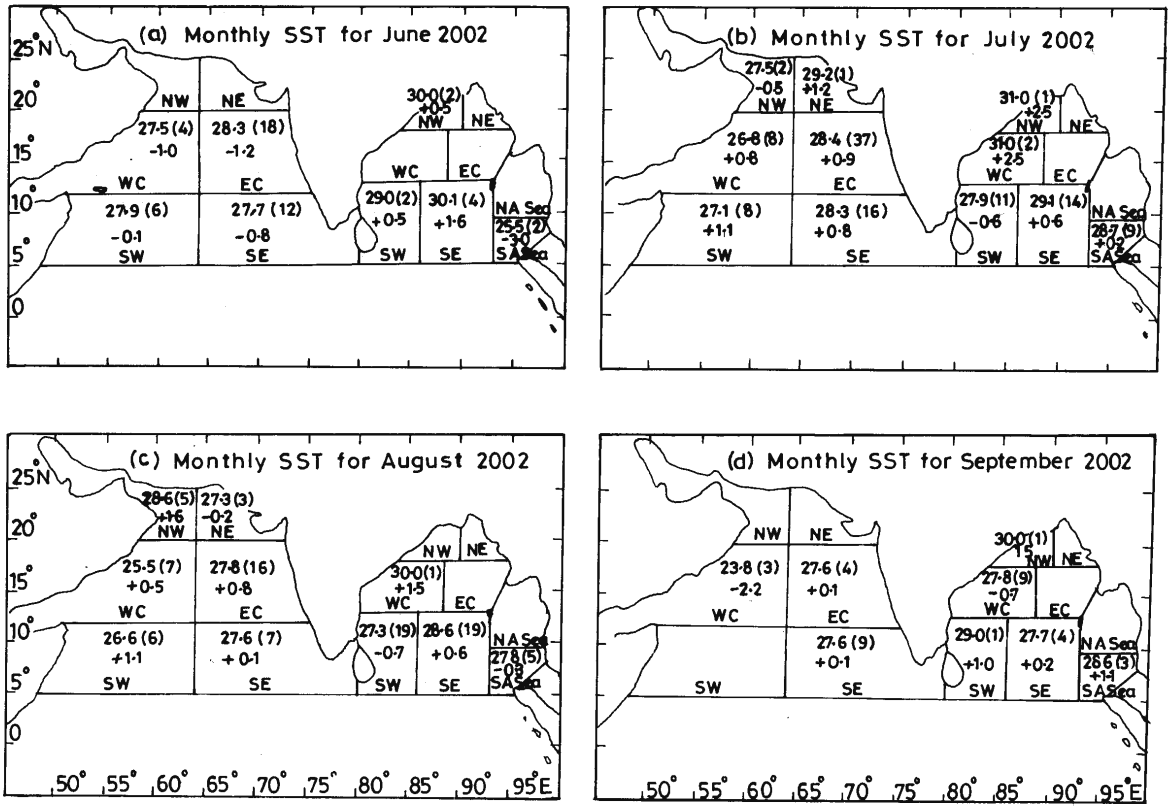
6.4. *Sub-Tropical Westerly Jet (STWJ)*

STWJ was seen over Srinagar on 7, 8, 10 June and over Guwahati on 5 and 9 June. It then shifted northwards and reappeared over Srinagar, Delhi, Jodhpur and Lucknow in the last week of September. The days, the Sub tropical Westerly Jet was observed in the past five years are given below :

Year	*Sub-Tropical Westerly Jet (STWJ)*
1997	Seen till first fortnight of June and last week of September.
1998	Seen only in first week of June.
1999	Seen only till 12 June.
2000	Made appearances 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 last week of September.

6.5. *Tropical Easterly Jet (TEJ)*

TEJ was observed over Minicoy from 7 June to 22 September. However, it was not seen regularly. It was not seen in 9 days in June, 14 days in July, 8 days in August and 14 days in September. The maximum wind observed was 120 kts at 173 hPa level at 0000 UTC of



Figs. 10(a-d). SST and SST anomaly in (°C). The numbers inside the brackets indicate the number of observation

3 July, at 117 hPa level at 1200 UTC of 29 July and at 150 hPa level at 0000 UTC of 19 August.

TEJ was observed over Thiruvananthapuram from 5 June to 29 September. However, it was not seen on 9 days in June, 4 days in July, 3 days in August and 14 days in September. The maximum wind observed was 110 kts at 100 hPa level at 1200 UTC of 30 July and 139 hPa at 1200 UTC of 11 August.

Over Chennai also it appeared from 10 June to 30 September. It was not seen on 7 days in June, 6 days in July, 7 days in August and 15 days in September. The Maximum wind observed was 105 kts at 137 hPa at 0000 UTC of 18 June, at 100 hPa at 1200 UTC of 9 August.

Over Port Blair TEJ appeared on 13 June and was seen till 1 September. It was not seen in June on 8 days, in July on 8 days and in August on 14 days. In September it was seen again on 6, 14, 21, 29 and 30. The maximum wind speed observed was 90 kts at 143 hPa level at 0000 UTC of 19 July and at 107 hPa at 1200 UTC of 10 August.

TEJ was seen over Mumbai on 11, 22, 25 and 30 June (4 days). It was seen in July on 1, 3, 8, 17, 18, 19, 20, 21, 22, 23, 25 and 29 (12 days). In August it was seen on 2, 3, 9, 10, 11, 12, 22, 24 and 28 (9 days). It was not seen in September. Maximum wind observed was 105 kts at 143 hPa at 1200 UTC of 22 June, at 115 hPa level at 1200 UTC of 23 July, at 107 hPa level at 1200 UTC of 10 August and at 100 hPa level at 0000 UTC of 11 August.

Maximum wind speed of 110 kts at 109 hPa was also observed over Nagpur at 1200 UTC of 11 August.

Similarly, Kolkata also reported maximum wind speed of 75 kts at 123 hPa at 0000 UTC of 10 July and Guwahati observed maximum wind speed of 85 kts at 101 hPa at 0000 UTC of 11 July and at 100 hPa at 0000 UTC of 14 July.

Maximum wind speed observed over Gorakhpur was 105 kts at 111 hPa on 0000 UTC of 30 July.

Above observations indicated that TEJ was split up and seen over Guwahati Latitude in the month of July. Details of TEJ in the past five years are as follows.

Year	*Tropical Easterly Jet (TEJ)*
1997	Appeared on 14 June. Less marked on 9 September Max. wind 115 kts at 114 hPa on 25 July.
1998	Appeared from 1st week of June till the end of September. Max. wind 150 kts over MNC at 103 hPa on 5 August.
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 HYD at 115 hPa on 21 July.

7. Sea surface temperature (SST)

Monthly mean SST values for June, July, August and September 2002 for Arabian Sea, Bay of Bengal as well as Andaman Seas are discussed below. The same is presented in pictorial form [Figs. 10 (a-d)] also.

The normal values for each sector for calculating the anomalies have been estimated from the normal isotherms. (Climatic Atlas of the Indian Ocean, Part I by Stephen Hastenrath and Peter J. Lamb.)

The main features of monthly SSTs are given below:

7.1. *June*

SSTs over all sectors of Arabian Sea (WC, EC, SW & SE) were cooler than normal, highest negative anomaly being –1.2°C in EC Arabian Sea. SSTs over south Bay (SW & SE) and NW Bay were more than normal and the highest positive anomaly was +1.6°C over SE Bay. The mean SST over south Andaman Sea was below normal by 3°C.

7.2. *July*

WC, EC, SW, SE and NE sectors of Arabian Sea were warmer than normal during the month with highest positive anomaly being +1.1° C in SW Arabian Sea. NW sector of Arabian Sea was cooler than normal. SSTs were warmer than normal over SE, WC and NW sections of Bay and also over south Andaman Sea. SST was cooler than normal over SW Bay.

7.3. *August*

SW, SE, WC, EC and NW sectors of Arabian Sea were warmer than normal, the highest positive anomaly being +1.6° C over NW Arabian Sea. NE Arabian Sea was cooler than normal. The SE, WC sectors of Bay and south Andaman Sea also had above normal temperature. SST over SW sector of Bay was cooler than normal.

7.4. *September*

During the month of September SSTs over EC and SE sectors of Arabian Sea were marginally warmer than normal. The WC Arabian Sea was cooler than normal. Over the Bay region SW, SE, NW and south Andaman Sea region were warmer than normal and WC Bay remained cooler than normal.

It is seen from the analysis that except the month of June, EC and SE sectors of Arabian Sea remained warmer than normal throughout the season. The WC and SW sectors of Arabian Sea were also warmer than normal during July and August. For the month of June, SSTs over EC, SE, WC and SW sectors of Arabian Sea remained cooler than normal. Again it was also seen that SE sector of Bay of Bengal was warmer than normal throughout the season.

8. Other features

8.1. *Weekly upper wind anomalies in monsoon 2002*

The circulation anomaly features during the monsoon season (June-September) 2002 are discussed below as noticed from the weekly wind vector anomalies at 850, 500 and 200 hPa levels. The main anomalous circulation features of monsoon 2002 are given in Table 8 and are discussed below. Also the zonal wind anomalies observed at four different stations over the Peninsula are given in Table 9.

8.1.1. *June wind anomaly features*

The circulation pattern for the week ending on 4 June was characterised by anomalous north-south trough roughly along 75° E passing through Kochi, Bangalore and Patiala embedded with anomalous cyclonic circulation over south Peninsula. This anomalous cyclonic circulation extended upto 500 hPa level. Next week, an E-W ridge was seen over northern Bay and adjoining Orissa and Chattisgarh region at lower and middle troposphere. An anomalous cyclonic circulation was seen at lower and middle levels over NE region of the country for the week ending 18 June and it extended upto middle tropospheric levels. At the same time the central

and northern part of the country was associated with an anomalous ridge extending upto 500 hPa level. For the week ending 25 June an anomalous cyclonic circulation with stronger westerlies prevailed over central and southern portion of the country at lower and middle tropospheric levels.

8.1.2. *July wind anomaly features*

For the week ending on 2 July an anomalous anticyclone was observed over central Bay which extended upto middle tropospheric levels. This anticyclone was associated with an E-W ridge over the southern part of the country. However, at lower levels the northern part of the country was associated with an anomalous cyclonic circulation. During week ending 9 July the E-W ridge moved further northwards and lay over central part of the country and extended upto 500 hPa level. For the week ending 16 July the anomalous E-W ridge persisted over central India and was prominent upto middle troposphere. During this week, the upper level easterlies and lower level westerlies were weaker than normal.

During the week ending 23 July, the anomalous E-W ridge persisted over central India. During this week also the lower level westerlies were weaker than normal. The upper level easterlies were slightly stronger than normal. During the last week of July, (ending on 30) the anomalous E-W ridge over the central India persisted and extended upto middle troposphere. During this week also the upper level easterlies and lower level westerlies were weaker than normal.

8.1.3. *August wind anomaly features*

In the first week of August ending on 6, the monsoon flow slightly improved from its very weak monsoon characteristic condition during July. The anomalous flow over peninsula was cyclonic associated with an anomalous cyclonic circulation over south peninsula thus indicating the revival of monsoon. During the week ending 13 August, the westerly flow remained stronger than normal upto middle tropospheric levels, associated with an anomalous cyclonic circulation over NW Bay and adjoining NE India, tilting southwards with height, thus, indicating strong monsoon condition. At extreme southern peninsula stronger easterlies were reported at upper levels. For the week ending 20 August the anomalous cyclonic circulation over NE India persisted and extended upto upper troposphere. An anomalous N-S ridge persisted roughly along 75^{o} E at lower levels during this week, thus, indicating subdued monsoon activity.

During last week of August (ending 27), an anomalous E-W trough was seen at lower and middle levels along around 22° N, thus, indicating revival of monsoon. The lower level westerlies and upper level easterlies were stronger than normal.

8.1.4. *September wind anomaly features*

For the week ending 3 September, there was an anomalous cyclonic circulation associated with an anomalous E-W trough over Orissa coast and neighbourhood at lower levels. Again, there existed an anomalous E-W ridge over peninsular India at lower and middle levels. The lower level westerlies were weaker than normal during the week. The anomalous cyclonic circulation over Orissa coast also persisted along with an anomalous E-W trough at lower and middle troposphere during the subsequent week ending on 10th September. Towards the southern parts of the country, the anomalous E-W ridge also persisted during the week. For the week ending 17 September, an anomalous E-W trough existed at lower levels over northern parts of the country. South of this trough the country was mainly covered by northwesterly wind. The upper level easterlies were also weaker during the week. During the week ending on 24 September an anomalous cyclonic circulation existed over central Bay, extending upto middle troposphere. An anomalous N-S ridge existed along around 75° E at middle tropospheric levels.

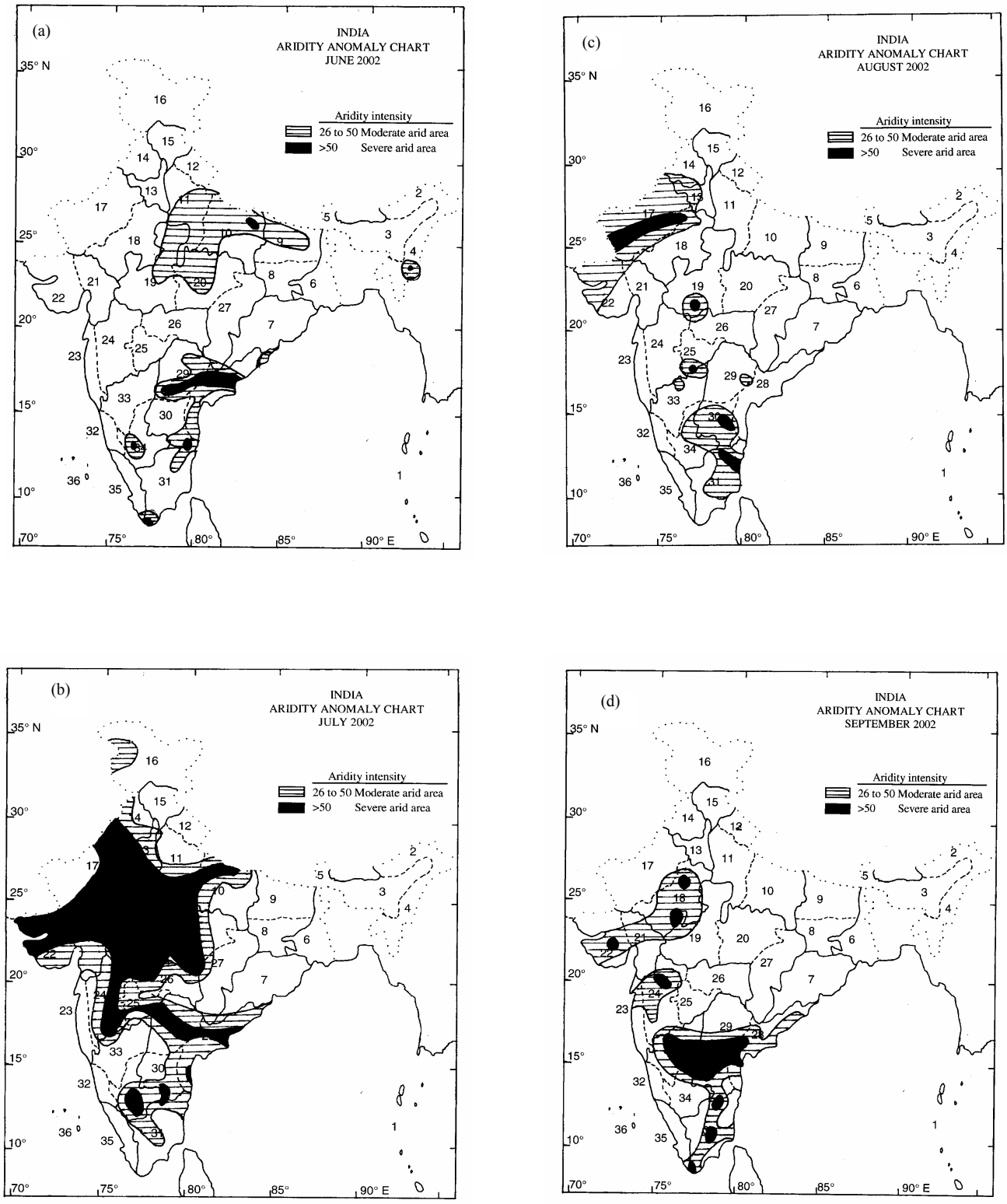
In the last week of the season (ending on 1 October), the anomalous flow was anticyclonic at lower levels over NW India. The low level westerlies were weaker than normal. At upper levels, an anomalous anticyclone appeared over NE India.

8.2. *Stratospheric features*

8.2.1. *Winds at 10 hPa*

The monthly stratospheric wind data at 30 hPa and 10 hPa of all the available RS stations during the monsoon season 2002 have been analysed. Rocket Sonde data from Thumba and Balasore were discontinued since September 1993 and March 1995 respectively. The data corresponding to 10 hPa were available only for the month of June and for only two stations, as given below :

Station	Date	Wind	
		Dir (deg.)	Speed (mps)
Lucknow	07 Jun 2002 1200 UTC	125	06
Karaikal	02 Jun 2002 0000 UTC	102	25
Karaikal	12 Jun 2002 1200 UTC	090	20



Figs. 11(a-d). Aridity anomaly chart for the month (a) June 2002, (b) July 2002 (c) August 2002 and (d) September 2002

8.2.2. *Winds at 30 hPa*

Figs. 9 (a-d) show the monthly anomaly flow patterns at 30 hPa for June to September of 2002. The base period of normals used for computing wind anomalies was 1967-96. From the figure, it was seen that during June, the zonal wind anomalies were mainly westerly over the region South of 23° N. During the subsequent months, the northern limit of the westerly zonal wind anomaly regime shifted southward. In July, August and September the northern limit of the westerly wind anomaly regime was around 15° N, 10° N and 15° N respectively.

Thus during the monsoon season 2002, the zonal wind anomalies at 30 hPa south of 10° N remained persistently westerly.

8.3. *Aridity conditions during monsoon 2002*

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

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

Where, PE is potential evapotranspiration which indicates 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 as per the following classification.

Aridity Anomaly	*Class*
Zero or less	Non arid
1 to 25	Mild arid
26 to 50	Moderate arid
More than 50	Severe arid

Aridity anomaly maps for June, July, August and September are given in Figs. 11(a-d).

Moderate to severe arid conditions were noticed in small northern, central and southeastern peninsular parts of the country in June. In July these areas increased and they were consisting of western and most of peninsular parts of the country. In August, the moderate and severe arid conditions decreased. They existed in small areas in western parts and southeastern peninsular parts. These areas decreased in western parts but increased a little in southeastern peninsular parts of the country during September.

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*

Small areas of southwestern, central and eastern parts of Telangana and central parts of coastal Andhra Pradesh. Isolated areas around Gorakhpur (east Uttar Pradesh); Shimoga (south interior Karnataka); Vellore and Kanyakumari (Tamil Nadu).

(b) *Moderate arid areas*

Small areas of eastern parts of west Uttar Pradesh; western and northeastern parts of east Uttar Pradesh; northwestern and central parts of east Madhya Pradesh; northeastern parts of west Madhya Pradesh; northwestern, central and southeastern parts of Bihar; northern, central and southern parts of coastal Andhra Pradesh; central parts of Telangana and adjoining eastern parts of north interior Karnataka; north-central, northeastern and southern parts of Tamil Nadu and western parts of south interior Karnataka. Isolated areas around Imphal (Nagaland-Manipur-Mizoram-Tripura) and Gopalpur (Orissa).

8.3.2. *July*

(a) *Severe arid areas*

Entire east Rajasthan; almost entire west Madhya Pradesh and large areas of Haryana, west Rajasthan,

Madhya Maharashtra, Saurashtra & Kutch and Telangana. Northern parts of east Uttar Pradesh; eastern, southern and southwestern parts of west Uttar Pradesh; southern and southwestern parts of Punjab; southeastern and western parts of east Madhya Pradesh; northeastern tip and northwestern parts of Vidarbha ; northern parts of Gujarat Region; central parts of coastal Andhra Pradesh; southern parts of Marathwada and adjoining northern parts of north interior Karnataka; central parts of south interior Karnataka; southern parts of Rayalaseema and adjoining northern parts of Tamil Nadu. Isolated area around Nellore (coastal Andhra Pradesh).

(b) *Moderate arid areas*

Large areas of coastal Andhra Pradesh and Rayalaseema. Small areas of western parts of west Rajasthan; a strip running across Punjab from northwest to east-central parts, northern and eastern parts of Haryana, central parts of west Uttar Pradesh and adjoining southern parts of Himachal Pradesh; a narrow strip running from across the northern parts of east Uttar Pradesh through central parts of west Uttar Pradesh and east Madhya Pradesh , western parts of Chattisgarh, western parts of Madhya Maharashtra and adjoining northeastern parts of Vidarbha, southern parts of east Madhya Pradesh and adjoining southeastern parts of west Madhya Pradesh, west central parts of Vidarbha and adjoining northwestern and central parts of Marathwada; central parts of Gujarat Region and adjoining southeastern parts of Saurashtra & Kutch; northeastern and southwestern parts of Telangana; northeastern parts of north interior Karnataka; eastern, southern and northwestern parts of south interior Karnataka; northeastern and western parts of Tamil Nadu. Isolated areas around Srinagar (Jammu & Kashmir)

8.3.3. *August*

(a) *Severe arid areas*

Small areas in the central parts of west Rajasthan and adjoining western parts of east Rajasthan; central parts of Rayalaseema and north-central parts of Tamil Nadu. Isolated areas around Khandwa (west Madhya Pradesh) and Osmanabad (Marathwada).

(b) *Moderate arid areas*

Large areas of west Rajasthan; south interior Karnataka and Rayalaseema. Small southern parts of Punjab and adjoining western parts of Haryana; northern, central and western parts of east Rajasthan; northwestern parts of Saurashtra & Kutch and adjoining northwestern parts of Gujarat Region; southern parts of west Madhya Pradesh; southern parts of Marathwada and adjoining northern parts of north interior Karnataka and northern, northwestern, central and eastern parts of Tamil Nadu. Isolated areas around Khammam (Telangana) and Bijapur (north interior Karnataka).

8.3.4. *September*

(a) *Severe arid areas*

Small areas of southern parts of Telangana; eastern, southeastern and western parts of north interior Karnataka and adjoining southern parts of Madhya Maharashtra; northern parts of south interior Karnataka; northern and northwestern parts of Rayalaseema; central parts of coastal Andhra Pradesh; northern parts of Tamil Nadu; northwestern parts of Marathwada and adjoining north-central parts of Madhya Maharashtra. Isolated areas around Jaipur (east Rajasthan), Nimach (west Madhya Pradesh), Rajkot (Saurashtra & Kutch), Madurai (Tamil Nadu) and Thiruvananthapuram (Kerala).

(b) *Moderate arid areas*

Large parts of east Rajasthan and Tamil Nadu. Small areas of central parts of Saurashtra & Kutch and Gujarat Region; western parts of west Madhya Pradesh; eastern parts of west Rajasthan; central, western and northeastern parts of Madhya Maharashtra and adjoining northwestern parts of Marathwada and northern parts of Konkan & Goa; southern parts of Kerala; a strip running through eastern, central and western parts of coastal Andhra Pradesh, central Telangana, northern parts of north interior Karnataka, southern parts of Madhya Maharashtra and again western, central and southern parts of north interior Karnataka, north-central parts of south interior Karnataka, central and southern parts of Rayalaseema ending in the southern parts of coastal Andhra Pradesh and southern parts of Lakshadweep.

9. Significant spells of heavy rains

During monsoon, the spatial distribution of *heavy* and *very heavy* rainfall is given in Table 10. The table also indicates the *activity* of monsoon and sub-division wise extent of rainfall in number of days when it was

widespread or *fairly widespread*. Month wise description is given below :

9.1. *Heavy rainfall during June*

During the month, *very heavy* rainfall occurred on 4 to 7 days in Sub-Himalayan West Bengal & Sikkim, Konkan & Goa, Madhya Maharashtra, coastal & south interior Karnataka and Kerala and on 1 to 3 days in Arunachal Pradesh, Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Bihar, Gujarat Region, Marathwada, Vidarbha and Telangana. *Heavy* rainfall also occurred on 8 to 12 days in Assam & Meghalaya, Gangetic West Bengal, Konkan & Goa, Madhya Maharashtra, Tamil Nadu, coastal Karnataka, north interior Karnataka and Kerala.

9.2. *Heavy rainfall during July,*

During the month, *very heavy* rainfall occurred on 9 days in Sub-Himalayan West Bengal & Sikkim; on 4 to 5 days in Arunachal Pradesh, Assam & Meghalaya, Bihar and coastal Karnataka and on 1 to 3 days in Gangetic West Bengal, Orissa, Jharkhand, east Uttar Pradesh, Himachal Pradesh, Konkan & Goa, Madhya Maharashtra, Vidarbha, south interior Karnataka and Kerala. *Heavy* rain also occurred on 7 to 9 days in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim and Konkan & Goa; on 4 to 6 days in Orissa, Bihar, east Uttar Pradesh, Himachal Pradesh, Madhya Maharashtra, south interior Karnataka and Lakshadweep and on 1 to 3 days in Andaman & Nicobar Islands, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Jharkhand, west Uttar Pradesh, Uttaranchal, Haryana, Punjab, Jammu & Kashmir, west Madhya Pradesh, east Madhya Pradesh, Gujarat Region, Chattisgarh, Telangana, Tamil Nadu and coastal Karnataka.

9.3. *Heavy rainfall during August*

During the month, *very heavy* rainfall occurred on 8 days in Himachal Pradesh; on 4 to 5 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, east Madhya Pradesh, Konkan & Goa and Chattisgarh and on 1 to 3 days in Andaman & Nicobar Islands, Arunachal Pradesh, Gangetic West Bengal, Orissa, Jharkhand, Bihar, east Uttar Pradesh, west Uttar Pradesh, Uttaranchal, Haryana, Punjab, east Rajasthan, west Madhya Pradesh, Gujarat Region, Saurashtra & Kutch, Madhya Maharashtra, Marathwada, Vidarbha, coastal Andhra Pradesh, Telangana, coastal & south interior Karnataka and Kerala. *Heavy* rain has also occurred on 10 to 14 days in Assam & Meghalaya, Orissa, east Uttar Pradesh and west Madhya Pradesh; on 7 to 9 days in Jammu & Kashmir, east Madhya Pradesh, Konkan & Goa and Madhya Maharashtra; on 4 to 6 days in Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, west Uttar Pradesh, Uttaranchal, Haryana, east Rajasthan, Gujarat Region, Vidarbha, Chattisgarh, Telangana, Tamil Nadu, coastal Karnataka, north interior Karnataka and south interior Karnataka and on 1 to 3 days in Andaman & Nicobar Islands, Sub-Himalayan West Bengal & Sikkim, Bihar, Punjab, Saurashtra & Kutch, Marathwada, coastal Andhra Pradesh, Rayalaseema and Lakshadweep.

9.4. *Heavy rainfall during September*

During the month, *very heavy* rainfall occurred on 6 days each in Sub-Himalayan West Bengal & Sikkim and west Uttar Pradesh and on 1 to 3 days in Arunachal Pradesh, Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Orissa, Jharkhand, Bihar, east Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, east Rajasthan, west Madhya Pradesh, east Madhya Pradesh, Gujarat Region, Konkan & Goa, Madhya Maharashtra and Chattisgarh. *Heavy* rain also occurred on 12 days in Orissa; on 6 to 8 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Jharkhand, east Uttar Pradesh, Konkan & Goa, Madhya Maharashtra and Tamil Nadu; on 4 to 5 days in Andaman & Nicobar Islands, Gangetic West Bengal, Bihar, Uttaranchal, west Madhya Pradesh, east Madhya Pradesh, south interior Karnataka and Kerala and on 3 days in Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, west Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, east Rajasthan, Saurashtra & Kutch, coastal Andhra Pradesh, Telangana, Rayalaseema and coastal & north interior Karnataka.

10. Significant temperature during the season

Significant temperatures were noticed only in the month of June. It was *appreciably to markedly above normal* or *above normal* in Haryana, Punjab, west Rajasthan and east Rajasthan during July and first half of August. Remaining months of the season, the temperature were within reasonable limits.

Heat wave conditions prevailed on 2 to 5 days in some parts of Rajasthan as well as Madhya Pradesh. Day temperatures were *appreciably* to *markedly above normal* on 7 to 8 days in some parts of west Rajasthan, east Rajasthan, Saurashtra & Kutch and Vidarbha; on 3 to 5 days in some parts of west Uttar Pradesh, Uttaranchal, Himachal Pradesh, Jammu & Kashmir, west Madhya Pradesh and Gujarat Region and on 1 to 2 days in some parts of Assam & Meghalaya, Gangetic West Bengal, Orissa, Jharkhand, east Madhya Pradesh, Konkan & Goa, Madhya Maharashtra and Chattisgarh. They were *above normal* on 8 to 10 days in some parts of east Uttar Pradesh, Haryana, Himachal Pradesh, west Rajasthan, east Rajasthan, Gujarat Region and Saurashtra & Kutch; on 5 to 7 days in some parts of Orissa, Jammu & Kashmir, west Madhya Pradesh, east Madhya Pradesh, Konkan & Goa, Madhya Maharashtra and coastal Andhra Pradesh; on 3 to 4 days in some parts of Assam & Meghalaya, Marathwada, Vidarbha, Chattisgarh and Telangana and on 1 to 2 days in some parts of Nagaland-Manipur-Mizoram-Tripura, Sub-Himalayan West Bengal & Sikkim, Gangetic West Bengal, Jharkhand, west Uttar Pradesh, Rayalaseema and north interior Karnataka. They were *appreciably* to *markedly below normal* on 10 to 14 days in some parts of Haryana and Punjab; on 4 to 6 days in some parts of east Uttar Pradesh, west Uttar Pradesh, Uttaranchal and Jammu & Kashmir and on 1 to 3 days in some parts of Nagaland-Manipur-Mizoram-Tripura, Sub-Himalayan West Bengal & Sikkim, Jharkhand, Bihar, Himachal Pradesh, west Rajasthan, west Madhya Pradesh, Madhya Maharashtra, Vidarbha, coastal Andhra Pradesh, Telangana, Rayalaseema and north interior Karnataka. They were *below normal* on 4 to 7 days in some parts of east Uttar Pradesh, west Uttar Pradesh and Punjab and on 1 to 3 days in some parts of Sub-Himalayan West Bengal & Sikkim, Orissa, Bihar, Uttaranchal, Haryana, Himachal Pradesh, Jammu & Kashmir, west Rajasthan, east Rajasthan, west Madhya Pradesh, east Madhya Pradesh, Gujarat Region, Saurashtra & Kutch, Madhya Maharashtra, Marathwada, Chattisgarh, coastal Andhra Pradesh and Telangana. Highest day temperature of 47.2^{o} C was recorded at Churu (Rajasthan) on 14 June.

11. Disastrous weather events and damage during monsoon months

11.1. *June*

Heavy rains, lightning and floods etc. took a toll of 402 (281 in Maharashtra, 73 in Gujarat, 21 in Orissa, 11 in West Bengal and 6 each in Assam & Meghalaya and Madhya Pradesh and 2 each in Karnataka and Kerala) human lives. Also 12 fishermen were reported missing in West Bengal. Crops in 3,000 acre land worth Rs. 1,20,00,000 got damage due to floods in West Bengal. In all 902 cattle heads (822 in Gujarat, 53 in Maharashtra and 27 in Madhya Pradesh) were lost due to floods. Loss of property worth Rs. 235 Lakhs due to heavy rain in Gujarat. Road communication was disrupted due to floods in some parts of the country during the month.

Earthquake of moderate intensity experienced in West Bengal during the month. No significant damage was reported.

11.2. *July*

In all, 271 (97 in Maharashtra, 69 in Bihar, 39 in Assam & Meghalaya, 33 in Gujarat, 15 in West Bengal, 8 in Orissa, 6 in Uttaranchal and 4 in Madhya Pradesh) people lost their lives due to *heavy* rains and floods. 21,199 houses were damaged in Assam & Meghalaya due to flood and standing crop of several lakhs perished due to floods.

11.3. *August*

In all, 540 (315 in Bihar, 86 in Assam, 54 in Maharashtra, 28 in Uttaranchal, 19 in Gujarat, 8 each in Arunachal Pradesh and Madhya Pradesh, 4 each in West Bengal, Sikkim and Andhra Pradesh, 3 each in Nagaland-Manipur-Mizoram-Tripura and Himachal Pradesh, 2 each in Tamil Nadu and Kerala) people lost their lives due to flood, heavy rain, lightning etc. Bihar experienced severe floods in the month. Water level of river Brahmaputra crossed danger mark in Assam. Normal life disrupted due to heavy rain in Maharashtra . In Assam, the road and rail communication remained cut-off due to floods; 400 villages damaged due to rising flood water of Brahmaputra river and damaged the standing crops worth 100 lakhs of rupees in large area.

11.4. *September*

Heavy rains, squall and thundershower took a toll of 86 (56 in Maharashtra, 27 in Gujarat and 3 in Assam) people. About Thirty-five thousand houses damaged, trees and electric pole uprooted in Assam due squall and

thundershower in Assam. NH-37 was disrupted. In Maharashtra, 38 houses and crop worth Rs. 100 lakhs were damaged due to heavy rain.

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 1067 people in different parts of the country. Bihar was the most affected met. sub-division where 315 people lost their lives due to floods. Other mainly affected areas are Maharashtra (233), Gujarat (152) and Assam & Meghalaya (134). Apart from the flood in river Brahmaputra, lightning also had been a major cause of death toll during this season. Water level of river Brahmaputra crossed danger mark in Assam during first half of August.

More details of damage due to floods and *heavy* rains in June, July, August and September have been discussed above in para 11.1., 11.2., 11.3. and 11.4. respectively.

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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 (Most places)	-	75 % or more stations of a meteorological sub-division reporting at least 2.5 mm rainfall.
Fairly widespread (Many places)	-	51% to 74 % stations of a meteorological sub-division; reporting at least 2.5 mm rainfall.
Heavy rain	-	rainfall amount from 6.5 cm to 12.4 cm.
Very heavy rainfall	-	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.
Vigorous	-	Average rainfall of a sub-division is more than 4 times or more than the normal with minimum 7 cm along the west coast and 5 cm elsewhere in atleast two stations in the sub-division.

Maximum/day temperatures

Heat wave conditions	-	departure of maximum temperature from normal is between + 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 atleast 40° C for plains and atleast 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.

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

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