MAUSAM, **53**, 3 (July 2002), 381-416

Weather in India

MONSOON SEASON (June to September 2001)*

1. Introduction

The rainfall activity during the southwest monsoon season 2001 was well distributed in space and time. The rainfall was *excess*† in 1, *normal* in 28 and *deficient* in the remaining 6 meteorological sub-divisions. No meteorological sub-division received *scanty* rainfall during the season. The rainfall distribution is shown in Fig. 3. The onset of monsoon over Kerala was about one week earlier than normal. The further advance of the monsoon over every part of the country was also ahead of the normal. The withdrawal from the country was later than normal and, as such, the total duration of the southwest monsoon rains was more than normal. The cyclogenesis in the Indian seas during the season was subdued with formation of only one cyclonic storm and one depression in the Arabian Sea and the Bay of Bengal, respectively.

2. Characteristic features of southwest monsoon 2001

2.1. Total seasonal monsoon rainfall over the country as a whole was 91% of its long period average. Thus making 2001 as the 13th successive normal ($\pm$ 10%) monsoon year as predicted by IMD's long range forecast.

2.2. The southwest monsoon set in over Kerala on 23 May, about a week earlier than its normal date of 1 June.

2.3. The onset of monsoon over Kerala was in association with a very severe cyclonic storm over Arabian Sea, 21-29 May 2001.

2.4. The southwest monsoon covered the entire country by 3 July, 12 days earlier than the normal date of 15 July, There was hiatus in the northern limit of monsoon from 24 June to 2 July Hiatus also occurred in eastern flanks of advancing monsoon from 4 to 14 June; and in the western flanks from 24 May to 4 June and from 17 to 24 June (Fig. 2).

2.5. The southwest monsoon withdrew from western parts of Rajasthan on 10 September, 9 days late as against normal date of 1 September. By 27 September it withdrew from most parts of northwest India, north Gujarat, Uttar Pradesh and parts of Madhya Pradesh. Then it withdrew after a long spell of 16 days *i.e.*, on 13 October, from northeast India, parts of Bihar & Jharkhand, east Madhya Pradesh, Chattisgarh, Orissa, Vidarbha & Marathwada and Madhya Maharashtra. It withdrew from the entire country on 16 October with a delay of one day only with simultaneous commencement of northeast monsoon rains over Tamil Nadu, Kerala, Karnataka & coastal Andhra Pradesh (Fig. 8).

2.6. One cyclonic storm formed during the month of September and only one depression formed in June in this season. July, August & September were devoid of depressions.

2.7. Rainfall during the monsoon 2001 was *excess* (E) in 1 and *normal* (N) in 28 meteorological sub-divisions.

Rainfall activity was good in June (29-E/N). It was subdued in July (17-E/N), August (17-E/N) and September (14-E/N).

2.8. In Orissa, not only the seasonal rainfall but also cumulative rainfall of all the weeks during the season was *excess* which caused flooding over the region. Cumulative rainfall was *excess* or *normal* throughout the monsoon season in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Orissa, Jharkhand, east Uttar Pradesh, west Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, east Madhya Pradesh & Chattisgarh, Saurashtra & Kutch, Vidarbha, Telangana and coastal Karnataka.

2.9. As seen in the week by week progress of rainfall, the eastern parts of the country received very good amount of rainfall throughout the season, the activity was in the first half of the season in northern and western parts and over peninsula, it was good at the end of the season.

2.10. Monsoon trough got established on 3 July and Tibetan anticyclone on 12 June. The off-shore trough persisted on most of the days from 30 May to 13 September along different parts of west coast.

2.11. Cross equatorial flow was in general normal in June, July and August and stronger than normal in September over the Arabian Sea and the Bay of Bengal.

† Note : Definition in words in '*Italics*' are given in Appendix.

* *Compiled by* : V. Thapliyal, A. B. Mazumdar and V. Krishnan, Meteorological Office, Pune-411005, India

Progress of the monsoon week by week
1 June – 30 September 2001

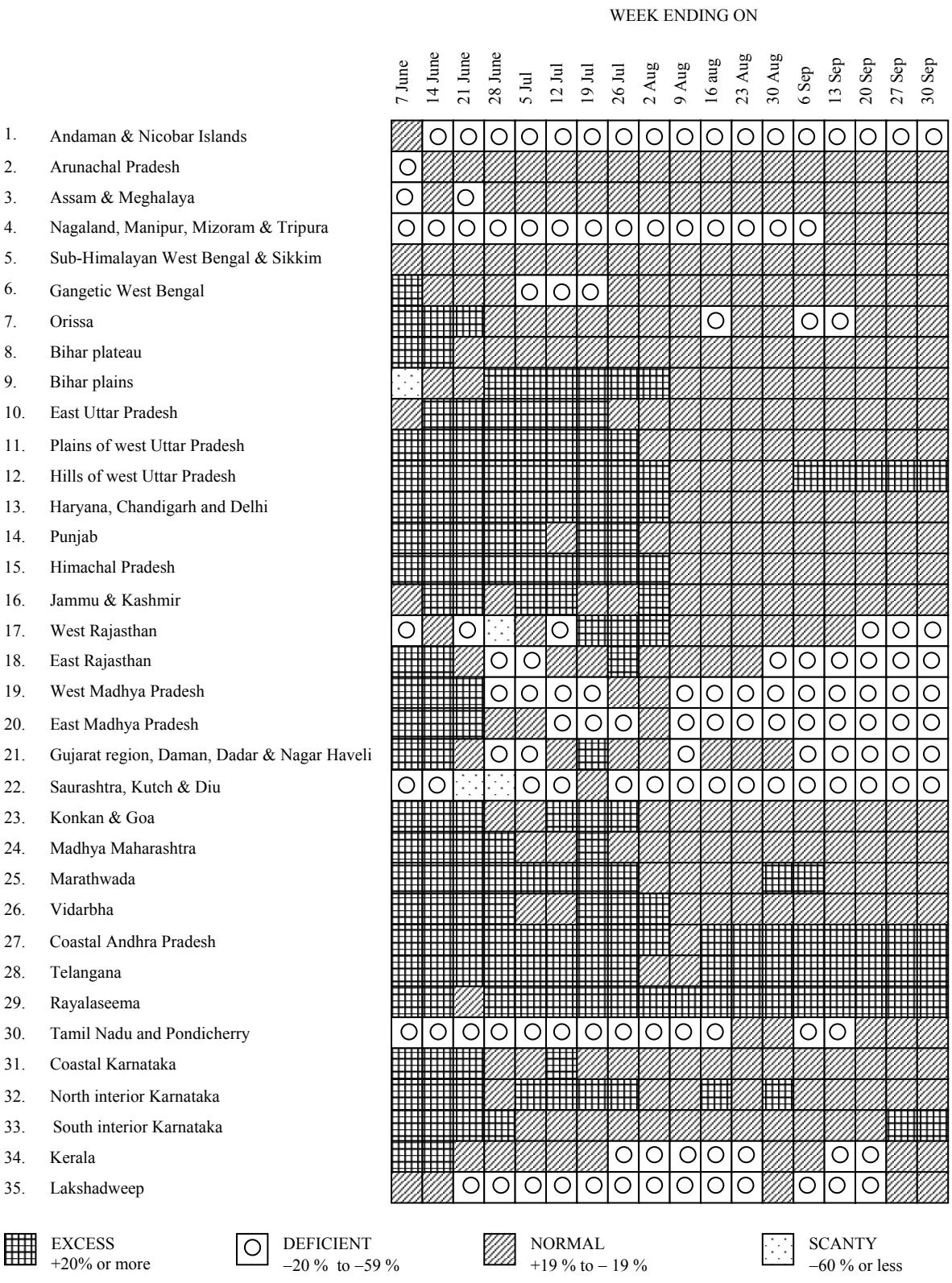


Fig. 1(a)

Progress of the monsoon week by week (cumulative)
1 June – 30 September 2001

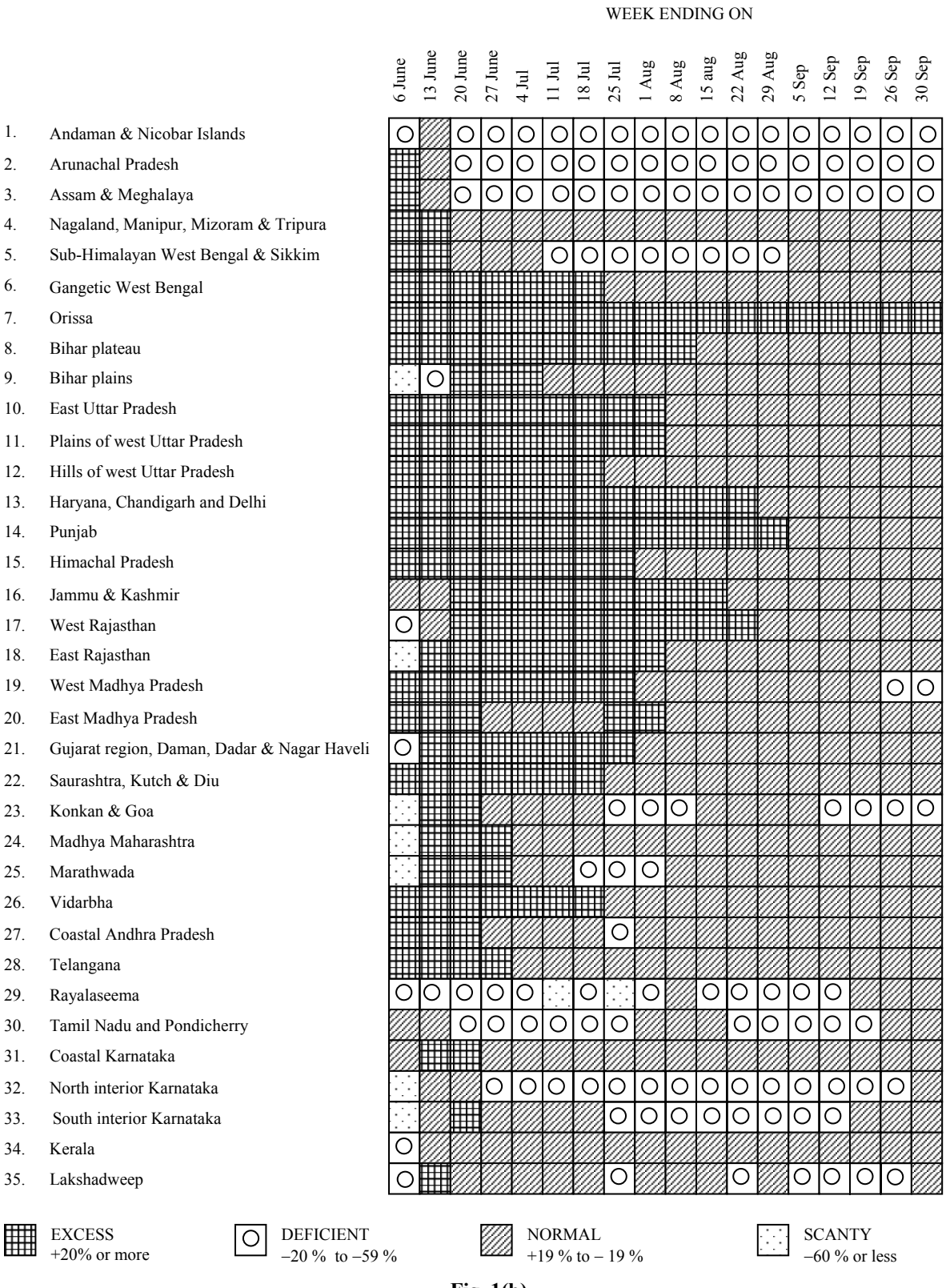


Fig. 1(b)

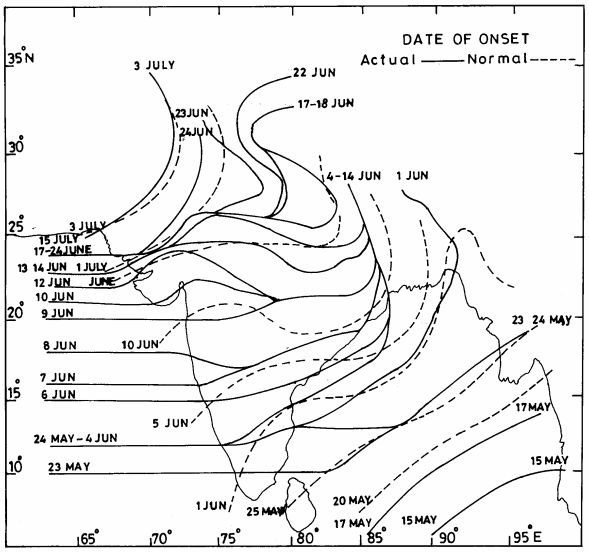


Fig. 2. Advance of southwest monsoon 2001

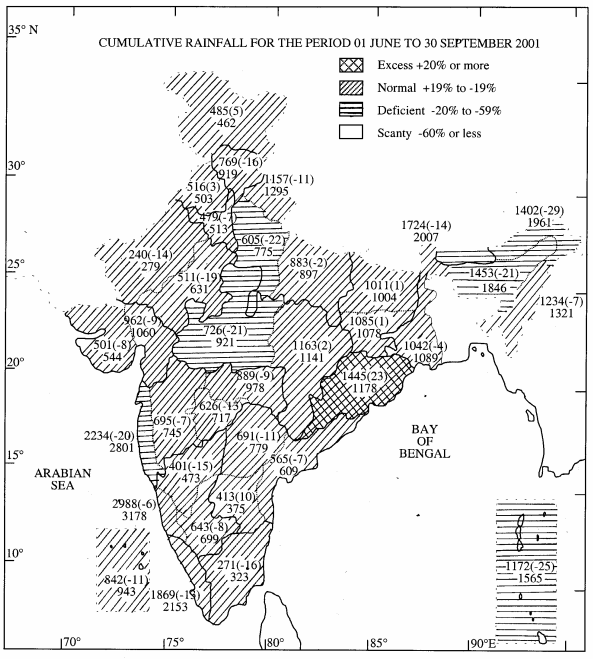


Fig. 3. Sub-division seasonal rainfall departure (%) for the period of June-September 2001 (Based on updated data)

2.12. Northeast monsoon rains commenced over Tamil Nadu, Kerala, Karnataka & coastal Andhra Pradesh on 16 October, 4 days earlier than normal date *i.e.*, 20 October. Northeast monsoon rains ceased in Tamil Nadu, Kerala, Karnataka & coastal Andhra Pradesh on 11 January, 11 days later than normal *i.e.*, end of December.

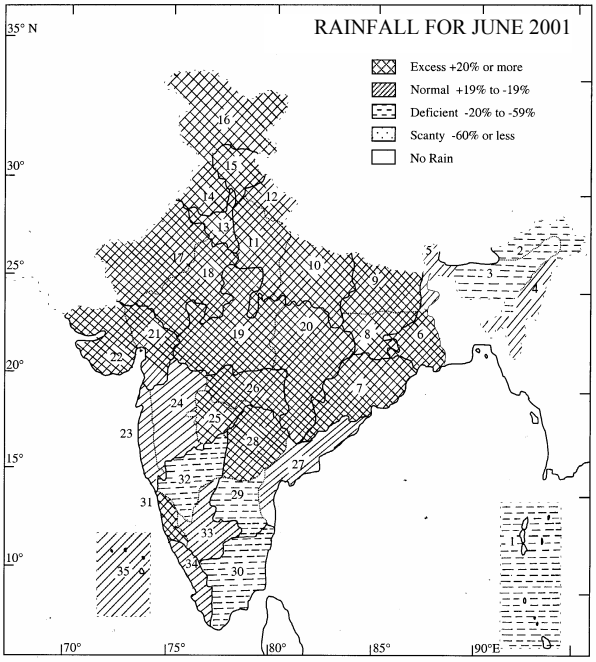


Fig. 4. Sub-divisionwise seasonal rainfall departure from normal (%) for June 2001. Sub-divisions are indicated by number on the map. The rainfall anomaly values for these 35 sub-divisions are indicated below :

1	–41	8	60	15	81	22	85	29	–56
2	–31	9	41	16	94	23	–18	30	–42
3	–21	10	135	17	92	24	17	31	21
4	16	11	115	18	104	25	20	32	–36
5	–9	12	72	19	66	26	90	33	–6
6	50	13	205	20	60	27	2	34	2
7	64	14	198	21	66	28	36	35	–7

3. Features of monsoon

3.1. *Advance of southwest monsoon*

Onset of southwest monsoon occurred over Kerala on 23 May, about a week earlier than its normal date of 1 June, like in 1999 (25 May), 1988 (26 May), 1974 (26 May), 1970 (24 May), 1964 & 1965 (26 May), 1961 (21 May). The onset of monsoon over Kerala was in association with an onset vortex in the form of a very severe cyclonic storm over Arabian Sea, 21-29 May 2001. In the years 1960 and 1961 also the early onset over Kerala was associated with cyclonic storms over Arabian Sea.

Isochrones of advance of southwest monsoon 2001 are shown in Fig. 2.

The entire country was covered by the monsoon by 3 July. This has been 12 days earlier than the normal date of 15 July, even though there has been hiatus in the northern limit of monsoon from 24 June to 2 July. In

TABLE 1

Rainfall figures (mm) for each month and season as a whole (June – September 2001)

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	279	471	-41	271	357	-24	328	360	-9	294	376	-22	1172	1565	-25
2.	Arunachal Pradesh	370	539	-31	419	651	-36	324	469	-31	289	302	-4	1401	1961	-29
3.	Assam & Meghalaya	435	552	-21	448	540	-17	297	425	-30	273	330	-17	1453	1846	-21
4.	Naga., Mani., Mizo. and Tripura	459	397	16	280	351	-20	243	323	-25	251	250	0	1234	1321	-7
5.	Sub-Himalayan West Bengal & Sikkim	467	516	-9	367	603	-39	438	496	-12	352	452	15	1724	2007	-14
6.	Gangetic West Bengal	369	246	50	259	310	-17	221	306	-28	194	227	-15	1042	1089	-4
7.	Orissa	364	222	64	625	356	75	330	355	-7	125	244	-49	1445	1178	23
8.	Jharkhand	312	195	60	355	334	6	253	323	-22	165	225	-27	1085	1078	1
9.	Bihar	238	168	41	235	312	-25	225	303	-26	313	220	42	1011	1004	1
10.	East Uttar Pradesh	247	105	135	293	302	-3	198	299	-34	145	191	-24	883	897	-2
11.	West Uttar Pradesh	173	80	115	280	364	6	126	269	-53	26	162	-84	605	775	-22
12.	Uttaranchal	291	169	72	436	449	-3	351	448	-22	80	229	-65	1157	1295	-11
13.	Haryana, Chandigarh & Delhi	155	51	205	186	175	6	126	179	-30	13	108	-88	479	513	-7
14.	Punjab	124	42	198	261	190	37	106	169	-37	25	101	-76	516	503	3
15.	Himachal Pradesh	174	96	81	295	346	-15	263	320	-18	37	157	-76	769	919	-16
16.	Jammu & Kashmir	110	57	94	210	168	25	118	158	-25	47	79	-41	485	462	5
17.	West Rajasthan	53	27	92	115	101	14	69	104	-34	3	46	-93	240	279	-14
18.	East Rajasthan	115	56	104	257	224	14	131	233	-44	8	117	-93	511	631	-19
19.	West Madhya Pradesh	104	117	66	310	315	-1	193	314	-39	29	175	-83	726	921	-21
20.	East Madhya Pradesh & Chattisgarh	275	172	60	485	367	32	311	382	-19	70	212	-67	1163	1141	2
21.	Gujarat region	242	145	66	383	433	-11	306	301	2	32	181	-83	962	1060	-9
22.	Saurashtra & Kutch	168	91	85	189	240	-21	125	129	-3	19	85	-78	501	544	-8
23.	Konkan & Goa	563	685	-18	850	1106	-23	616	663	-7	204	347	-41	2234	2801	-20
24.	Madhya Maharashtra	164	140	17	199	271	-27	174	179	-3	159	155	2	695	745	-7
25.	Marathwada	176	146	20	65	206	-68	293	187	57	92	179	-48	626	717	-13
26.	Vidarbha	325	171	90	180	337	-47	335	272	23	49	197	-75	889	978	-9
27.	Coastal Andhra Pradesh	113	111	2	118	168	-30	160	160	0	173	170	2	565	609	-7
28.	Telangana	184	135	36	122	243	-50	241	212	13	144	189	-24	691	779	-11
29.	Rayalaseema	26	60	-56	57	85	-33	89	98	-9	241	132	83	413	375	10
30.	Tamil Nadu	30	52	-42	81	72	13	48	97	-50	111	102	9	271	323	-16
31.	Coastal Karnataka	1116	923	21	988	1214	-19	687	715	-4	196	326	-40	2988	3178	-6
32.	North interior Karnataka	57	90	-36	54	132	-59	105	109	-3	183	142	30	401	473	-15
33.	South interior Karnataka	130	139	-6	171	256	-33	148	172	-14	195	132	48	643	699	-8
34.	Kerala	709	697	2	587	765	-23	348	439	-21	225	252	-11	1869	2153	-13
35.	Lakshadweep	285	307	-7	200	283	-30	144	192	-25	213	161	33	842	943	-11

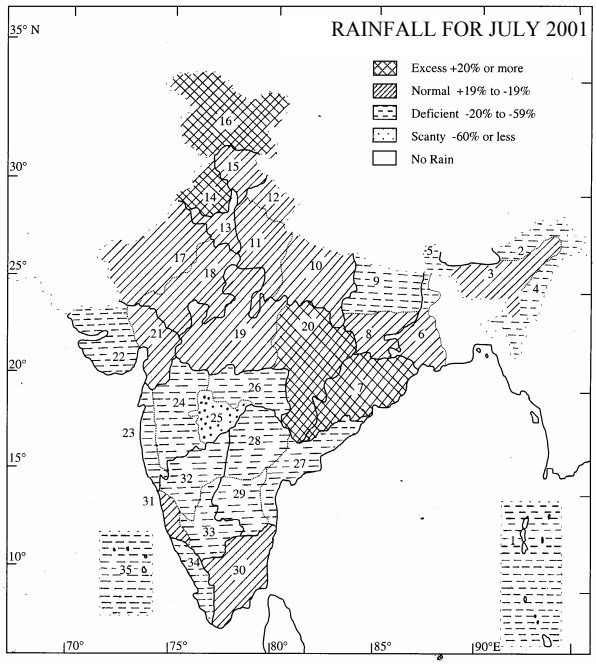


Fig. 5. Sub-divisionwise seasonal rainfall departure from normal (%) for June 2001. Sub-divisions are indicated by number on the map. The rainfall anomaly values for these 35 sub-divisions are indicated below :

1	–24	8	6	15	–15	22	–21	29	–33
2	–36	9	–25	16	25	23	–23	30	13
3	–17	10	–3	17	14	24	–27	31	–19
4	–20	11	6	18	14	25	–68	32	–59
5	–39	12	–3	19	–1	26	–47	33	–37
6	–17	13	6	20	32	27	–30	34	–23
7	75	14	37	21	–11	28	–50	35	–30

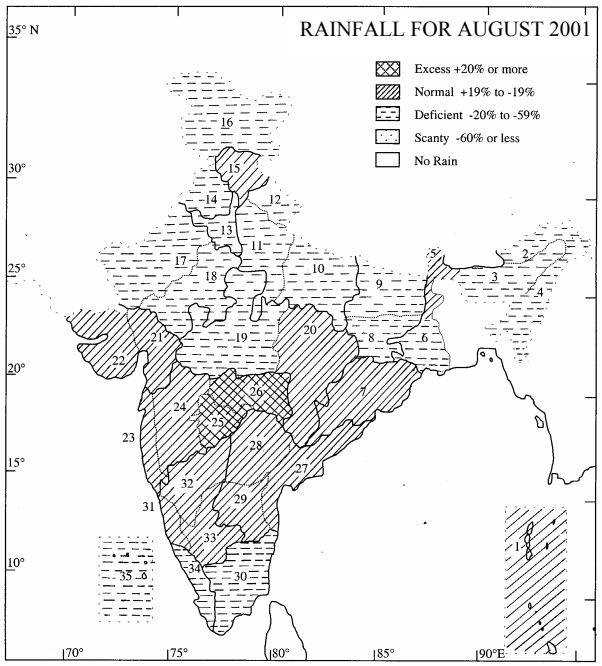


Fig. 6. Sub-divisionwise seasonal rainfall departure from normal (%) for June 2001. Sub-divisions are indicated by number on the map. The rainfall anomaly values for these 35 sub-divisions are indicated below :

1	–9	8	22	15	–18	22	–3	29	–9
2	–3	9	–26	16	–25	23	–7	30	–50
3	–30	10	–34	17	–34	24	–3	31	–4
4	–25	11	–53	18	–44	25	–57	32	–3
5	–12	12	–22	19	–39	26	23	33	–14
6	–28	13	–30	20	–19	27	0	34	–21
7	–7	14	–37	21	2	28	13	35	–25

addition, there have been stagnation from 4 to 14 June in the eastern flanks of advancing monsoon; and from 24 May to 4 June and from 17 to 24 June in the western flanks. In the years 1970 and 1978 also monsoon covered the entire country by 3 July.

3.2. *Weekly rainfall distribution*

3.2.1. *Week by week distribution*

Meteorological sub-divisionwise weekly rainfall departures (percentage departure from normal rainfall) during the southwest monsoon season from 1 June 2001 to 30 September 2001 comprising of 18 weeks are given in Fig. 1(a). Rainfall activity over northeast India was generally subdued except in the first week of June, end of July and in August. In the eastern part (Gangetic West Bengal and Orissa) rainfall activity has been very good throughout the season with number of weeks recording *excess*/*normal* rainfall. In the northern part, rainfall activity has been exceptionally good till mid July after that it was generally subdued. In the western parts, rainfall activity was *excess* in the month of June and after that only a few weeks had above normal rainfall. In the central part of the country also the rainfall activity was good in the month of June followed by only a few weeks of above normal rainfall. Over peninsula, the rainfall activity was above normal mainly in the end of the season preceded by, only a few spells of above normal weekly rainfall activity.

3.2.2. *Weekly cumulative rainfall distribution*

Meteorological sub-divisionwise cumulative rainfall departures (percentage departure from normal) during the southwest monsoon season from 1 June 2001 to 30 September 2001 comprising of 18 weeks are given in Fig. 1(b).

Rainfall was very well distributed week by week throughout the period from 1 June 2001 to 30 September 2001.

From the week ending 13 June onwards, more than 74% of the sub-divisions received *excess* or *normal*

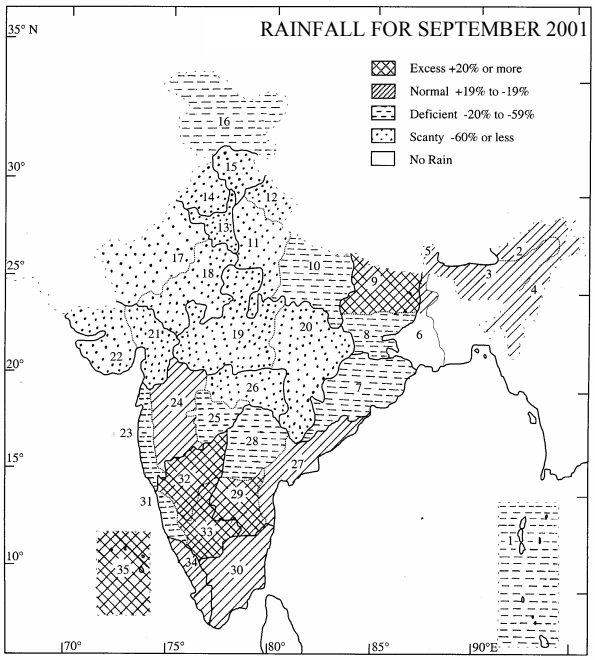


Fig. 7. Sub-divisionwise seasonal rainfall departure from normal (%) for September 2001. Sub-divisions are indicated by number on the map. The rainfall anomaly values for these 35 sub-divisions are indicated below :

1	–22	8	–22	15	–76	22	–78	29	83
2	–4	9	42	16	–41	23	–41	30	9
3	–17	10	–24	17	–93	24	2	31	–40
4	0	11	–84	18	–93	25	–48	32	30
5	5	12	–65	19	–83	26	–75	33	48
6	–15	13	–88	20	–67	27	2	34	–11
7	–49	14	–76	21	–83	28	–24	35	33

rainfall except for the week ending 25 July where it was 66%, for the week ending 6 June, 63% of the sub-divisions received *excess* or *normal* rainfall.

Cumulative rainfall was *excess* or *normal* throughout the monsoon season in sub-divisions Nagaland-Manipur-Mizoram & Tripura, Gangetic West Bengal, Orissa, Jharkhand, east Uttar Pradesh, west Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, east Madhya Pradesh & Chattisgarh, Saurashtra & Kutch, Vidarbha, Telangana and coastal Karnataka. Rainfall was also *excess* or *normal* throughout the period in the sub-divisions Bihar (except for the week ending on 6 and 13 June), west Rajasthan, east Rajasthan, Gujarat region, Madhya Maharashtra & Kerala (except for the week ending on 6 June), west Madhya Pradesh (except for the week ending on 26 & period ending on 30 September), Marathwada (except for the week ending on 6 June, 18 & 25 July and 1 August) and coastal Andhra Pradesh (except for the week ending on 25 July).

Rainfall was *deficient* or *scanty* throughout the season in the sub-divisions Andaman and Nicobar Islands

TABLE 2

Districtwise distribution of monsoon rainfall for the years 1996 to 2001

Years	Excess/Normal (%)	Deficient/Scanty (%)
1996	82	18
1997	81	19
1998	83	17
1999	67	33
2000	66	34
2001	68	32

(except for the week ending on 13 June), Arunachal Pradesh and Assam & Meghalaya (except for the week ending on 6 and 13 June), Rayalaseema (except for the week ending on 8 August and 19, 26 and period ending on 30 September), north interior Karnataka (except for the weeks ending on 13 & 20 June and period ending on 30 September). Rainfall was *deficient* or *scanty* in the sub-divisions Sub-Himalayan West Bengal & Sikkim for the week ending on 11, 18 and 25 July, 1, 8, 15, 22 & 29 August; Konkan & Goa for the week ending 6 June, 25 July, 1 & 8 August and 12 September onwards; Tamil Nadu for the week ending from 20 June to 25 July and 22 August to 19 September; south interior Karnataka for the week ending 6 June, 25 July to 12 September and Lakshadweep for the week ending 6 June, 25 July, 22 August and 5 to 26 September.

3.3. *Monthly rainfall distribution*

Figs. 4-7 show monthwise distribution of monsoon rainfall.

Rainfall Figures and departures for each month and season as a whole, sub-divisionwise, are given in Table 1 and principal amounts of daily rainfall are given in Table 11.

3.4. *Seasonal rainfall distribution*

Meteorological sub-divisionwise seasonal rainfall distribution in terms of percentage departures from normal is given in Table 1 and in Fig. 3. The seasonal rainfall was *excess* in 1, *normal* in 28 and *deficient* in the remaining 6 meteorological sub-divisions. Seasonal total rainfall for the country as a whole was normal and country received 91% of its long period average value.

3.5. *Districtswise distribution of monsoon rainfall*

Sixty-eight percentage of districts received *normal/excess* rainfall and 32% of districts received either *deficient* or *scanty* rainfall during the period 1 June – 30

September 2001. Similar distribution has been occurring since the last three years (Table 2).

3.6. *Withdrawal of southwest monsoon*

The southwest monsoon withdrew from western parts of Rajasthan on 10 September, which was 9 days late than the normal date of 1 September. It withdrew from most parts of northwest India, north Gujarat, Uttar Pradesh and parts of Madhya Pradesh (delay of 4 days) by 27 September. Then it withdrew after 16 days *i.e.*, on 13 October, from northeast India, parts of Bihar & Jharkhand, east Madhya Pradesh, Chattisgarh, Orissa, Vidarbha & Marathwada and Madhya Maharashtra (delay of 13 days). It withdrew from the entire country on 16 October with a delay of one day only with simultaneous commencement of northeast monsoon rains over Tamil Nadu, Kerala, Karnataka & coastal Andhra Pradesh (Fig. 8).

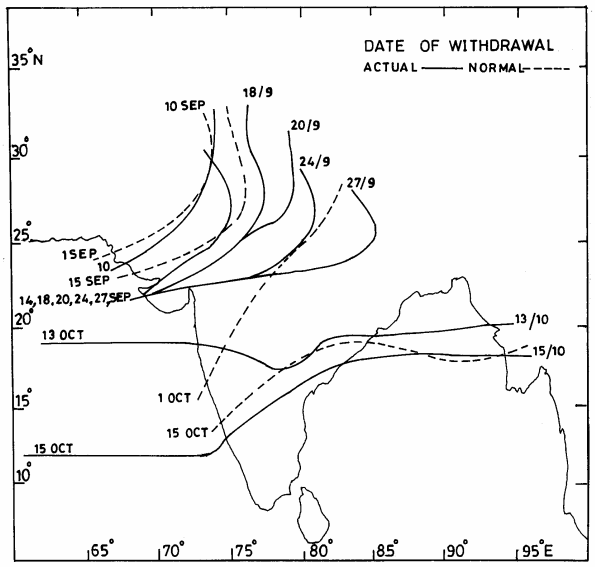


Fig. 8. Withdrawal of southwest monsoon 2001

3.7. *El-Nino phenomenon*

El Nino (La Nina) is the general term used to indicate the anomalous rise (fall) in Sea Surface Temperatures (SSTs) over the east and central Pacific. A see-saw relationship between Sea Level Pressure (SLP) over the southeastern Pacific Ocean and the Indian Ocean is known as Southern Oscillation (SO). The planetary-scale tropical SLP anomalies associated with the SO occur in conjunction with episodes of El Nino/La Nina in the tropical Pacific. The atmospheric component, *i.e.*, SO and its oceanic counterpart, *i.e.*, El Nino together are known as "El-Nino Southern Oscillation" or ENSO. 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 is generally expressed as a measure of the strength of the Walker Circulation across the Pacific and 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 the three regions in the Pacific Ocean, widely known as Nino 1+2, Nino 3 and Nino 4. In general, there exists an inverse relationship between ENSO and Indian summer monsoon rainfall.

Table 12 depicts the monthly values of SST anomaly indices at various geographical regions of tropical Pacific and SOI for the period October 2000 to September 2001. The cold episode (La Nina) condition, which was started during the middle of 1998, matured in the beginning of 2000 and subsequently started weakening with appearance of very weak warm conditions occasionally after February 2001. All the SST indices in the Table 12 show negative values during initial months(January & February) of the year 2001. However starting from March 2001, the SST indices showed more variability in their monthly values with combination of positive and negative values in subsequent months. The Nino 4 index after reaching to 0 (zero) in May 2001 increased to 0.6 in September 2001. The Nino 3 index, on the other hand, after reaching its lowest negative value (–0.3) in February 2001, become positive during March 2001 and again turned to negative from May 2001 except 0 (zero) value in June 2001. The Nino 1+2 index showed more variability in its monthly values with positive values during March and April 2001 and negative values after and before this period.

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*

There were only one cyclonic storm *i.e.*, during 24 to 27 September over Arabian Sea and one depression *i.e.*, during June 12 to 13 over northwest Bay formed during the season. Tracks of these systems are given in Fig. 9.

4.1.1. *Depression over the Bay of Bengal (12-13 June)*

A low pressure area formed over northwest Bay and neighbourhood on 9. It became well-marked on 11 over the same area and concentrated into a depression on morning of 12 near Lat. 20° N/ Long. 87° E, about 80 kms eastsoutheast of Paradip. Moving in a northwesterly

TABLE 3

Details of the weather systems during June 2001

S. No. (1)	System (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(**A**)	*Depression*					
1.	Depression	12 – 13	Northwest Bay and neighbourhood	Northwesterly	West Madhya Pradesh and Chattisgarh	A low pressure area formed over northwest Bay and neighbourhood on 9. It became well-marked on 11 over the same area and concentrated into a depression on 1203 UTC near Lat. 20° N/ Long. 87° E, about 80 km eastsoutheast of Paradip. Moving in a westnorthwesterly direction, it crossed coast in the afternoon of 12 and lay centred at 1212 UTC close to Bhubaneswar. Then it moved in a northnorthwesterly direction and lay centred at 1303 UTC about 50 km southeast of Keonjhargarh. It weakened into a well-marked low pressure area on 14 over east Madhya Pradesh & Chattisgarh and neighbourhood and into a low pressure area on 15 over west Madhya Pradesh and neighbourhood and became less marked on 16. Associated cyclonic circulation extended upto mid tropospheric levels
(**B**)	*Low pressure areas*					
1.	Feeble low pressure area	12	Northeast Arabian Sea and adjoining areas of Saurashtra & Kutch	Stationary	*In situ*	It was seen as a cyclonic circulation between 1.5 and 3.6 km a.s.l. over Saurashtra & Kutch and south Gujarat region from 7 to 11. Under its influence this feeble low pressure area formed on 12. Associated cyclonic circulation extended upto mid tropospheric levels. The low pressure area became less marked on 13. However, the associated cyclonic circulation between 2.1 and 5.8 km a.s.l. persisted on 13. It moved over to south Rajasthan and neighbourhood and became less marked on 18
(**C**)	*Cyclonic circulations*					
1.	Lower tropospheric levels	7 – 12	North Pakistan and adjoining parts of Punjab and Jammu & Kashmir	Easterly	Northwest Rajasthan and adjoining Haryana and west Uttar Pradesh	Seen upto 4.5 km a.s.l. on 7 & 8
2.	Do	13 – 18	North Pakistan and adjoining Jammu & Kashmir	Southeasterly	Northwest Madhya Pradesh and adjoining west Uttar Pradesh.	
3.	Mid tropospheric levels	16 – 22	Bangladesh and adjoining Gangetic West Bengal	Northwesterly	Bihar and neighbourhood	Merged with another cyclonic circulation (sys. No. 7)
4.	Do	17 – 18	North Pakistan and adjoining Jammu & Kashmir and Punjab	Easterly	Haryana and adjoining areas	
5.	Do	19	Central Pakistan	Stationary	*In situ*	
6.	Do	21 – 25	South Pakistan	Northeasterly	Haryana and neighbourhood	
7.	Do	22 – 25	North Bay and adjoining Bangladesh, Gangetic West Bengal and Myanmar	Westerly	Jharkhand and adjoining areas of Orissa and Gangetic West Bengal	Merged with another cyclonic circulation (sys no 8)

TABLE 3 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
8.	Mid tropospheric levels	23 – 28	Northern parts of Rajasthan and adjoining west Madhya Pradesh, Haryana and Punjab	Easterly	West Uttar Pradesh and neighbourhood	
9.	Do	26 Jun – 12 Jul	Northwest Bay and adjoining Orissa and Gangetic West Bengal	Westnorth-westerly	Gujarat region and neighbourhood	It was seen as a trough in the lower tropospheric levels over the same area on 13 and became less marked on 14
10	Do	26 – 30	Central Pakistan	Easterly	Haryana and neighbourhood	
11.	Do	27 Jun – 3 Jul	South Pakistan and adjoining Saurashtra & Kutch and Rajasthan	Stationary	*In situ*	
(**D**)	*Embedded cyclonic circulations*					
1.	Lower tropospheric levels	2 – 5	West Uttar Pradesh	Stationary	*In situ*	
2.	Do	3	West-central Bay off coastal Andhra Pradesh	Do	Do	

direction, it crossed coast in the afternoon of 12 near Paradip and lay centred about 50 kms southeast of Keonjhargarh in the morning of 13. It weakened into a well-marked low pressure area on 14 over east Madhya Pradesh & Chattisgarh and neighbourhood and into a low pressure area on 15 over west Madhya Pradesh and neighbourhood.

4.1.2. *Cyclonic storm over the Arabian Sea (24-27 September)*

Under the influence of an upper air cyclonic circulation, a low pressure area formed over east-central Arabian Sea on 24 morning. It concentrated into a depression at 0900 UTC of 24 over east-central Arabian Sea and lay centred near Lat. 17.0° N/ Long. 69.5° E and became deep depression at 1800 UTC of 24 and lay centred near Lat. 17.0° N/Long. 69.0° E. Remaining practically stationary for some time and then moving in a westerly to northwesterly direction, it intensified into a cyclonic storm at 0900 UTC of 25 and lay centred near Lat. 17.0° N/ Long. 68.0° E. It moved in a northwesterly direction and weakened into a deep depression at 1200 UTC of 27 and lay centred near Lat. 18.5° N/ Long. 63.5° E. It further weakened into a depression at 2100 UTC of 27 and lay centred near Lat. 18.5° N/Long. 62.5° E. It weakened into a low pressure area at 0300 UTC of 28 over west-central Arabian Sea. It became less marked on 29 morning over the same area.

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. All these systems (except one) initially formed as upper air cyclonic circulations. Monthwise break-up of the systems are 1 in June, 2 in July and 5 in August and 2 in September. Details are given in Tables 3 to 6.

4.3. *Cyclonic circulations (CYCIR)*

In all 52 cyclonic circulations (in lower and upper tropospheric levels) including 4 embedded cyclonic circulations, formed in this season. The monthwise break-up of cyclonic circulations is 13 in June, 14 in July and 12 in August and 13 in September. Details are given in Tables 3 to 6.

4.4. *Off-shore trough*

Off-shore trough along different parts of west coast (surface & lower levels) persisted on most of the days from 30 May to 13 September except during 1-4 June and

TABLE 4

Details of the weather systems during July 2001

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 area*					
1.	Well-marked low pressure area	3 – 11	North Bay and adjoining Bangladesh and Gangetic West Bengal	Northwesterly	Northwest Madhya Pradesh and adjoining east Rajasthan	Under the influence of an upper air cyclonic circulation between 2.1 and 5.8 km a.s.l. the low pressure area was formed. It became well-marked on 4. It lay as a low pressure area over Jharkhand and neighbourhood on 9 and became less marked on 12. However, the associated cyclonic circulation extended upto mid tropospheric levels on 12 and became less marked on 14
2.	Low pressure area	16 – 21	Orissa and adjoining areas of Gangetic West Bengal and Jharkhand	Westnorth-westerly	Jharkhand and neighbouring areas	It was first observed as a cyclonic circulation over northwest Bay and neighbourhood. Associated cyclonic circulation extended upto mid tropospheric levels. The low pressure area became less marked on 22, however, the cyclonic circulation was observed even over the same area on 23. It became less marked on 28
(**B**)	*Cyclonic circulations*					
1.	Mid tropospheric levels	1 – 2	North Pakistan and adjoining areas of Punjab and Jammu & Kashmir	Stationary	*In situ*	
2.	Do	10 – 16	North Pakistan and adjoining areas of Punjab and Jammu & Kashmir	Easterly	Himachal Pradesh and adjoining areas of Jammu & Kashmir	
3.	Do	12 – 13	Northwest Madhya Pradesh and adjoining east Rajasthan and west Uttar Pradesh	Northnorth-easterly	West Uttar Pradesh and adjoining areas of Haryana	
4.	Do	12	Saurashtra & Kutch and neighbourhood	Stationary	*In situ*	It was seen as a trough in lower tropospheric westerlies on 13 and became less marked on 14
5.	Do	12 – 15	North Orissa and adjoining West Bengal and Jharkhand	Northwesterly initially and then northeasterly	Bihar and neighbourhood	
6.	Lower levels	15 – 19	North Pakistan and adjoining areas of Jammu & Kashmir and Punjab	Eastnorth-easterly	Himachal Pradesh and adjoining areas of Uttaranchal and Haryana	
7.	Do	20 – 26	Central parts of Uttar Pradesh	Westerly	West Uttar Pradesh	
8.	Lower tropospheric levels	20 – 22	Jammu & Kashmir	Stationary	*In situ*	

TABLE 4 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
9.	Lower levels	23	Punjab and adjoining areas of Haryana and northwest Rajasthan	Stationary	*In situ*	
10.	Mid tropospheric levels	24 – 26	South Pakistan and adjoining areas of Gujarat State and northeast Arabian Sea	Do	Do	It lay as a trough over the same area on 27 & 28 and subsequently became less marked
11.	Lower levels	24 – 29	North Pakistan and adjoining northwest Rajasthan	Northeasterly	Haryana and neighbourhood	Moved away northeastwards on 30
12.	Lower levels	29 – 31	Central Pakistan and adjoining areas of Haryana and Jammu & Kashmir	Stationary	*In situ*	
13.	Lower tropospheric levels	29 – 31	South Pakistan	Stationary	*In situ*	It lay as trough on 1 and 2
14.	Mid tropospheric levels	29 – 31	Central Pakistan and adjoining Punjab	Easterly	Punjab and adjoining Haryana and Jammu & Kashmir	
(**C**)	*Western disturbance*					
1.	As an upper air system	31 Jul – 1 Aug	Afghanistan and adjoining areas of north Pakistan and Jammu & Kashmir	Northeasterly	Jammu and Kashmir and neighbourhood	Moved away northeastwards
(**D**)	*Trough in westerlies*					
1.	Lower levels	28– 31	88^0 E, north of 20^0 N	Quasi-stationary	88^0 E, north of 20^0 N	
(**E**)	*Trough in easterlies*					
1.	Mid tropospheric levels	31 Jul - 1 Aug	Southwest and adjoining west-central Bay	Stationary	*In situ*	

11 September. The details of the positions of the off-shore trough for 2001 are given in Table 7(a) and for 1996-2001 are given in Table 7(b).

4.5. *Low level troughs*

During the season, only 1 trough formed in July. Detail is given in Table 4.

4.6. *Upper level troughs*

During the season, 2 mid and upper tropospheric troughs (1 each in July and September) formed.. Details are given in Tables 4 and 6.

4.7. *Eastward moving circulations/western disturbances*

During the season only 1 (July) eastward moving circulations/western disturbances formed. Detail is given in Table 4.

5. Extra Indian systems

5.1. *Cross equatorial flow*

5.1.1. *Along the equator*

In general the cross equatorial flow was stronger by about 5-10 kts than normal (5-10 kts) along the equator

TABLE 5

Details of the weather systems during August 2001

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 area*					
1.	Low pressure area	3 – 5	Northwest Bay and adjoining areas of coastal Orissa and Gangetic West Bengal	Northwesterly	Vidarbha and adjoining areas of Madhya Pradesh & Chattisgarh	Associated cyclonic circulation extended upto mid tropospheric levels. Merged with the seasonal trough on 6
2.	Do	6 – 10	West-central Bay off north Andhra coast	Northnorth-westerly	Orissa, adjoining areas of Jharkhand, east Madhya Pradesh & Chattisgarh	Associated cyclonic circulation extended upto mid tropospheric levels and tilted southwestwards with height on 7. The low pressure area became less marked on 11, however, the associated cyclonic circulation was observed over central parts of Madhya Pradesh and adjoining Vidarbha on 12. It became less marked on 18 over northwest Madhya Pradesh and adjoining east Rajasthan
3.	Do	14	Coastal Gangetic West Bengal and adjoining north Bay, north Orissa and Jharkhand	Stationary	*In situ*	It was first observed as a cyclonic circulation over Gangetic West Bengal and adjoining areas of Orissa and Jharkhand. Associated cyclonic circulation extended upto mid tropospheric levels which became less marked on 16 over Jharkhand and neighbourhood
4.	Do	19 – 22	Northwest Bay off Orissa-West Bengal coasts	Quasi-stationary	Northwest Bay and adjoining areas of Orissa	Associated cyclonic circulation extended upto mid tropospheric levels tilting southwestwards with height and became less marked on 23
5.	Well-marked low pressure area	29 Aug – 3 Sep	Northwest Bay	Westnorth-westerly	East Uttar Pradesh adjoining Bihar	Under the influence of an upper air cyclonic circulation, the low pressure area formed and became well-marked on 31. It lay as a low pressure area on 1 over Jharkhand and neighbourhood. Associated cyclonic circulation extended upto mid tropospheric levels tilting southwestwards with height which became less marked on 5 over east Uttar Pradesh and adjoining Bihar
(**B**)	*Cyclonic circulations*					
1.	Mid tropospheric levels	3 – 10	South Pakistan and adjoining areas of Kutch and south Rajasthan	Quasi-stationary	West Rajasthan and adjoining areas of Gujarat State	
2.	Lower tropospheric levels	2 – 5 eve	North Pakistan and adjoining Jammu & Kashmir	Northeasterly	Northern parts of Jammu and Kashmir	
3.	Do	7 – 8	North Pakistan and adjoining areas of Punjab and Jammu & Kashmir	Stationary	*In situ*	
4.	Do	9 – 12	Central Pakistan and adjoining areas of west Rajasthan	Easterly	Haryana and adjoining areas of Punjab and Uttaranchal	

TABLE 5 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
5.	Lower tropospheric levels	12 Aug – 15 Sep	South Pakistan and adjoining areas of southwest Rajasthan	Quasi-stationary	South Pakistan, south Rajasthan, Gujarat and northeast Arabian Sea	It lay as a trough from 17 to 19 over south Pakistan, south Rajasthan, Gujarat and northeast Arabian Sea. and again from the evening of 26 August to 7 September over the same area
6.	Mid tropsheric levels	13 – 17	North Pakistan and adjoining Punjab and Jammu & Kashmir	Easterly	Himachal Pradesh and neighbourhood	
7.	Lower tropospheric levels	18 – 22	East Uttar Pradesh and adjoining Bihar	Westerly	Northeast Madhya Pradesh and adjoining east Uttar Pradesh	
8.	Mid tropospheric levels	24 – 27	Gangetic West Bengal and adjoining areas of Jharkhand	Northerly	Bihar and neighbourhood	It lay as a trough on 28
9	Mid tropospheric levels	20 – 24	Haryana and adjoining areas of west Uttar Pradesh and Uttaranchal	Easterly	Uttaranchal and adjoining areas of Himachal Pradesh and west Uttar Pradesh	
10.	Do	22 – 27	North Pakistan and adjoining areas of Punjab and Jammu & Kashmir	Eastnorth-easterly	Jammu & Kashmir	Moved away northeastwards
11.	Lower tropospheric levels	28 – 31	North Pakistan and adjoining Jammu & Kashmir	Easterly	Jammu & Kashmir	Moved away northeastwards
12.	Mid tropospheric levels	29 Aug – 10 Sep	Central Pakistan and adjoining northwest Rajasthan and Punjab	Northeasterly	Punjab and adjoining areas of Haryana and Himachal Pradesh	On 10, it extended only in the lower levels

over the Arabian Sea and Bay of Bengal, *i.e.* within ± 5° Latitude of the equator by about 5 kts during June to September.

5.1.2. *Over the Arabian Sea*

(Ship data meagre over northern parts of the Arabian Sea).

In June, the surface wind was nearly normal (15-20 kts) during the Ist week and was less than normal in the remaining weeks by about 5 kts.

In July and August, surface winds were nearly normal (20-25 kts).

In September, surface winds were stronger than normal (5-10 kts) by about 5 kts or so.

5.1.3. *Over the Bay of Bengal*

(Ship data meagre over northern parts of the Bay of Bengal).

In June, the surface winds were nearly normal (10-15 kts).

In July, they were stronger than normal (10-15 kts) by about 5 kts in Ist and IInd week and normal during the remaining weeks.

In August, they were stronger than normal (10-15 kts) by about 5 kts during the month except during the last week.

In September, the surface winds continued to be stronger than normal (5-10 kts) by 5-10 kts.

TABLE 6

Details of the weather systems during September 2001

S. No.	System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(**A**)	***Cyclonic storm***					
1.	Cyclonic Storm	24 – 27	East-central Arabian Sea	Westnorth-westerly	Northwest and adjoining west-central Arabian Sea off Arabia coast	A cyclonic circulation extending upto mid tropospheric levels lay over east-central Arabian Sea on 23 and 24. Under its influence, a depression formed at 0900 UTC of 24 over east-central Arabian Sea and lay centred near Lat. 17.0° N/Long. 68.0° E and became deep depression at 0300 UTC of 25 and lay centred near Lat. 17.0° N/Long. 67.5° E, about 600 km southwest of Mumbai. Remaining practically stationary for some time and then moving slightly westwards, it intensified into a cyclonic storm at 0300 UTC of 26 and lay centred near Lat. 17.5° N/Long. 67.0° E, about 520 km southwest of Veraval. It moved in a westnorthwesterly direction and weakened into a deep depression at 0900 UTC of 27 and lay centred near Lat. 18.5° N/Long. 63.5° E at 1200 UTC of 27. It further weakened into a depression at 2100 UTC of 27 and into a low pressure area over northwest and adjoining west-central Arabian Sea off Arabia coast at 0300 UTC of 28. It became less marked on 29 morning over the same area
(**B**)	***Low pressure area***					
1.	Low pressure area	18	North Bay and adjoining areas of Gangetic West Bengal and Bangladesh	Northnorth-easterly	Bangladesh and adjoining Nagaland-Manipur-Mizoram & Tripura and Assam & Meghalaya	It was first observed as a cyclonic circulation over east-central Bay on 15. Associated cyclonic circulation extended upto mid tropospheric levels which became less marked on 24 over Jharkhand and adjoining east Madhya Pradesh and Chattisgarh
2.	Well-marked low pressure area	28 Sep - 6 Oct	Southwest Bay off Tamil Nadu-Andhra coasts	Northwesterly	East Madhya Pradesh & Chattisgarh and adjoining Jharkhand, Bihar and east Uttar Pradesh	Under the influence of a cyclonic circulation extending upto mid tropospheric levels over southwest Bay off Tamil Nadu-Andhra coast, a low pressure area formed over the same area on 28. It became well-marked on 29 and again seen as a low pressure area over Vidarbha and neighbourhood on 2 October. It became less marked on 6 and lay as a trough in the lower levels from Bihar to Chattisgarh. It was seen from Sub-Himalayan West Bengal & Sikkim to north Bihar on 8 and became less marked thereafter. A trough from this system on sea level chart extended westwards to east-central Arabian Sea on 30 September and 1 October
(**C**)	*Cyclonic circulations*					
1.	Mid tropospheric levels	1 – 2	West-central Bay and adjoining southwest Bay off Andhra-Tamil Nadu coasts	Westerly	Tamil Nadu and neighbourhood	
2.	Lower tropospheric levels	3 – 10	Central Pakistan and adjoining areas of north Pakistan and Punjab	Easterly	Punjab and adjoining areas of Haryana and Himachal Pradesh	

TABLE 6 (*Contd*.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
3.	Mid tropospheric levels	5 – 15	Gangetic West Bengal and adjoining Jharkhand, Bangladesh and northwest Bay	Westnorth-westerly	Bihar and adjoining areas of Jharkhand and east Uttar Pradesh	Tilted southwestwards with height on 6 and 7
4.	Do	10 – 15	Central Pakistan and adjoining areas of west Rajasthan	Eastnorth-easterly	Haryana and neighbourhood	
5.	Lower tropospheric levels	15 – 17	North Pakistan and adjoining Jammu & Kashmir	Easterly	Himachal Pradesh and adjoining Punjab and Jammu & Kashmir	
6.	Mid tropospheric levels	15 mor – 16 eve	Nagaland-Manipur-Mizoram & Tripura and adjoining Bangladesh	Stationary	***In situ***	
7.	Do	19 – 28	North Pakistan and adjoining areas of Jammu & Kashmir	Easterly	West Uttar Pradesh and adjoining Uttaranchal	Moved away northeastwards
8.	Do	23 – 26	North Pakistan and adjoining Jammu & Kashmir	Easterly	Punjab and adjoining Jammu & Kashmir and Pakistan	
9.	Do	25 mor – 25 eve	South Pakistan and adjoining Saurashtra & Kutch and Rajasthan	Stationary	*In situ*	
10.	Lower levels	26	Telangana and adjoining south Madhya Pradesh and Maharashtra	Southeasterly	Andhra Pradesh and adjoining Tamil Nadu	
11.	Mid tropospheric levels	28 Sep – 3 Oct	Tenasserim coast and adjoining north Andaman Sea			Under the influence of this cyclonic circulation, a low pressure area formed over south and adjoining central Bay in the month of October which after crossing the southern peninsula, influenced the formation of cyclonic storm over the Arabian Sea during October
12.	Lower tropospheric levels	29 Sep – 1 Oct	Central Pakistan and adjoining west Rajasthan	Northeasterly	Central parts of Rajasthan	
(**D**)	*Embedded cyclonic circulation*					
1.	Mid tropospheric levels	15	Konkan & Goa and adjoining east-central Arabian Sea	East-west oscillatory	-	Moved over to east-central Arabian Sea and caused the formation of the system (1) 1 over there
(**E**)	*Troughs in westerlies*					
1.	Mid and upper tropospheric westerly	20	Long. 73° E, north of Lat. 24° N	Stationary	*In situ*	

TABLE 7 (a)

Positions of off-shore troughs during the monsoon period 2001

Date	Position
30 May	south Gujarat coast to Lakshadweep area
31 May	Karnataka coast to Lakshadweep area
5 June	Konkan coast to north Kerala coast
6-9 June	north Maharashtra coast to Lakshadweep area
10-11 June	south Gujarat coast to Lakshadweep area
12 June	low pressure area to Lakshadweep area
13-17 June	northeast Arabian Sea to south Kerala coast
18-23 June	north Maharashtra coast to south Kerala coast
24 June	north Maharashtra coast to north Kerala coast
25 June	north Maharashtra coast to Karnataka coast
26 June	south Maharashtra coast to Kerala coast
27-28 June	north Maharashtra coast to Kerala coast
29 June-2 July	north Maharashtra coast to south Kerala coast
3-9 July	south Gujarat coast to north Kerala coast
10-13 July	south Gujarat coast to Lakshadweep area
14-20 July	north Maharashtra coast to Kerala coast
21-22 July	north Maharashtra coast to Karnataka coast
23 July-5 August	north Maharashtra coast to Kerala coast
6-12 August	north Maharashtra coast to Karnataka coast
13 August–11 September	north Maharashtra coast to Kerala coast
12-13 September	north Gujarat coast to north Karnataka coast

TABLE 7(b)

Details of off-shore trough from 1996– 2001

Year	Details of off – shore trough
2001	Off-shore trough along different parts of west coast (surface and lower levels) noted upto 4 September except during 1-4 June & 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, 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 1997, the off-shore trough along different parts of the west coast (surface and in lower levels) persisted on most of the days
1996	Off-shore trough along west coast (surface and lower levels) persisted on most of the days

5.1.4. *Mid latitude troughs*

Monthwise break-up of troughs in westerlies found between 60° E – 90° E and reaching upto or south of 30° N is given in Table 13. There were a total of 21 mid and upper tropospheric troughs during the season.

As a comparison, there were 13, 29, 17, 31 & 18 mid and upper tropospheric westerly troughs in 2000, 1999, 1998, 1997 & 1996 respectively.

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

There were 18 systems (Tropical depression stage and above) in the northwest Pacific Ocean/ South China Sea during June to September 2001. The monthwise breakup is shown in Table 14.

5.3. *Systems in southern hemisphere*

5.3.1. *Tropical storms*

No weather systems (TD, TS or Typhoon) formed over south Indian Ocean during June to September 2001.

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

During June to September 2001, there were in all 14 (5 in June, 4 in July, 2 in August and 3 in September)

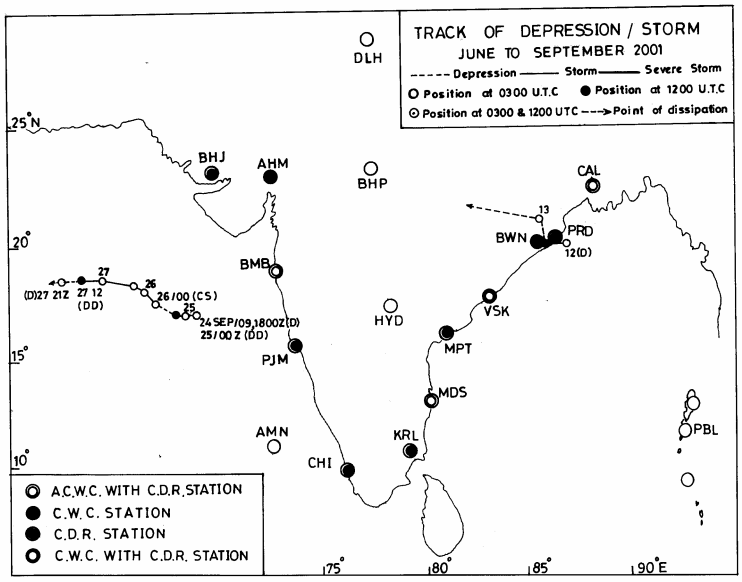


Fig. 9. Tracks of depression/storms (June to September 2001)

upper air troughs in westerlies which moved across Indian Ocean from west to east to the north of Lat.30° S.

5.3.3. *Mascarene High*

The intensity of Mascarene High at 30° S/ 60° E was above normal (1026 hPa) by 2 hPa in August, were below normal (1025 hPa) in July and September by 1 to 3 hPa (approx.) and were normal (1023 hPa) in June. The details are given in the Table 15.

5.3.4. *Australian High*

The intensity of Australian high pressure area at 30° S/ 140° E was above normal during June (1020 hPa) and July (1021 hPa) (2 to 1) and less than normal by (–1 hPa) during August (1019 hPa) and September (1017 hPa). The details 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 23 May and remained more or less over the same area till 30 September.

The lowest & second lowest observed pressure values (hPa) of the heat low were:

May	989 on 25, 991 on 24 & 28
June	987.0 on 20 & 21 and 989.0 on 11, 16, 17 & 22
July	989.0 on 12 and 990.0 on 16
August	990.0 on 29 and 991.5 on 2
September	995.0 on 5 & 10 and 996.5 on 2

Details of lowest observed isobaric values of the heat low during past 5 years are given Table 17.

6.2. *Axis of the monsoon trough*

Monsoon trough was established on 3 July and was almost south of its normal position upto 5 July. The normal position was from Ganganagar to Kolkata through Allahabad. Western end of the monsoon trough was north of normal position by 1° to 2° and the eastern end to the south of normal position by 1° to 2° from 6 to 8 July. Then monsoon trough was in south of normal position due to formation of a low pressure area over north Bay. Again, western end of monsoon trough was north of normal position by 1° to 2° from 14 to 26 July with eastern end of monsoon trough either in south of normal position or in almost normal position in association with low pressure area over north Bay. It moved northwards and lay close to foot hills of Himalayas from 28 July to 2 August. During this period the country as a whole experienced subdued rainfall activity. The trough moved south of normal position due to formation of a low pressure area over north Bay on 3 August and remained south of normal position by 2°-6° upto 13 August. Subsequently, western end of monsoon trough was north of normal position by about 1°-1.5° & eastern end remained either south of normal position due to formation of low pressure area over north Bay or in almost normal position from 14 August to 12 September, it again was north of normal position on 13 & 14 September. From 15 to 18 September, again western end of monsoon trough was north of normal position by about 1° & eastern end was either south of normal position by 1° or in normal position. On 19 September, it was again north of normal

TABLE 8

Main features of weekly wind anomalies (during June to September 2001)

Week ending	850 (hPa)	500 (hPa)	200 (hPa)	Remarks
6 Jun	N-S trough from West Bengal to south Bay and a ridge to the south	E-W ridge from north Konkan to central Bay and trough at extreme north and south	E-W ridge from west Rajasthan	Anomalous flow was mainly anticyclonic over central India. Upper level easterlies over south peninsula (stronger then normal)
12 Jun	Trough over the northern parts of the country	E-W trough approximately along 15° N	A E-W ridge along 22° N	Anomalous flow over peninsula was cyclonic and that over north was anticyclonic
19 Jun	E-W trough along 25° N Lat.	Trough along 23° N and ridge north of that	E-W ridge between 27° N and 23° N	Anomalous flow was cyclonic over north India and anticyclonic over south peninsula
26 Jun	N-S ridge from J & K to Madhya Maharashtra	E-W ridge approximately along 27° N	E-W ridge along northern part of the country	Anomalous flow in the lower levels over northern parts were mainly cyclonic 25
3 Jul	E-W trough between 27° N & 22° N	E-W trough along 20° N	E-W ridge approximately along 28° N	Anomalous flow in the lower levels over north India was cyclonic and south peninsula anticyclonic
10 Jul	Trough from West Rajasthan to north Bay	E-W trough between 25° N	Easterlies over entire country	Lower level westerlies were stronger than normal
17 Jul	Cyclonic circulation over Gangetic West Bengal and neighbourhood	E-W trough between 25° N and 19° N through the cyclonic circulation	Easterlies over the entire country	Anomalous flow mainly anticyclonic over south peninsula in the lower levels
24 Jul	Trough approximately along 25° N to central Bay and one branch to NE India	E-W trough over north peninsula and a ridge along 8° N Lat.	All easterlies	Upper level easterlies were stronger than normal
31 Jul	All westerlies	E-W ridge approximately along 20° N Lat. and a shallow trough north of it	E-W ridge along 28° N	Easterlies were stronger than normal especially to the northern peninsula
7 Aug	Broken trough at the northern part of the country through a cyclonic circulation ovcr Orissa and neighbourhood	Trough approximately along 18° N Lat.	E-W ridge along 30° N	Stronger than normal easterlies to the north
14 Aug	Trough between 27° N and 20° N trough the cyclonic circulation over Orissa and neighbourhood	E-W trough approximately along 20° N Lat.	Mostly easterlies	In the lower levels, anomalous flow was cyclonic over northern part and anticyclonic over south peninsula
21 Aug	N-S ridge from Jammu & Kashmir to interior Karnataka and cyclonic circulation over Orissa and neighbourhood	Trough between 24° N and 17° N	Ridge along 29° N	Anomalous flow was mainly anticyclonic over the country
28 Aug	N-S ridge from Jammu & Kashmir to Madhya Maharashtra and a trough from cyclonic circulation over Gangetic West Bengal and neighbourhood	N-S trough from East Uttar Pradesh to cyclonic circulation over central Bay	Anticyclonic at 25° N Lat.	Anomalous flow was mainly anticyclonic over thc country
4 Sep	N-S ridge from Jammu & Kashmir to Madhya Maharashtra	Ridge between 24° N and 18° N and a trough between 20° N and 16° N	Anticyclone over central India. Ridge along 25° N Lat.	Anomalous flow mainly anticyclonic in all levels
11 Sep	N-S ridge from Jammu & Kashmir to Karnataka	E-W ridge between 15° N and 10° N	Ridge between 22° N and 27° N	Anomalous flow mainly anticyclonic in the lower tropospheric levels
18 Sep	E-W ridge ~ along 22° N and E-W trough along 18° N	A ridge across central peninsula	Ridge from 20° N lat. to 27° N Lat.	Upper level westerlies to the northern latitudes were stronger than normal
25 Sep	Cyclonic circulation over Madhya Maharashtra and neighbourhood	Ridge along northern parts of the country	E-W ridge between 20° N to 25° N	Anomalous flow were anticyclonic over north India. Upper level easterlies were weaker than normal over the south peninsula
2 Oct	Trough along 25° N	Trough from 10° N latitude to 20° latitude (NE-SW)	Anticyclonic over central India and ridge line along 20° N latitude	Lower level anomalous circulation was cyclonic and upper level anticyclonic

TABLE 9

Zonal wind anomalies

Week ending dates	5 Jun	12 Jun	19 Jun	26 Jun	30 Jun	10 Jul	17 Jul	24 Jul	31Jul	7 Aug	14 Aug	21 Aug	28 Aug	4 Sep	11 Sep	11 Sep	25 Sep	2 Oct
Thiruvananthapuram (TRV)																		
850	5.0	-	1.2	-1.2	0.5	10.2	-3.3	-3.4	-.3.0	-3.7	-5.4	-1.4	-0.1	5.6	-5.5	-15.9	-8.1	10.0
500	-6.9	-	-2.5	-7.3	-4.5	2.0	-4.2	-11.0	-15.7	-0.5	-7.6	3.5	2.4	-1.3	-11.4	-10.0	-	-3.8
200	-22.1	-	-22.7	-11.5	-9.8	-1.4	--6.4	-3.7	2.1	-5.3	-15.2	-5.7	-0.9	1.0	-13.4	-0.7	-	-
Chennai (MDS)																		
850	0.4	12.6	16.0	4.0	3.8	14.3	-0.7	-5.1	-15.2	0.6	0.7	11.1	4.2	1.3	-7.8	-8.4	-1.8	9.0
500	-10.8	8.0	15.4	3.2	-4.9	6.7	0.6	-5.8	-25.4	0.8	2.6	13.5	-1.3	-1.3	-5.2	-10.6	-6.7	2.7
200	-22.7	-11.5	0.6	-13.7	-8.2	5.2	-1.3	-3.4	-4.7	4.2	-0.3	2.4	-3.1	-6.6	-14.3	2.2	7.8	-6.6
Mumbai (BMB)																		
850	5.2	-9.5	-	2.5	1.1	-0.6	11.5	0.6	-3.9	-4.2	-3.0	0.6	2.1	1.4	-1.6	-7.3	-11.6	-6.2
500	-3.4	-	-	-	2.4	-3.3	1.2	-3.2	-7.2	-10.2	2.4	-	0.0	-8.2	5.1	-2.6	-4.6	-5.4
200	-15.2	-	-	--	-13.0	-2.9	-9.0	-13.7	-16.2	-9.7	0.5	-	-2.4	-4.2	8.3	4.5	10.8	0.0
Nagpur (NGP)																		
850	10.2	2.1	8.5	12.5	13.7	-4.1	19.8	7.2	1.2	-17.6	-9.8	-	5.7	6.9	-0.3	-5.7	-1.4	-11.4
500	4.0	-10.5	-3.3	9.7	5.8	-0.7	0.7	0.6	4.2	-17.2	-11.6	-	5.7	3.3	10.4	7.2	1.1	-13.4
200	-14.1	0.8	-1.1	-14.7	-10.8	0.7	-15.6	-12.0	-18.3	-2.5	-0.4	--	4.1	-16.3	-29.2	-22.7	-17.8	-

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

position by about 2°-3°. It was not seen from 20 September onwards. For ready comparison, the positions of monsoon trough in the past five years are given below :

Year	*Axis of Monsoon Trough*
1996	Established on 8 July. Less marked on 6 September Break from 1 to 7 July and on 8 August.
1997	Established 25 June. Less marked on 6 September. Break 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.

6.3. *Tibetan Anticyclone/High*

Tibetan Anticyclone (TA) was established at 500, 300 and 200 hPa levels on 12 June. During the past 10 years, in 1998 Tibetan Anticyclone appeared on 13 June which is almost similar to the year 2001.

In June, it was south of the normal position on 11 days at 300 & 200 hPa.

In July, it was north of the normal position on 24 & 20 days at 300 & 200 hPa respectively.

In August, also at 300 & 200 hPa it was north of normal position on 21 and 23 days respectively. TA was not seen in last week of August.

In September, 300 & 200 hPa position was south of normal position on 6 days during 1-13 September. TA was not seen from 13 September onwards. In the past five years, the details of the Tibetan Anticyclone is given below:

Year	*Tibetan Anticyclone*
1996	Appeared in 3rd week of June. Less marked in 2nd week of September.
1997	Appeared in 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.

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

STWJ was seen over Srinagar from 27 to 31 May, over Delhi 24 to 30 May, Guwahati from 1 to 7 June. It then shifted northwards & reappeared over Srinagar & Delhi in the last week of September.

TABLE 10

Statistics of special rainfall distribution
(No. of days for monsoon season 2001 as a whole with heavy to very heavy rainfall)

S. No	Sub – division	Vig.	Act.	V. Heavy	Heavy	W/Fw
1.	Andaman & Nicobar Islands	-	-	-	8	39
2.	Arunachal Pradesh	2	16	1	7	42
3.	Assam & Meghalaya	-	8	13	42	39
4.	Naga., Mani., Mizo. & Trip.	3	16	1	5	49
5.	S.H.W.B. & Sikkim	2	26	17	24	46
6.	Gangetic West Bengal	1	21	5	27	38
7.	Orissa	4	19	16	29	34
8.	Jharkhand	2	11	2	2	21
9.	Bihar	8	15	16	18	10
10.	East Uttar Pradesh	-	-	10	18	33
11.	West Uttar Pradesh	-	-	2	10	23
12.	Uttaranchal	-	-	2	12	51
13.	Haryana	2	4	3	6	7
14.	Punjab	4	4	5	7	3
15.	Himachal Pradesh	2	10	8	16	16
16.	Jammu & Kashmir	3	3	-	7	7
17.	West Rajasthan	-	-	3	3	9
18.	East Rajasthan	-	-	4	13	12
19.	West Madhya Pradesh	4	11	3	4	14
20.	East Madhya Pradesh & Chattisgarh	3	24	5	5	26
21.	Gujarat Region	5	13	18	6	22
22.	Saurashtra & Kutch	3	3	5	2	10
23.	Konkan & Goa	1	18	19	23	67
24.	Madhya Maharashtra	2	14	11	24	18
25.	Marathwada	1	8	1	8	21
26.	Vidarbha	1	8	-	10	22
27.	Coastal Andhra Pradesh	1	15	1	1	3
28.	Telangana	5	18	-	5	9
29.	Rayalaseema	4	11	1	3	4
30.	Tamil Nadu & Pondicherry	2	-	7	20	-
31.	Coastal Karnataka	1	19	14	27	73
32.	North interior Karnataka	3	10	1	17	1
33.	South interior Karnataka	3	10	13	32	8
34.	Kerala	1	23	16	19	52
35.	Lakshadweep	-	-	1	-	33

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 cms in the west coast and 5 cms 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 cms in the west coast and 3 cms elsewhere)

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

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

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

TABLE 11

Principle amounts of rainfall during June – September 2001

Date (1)	June (2)	July (3)	August (4)	September (5)
1.	Rajghat 12, Bhalukpong 11, AIE N. H. Xing & Gorakhpur 10 each, Dholai & Sultanpur 9 each, Guwahati, Amraghat, Kolkata, Pandoh & Kayamkulam 8 each, Baripada & Kudulu 7 each	Ludhiana 13, Jhansi 12, Khajuraho 10, Karimganj & Ankola 9 each, Kerunighat 8, Sagar, Gwalior, Dhokla & Agumbe 7 each	Nagrakata 28, Murti 19, Diana 15, Hasimara 13, Agartala 10, Karimganj & Kuppam 8 each, Rajghat, Pamban, Tirupattur & Thiruvananthapuram 7 each	Mirzapur 19, Varanasi 11, Jaunpur 10, Khowong, Lakhipur, Khadda, Triveni & Bridgeghat 9 each, Khadda, Amraghat, Palmerganj & Chepan 7 each
2.	Dehra Dun 15, Karimganj 8, Purushottampur 7	Sengod 29, Guna 28, Kota 25, Bilaspur Dam 23, Piplda, Regod & Verdha 22 each, Bundi & Ladpura 20 each, Jhansi & Karwar 8 each	Bhongir 11, Hasimara 10, Beki Mathanguri & Mahabubnagar 9 each,Galgalia, Srisailam & Kota 8 each, Sattenapalli, Yerragon-dalpalem, Yellandu & Uppinangaddy 7 each	Khadda 25, Bansi 19, Kakrahi & Rengali 17 each, Passighat & Mukhlishpur 16 each, Triveni & Basti 13 each, Cooch Behar & Chanpatia 12 each, Ahirwalia 11, Koilwar & Darauli 9 each, North Lakhimpur, NH-31 & Alipurduar 8 each, Barobisha, Chepan & L. B. Ghat 7 each
3.	Baghdogra 19, Gajoldoba 14, Barobisha 13, Cooch Behar & Champasarai 12 each, Kokrajhar & Sevoke 10 each, Dhubri, Domohani & Mathabhanga 9 each, Chepan 8, Chotila 7	Nandsamand 35, Kota 20, Barsar 19, Baran 13, Ambala, Bangana, Nahan & Raipur 9 each, Jammu, Marwar, Sojat & Udaipur 8 each, Nagrakata, Jaitaran, Beawar, Mulki & Bhagamandala7 each	Panambur 13, Karwar & Mulki 12 each, Mangalore 11, Udupi & Kota 9 each, Puttur 8, Katerniaghat, Jagdalpur, Uppinangaddy, Belthangady & Kannur 7 each	Rengali 17, Passighat 15, Khadda 13, Gorakhpur 12, Champasarai & Baghdogra 10 each, Domohani & Balrampur 8 each, Tezu, Kokrajhar, Hasimara & Guler 7 each
4.	Shillong 12, Bankura, Krishnanagar, Champua & Ranchi 10 each, Sunnibhaji 9, Dibrugarh, Dhollabazar, Malda & Rajgarh 8 each, Passighat, Pangram, Dharampur & Mohadi 7 each	Naraj 29, Bhubaneswar & Gandevi 18 each, Bhira 17, Nawashahar & Valsad 16 each, Tikarpara & Raipur Dam 15 each, Vapi 13, Jharsuguda, Nahar Sagar, Silvasa & Mahabaleshwar 12 each, Nimapada, Alipingal, Ahmedabad & Agumbe 11 each, Puri & Mukerian 10 each, Swampatna, Cuttack & Arwar 9 each, Kondul, Balasore, Halwara, Batala & Bassi Dam 8 each, Sambalpur, Phulbani, Ludhiana, Surat & Mumbai 7 each	Ratnagiri 19, Chiplun 14, Kankavali 13, Narsampet 12, Tekkali & Londa 11 each, Banwasi 10, Bhadrachalam, Siddapura & Kollu 9 each, Talaguppa 8, Hanumansetu, Baijnath, Jammu, Kaprada, Mahabaleshwar, Manchikeri, Sirsi, Khanapura & Kamarddi 7 each	Bhalukpong 18, Gajoldoba 13, Sonbarsa & Araria 12 each, Sankalan,& Champasarai 10 each, NH-31, Sikandarpur 9
5.	Karimganj 22, Matizuri 17, Lakhipur, Chottabekra & Sevoke 14 each, Dholai 13, Agartala 12, Champasarai 11, Amraghat, Cooch Behar & Kottayam 9 each, Gharmura, Kokrajhar, Gajoldoba, Ranchi & New Delhi 7 each	Sardarnagar 32, Bhawanipatna 28, Nimbahera 18, Jamnagar 16, Peermade & Agumbe 15 each, Gerusoppa & Valpor 13 each, Maya Bandar 9	Godhara 21, Ramgarh, Alibag, Honavar & Agumbe 10 each, Chotta Udaipur 9, Jagdalpur, Ahmedabad & Buldhana 8 each, Thasra, Bhiloda, Karjan, Bobbili, Nizamabad, Kumta & Hosdurg 7 each	Domohani 10, NH-31 8, Bansi & Kakrahi 7 each
6.	Annapurnaghat & Amraghat 19 each, Panambur 18, Matijuri & Mangalore 17 each, Karimganj & Lakhipur 16 each, Kasargode 15, Gajoldoba 14, Kokrajhar 13, Dholai, AIE N. H. Xing & Murti 11 each, Beki Mathanguri, Gharmura, Chottabekra & Nagrakata 10 each, Kolasib, Salur, Kochi & Kannur 9 each, Passighat, Diana, Jamshedpur, Baijnath & Prakasam Barrage 8 each, Cooch Behar & Balimundali 7 each	Bhawanipatna 26, Agumbe 15, Siddapura 13, Dehra Dun & Munnar 12 each, Satna 9, Matijuri 8, Perur & Gohar 7 each	Uppinangaddy 32, Karimganj 10, Port Blair & Pardi 9 each, Sevoke 8, Umbergaon, Daman, Sanad, Mancherial & Bodhan 7 each	Bhagalpur 11, Kampur Hat & Jamsolaghat 9 each, Cherrapunji 8, Digha, Chargharia, Taibpur & Pandoh 7 each

TABLE 11 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
7.	Annapurnaghat & Panambur 15 each, Barobisha 14, Chalakkudy 12, Nagrakata & Mangalore 11 each, Chepan 10, Karimganj, Kokrajhar & Cooch Behar 9 each, Karwar 8, Murti, Kotraguda, Washim & Amini Divi 7 each	Bolangir 21, Munnar 18, Bhagamandala 13, Nawashahar & Satna 10 each	Valsad 16, Navsari 13, Jammu 9, Katra 8, Jagdalpur & Gandevi 7 each	Balurghat 11, D. P. Ghat & Suri 8 each, Cherrapunji & Tilpara Barrage 7 each
8.	Shirali 19, Vengurla 16, Kudulu 15, Mangalore 12, Jalgaon & Thaliparamba 10 each, Ahmednagar & Malkapur 9 each, Hut Bay, North Lakhimpur, Dapoli, Hingoli, Narsampet & Kannur 7 each	Gaganbavada 26, Munnar 23, Poladpur & Bhagamandala 20 each, Jaipatna 16, Jogindernagar 13, Subramanya 11, Sikar 10, Indore 8	Dahanu 18, Navsari 17, Umbergaon 16, Nadiad 13, Ahmednagar 12, Mahidam & Daman 11 each, Galiakot 10, Fatehgarh, Bhikagaon & Vapi 9 each,Banswara, Sangwara & Valsad 8 each, Bhungra, Fatehgarh, Garhi Sujangarh, Ukai, Silvasa & Tuni 7 each	Baltara 16, Munger 13, Gheropara 10, Rewaghat 9, Tantloi & Triveni 8 each, Tezpur, Ahirwalia & Patna 7 each
9.	Bhalukpong 14, Hut Bay & Jalpaiguri 10 each, Maya Bandar, Umrala & Ratnagiri, 9 each, Patur 8, Malwan, Wardha, Shirali, Honavar & Piravom 7 each	Panvel 28, Mahabaleshwar 27, Munnar 26, Poladpur & Bhagamandala 24 each, Gaganbavada 23, Jabalpur 16, Silvasa & Bolangir 13 each, Vapi 12	Nahan 26, Khed 22, Valsad, Guhagar, Chiplun & Dapoli 16 each, Mandangad & Shrivardhan 14 each, Harnai 13, Ratnagiri 11, Limbdi, Dahanu & Khandala 10 each, Gohar, Umbergaon, Palitana, Mahabaleshwar & Narsampet 9 each, Sikandarpur, Guler, Chuda, Talaja, Mumbai, Partur & Hyderabad 8 each, Bansi, Nadaun, Dholaka, Vapi, Mahuwa & Bhira 7 each	Passighat & Jainagar 9 each, Port Blair 8, Jhanjharpur, Kamtaul & Patna 7 each
10	Maya Bandar 12, Khed 10, Baghdogra & Khasala 9 each, Lakhimpur 8, Gajoldoba, Dapoli & Agumbe 7 each	Mahabaleshwar 22, Bhira & Broach 21 each, Dharampur 19, Mandira Dam 17, Aklera, Agumbe & Chepan 14 each, Gaganbavada 13, Munnar 12	Karjat 15, Murbad 12, Khagaria & Gwalior 11 each, Gudari, Hissar, Halwara & Nanded 8 each, Ahirwalia, Basuan, Matheran,& Mahabaleshwar 7 each	Kakinada 9, Chargharia 8, Alipurduar & Cooch Behar 7 each
11	Hut Bay & Vyara 11 each, Baghdogra 9, Mumbai, Valparai, Thodupuzha & Piravom 8 each, Anjangaon, Kozhikode & Manjeri 7 each	Kansabati Dam 18, Palanpur 14, Batala & Mangalore Kheroj 12 each, Agumbe & Perinthal-manna 11 each, Puri Kangra 9, Kathua & Tirora 7 each	Hissar 11, Tohana & Baroda 10 each, Modasa 9, Bokajan, Amraghat & Mangrol 8 each, Daman 7	Gajoldoba 12, Dharampuri & Chennai 9 each, Manas NH X-ing 8,
12	Lanja 14, Berhampore, Chattrapur, Rajapur, Khed & Honavar 13 each, Gopalpur & Hosdurg 12 each, Paradip, Kanakavali, Hyderabad & Agumbe 11 each, Madhabarida, Nimapada, Kalyanpur & Ratnagiri 9 each, Domohani, Shahuwadi, Ahmedpur & Thaliparamba 8 each, Bhubaneswar, Mohana, Surada, Dapoli, Mangaon, Pakala, Chandgad, Kolhapur, Malam & Parambikulam 7 each	Bhanera 15, Chouldhowaghat 11, Pendra 10, Champura, Swampatna, Allahabad & Tharad 9 each, Gogunda & Pesagan 8 each, Keonjhargarh, Rengali, Kangra, Mawali, Songadh, Murbad & Igatpuri 7 each	Umbergaon 14, Baghdogra, Daman & Valsad 13 each, Champasarai 11, Chottabekra & Bhopal 10 each, Hasimara, Diana, Vapi & Dhrangodhra 8 each, Sibsagar, Nagrakata & New Kandla 7 each	Magra 17, Kursela 16, Rampurhat, Araria & Chatia 9 each, Diamond Harbour & Baltara 8 each, Matijuri & Kailashshahar 7 each
13	Kotraguda 19, Bhubaneswar 18, Nimapada 14, Aluwa 12, Berhampore & Phulbani 11 each, Banpur 9, Madhabarida, Alipingal, Valparai, Hosdurg & Vythiri 8 each, Cuttack, Surada, Rayagada, Kalyanpur, Selu, Vaikom, Cochi, Cannur & Kottayam 7 each	Satna 15, Nagratasurian 14, Abdasa & Naliya 13 each, Roha 11, Dehragopipur, Khajuraho, Nakhatrana & Lakhpat 10 each, Bharwain, Matheran & Karkala 8 each, Passighat, Pendra, Pali & Honavar 7 each	Jogindernagar 10, Champasarai & Wardha Dam 9 each	Gajoldoba 14, Jalpaiguri 11, Domohani 10, Baghdogra 9, Sevoke 8, Kailashshahar & Champasarai 7 each

TABLE 11 (*Contd.*)

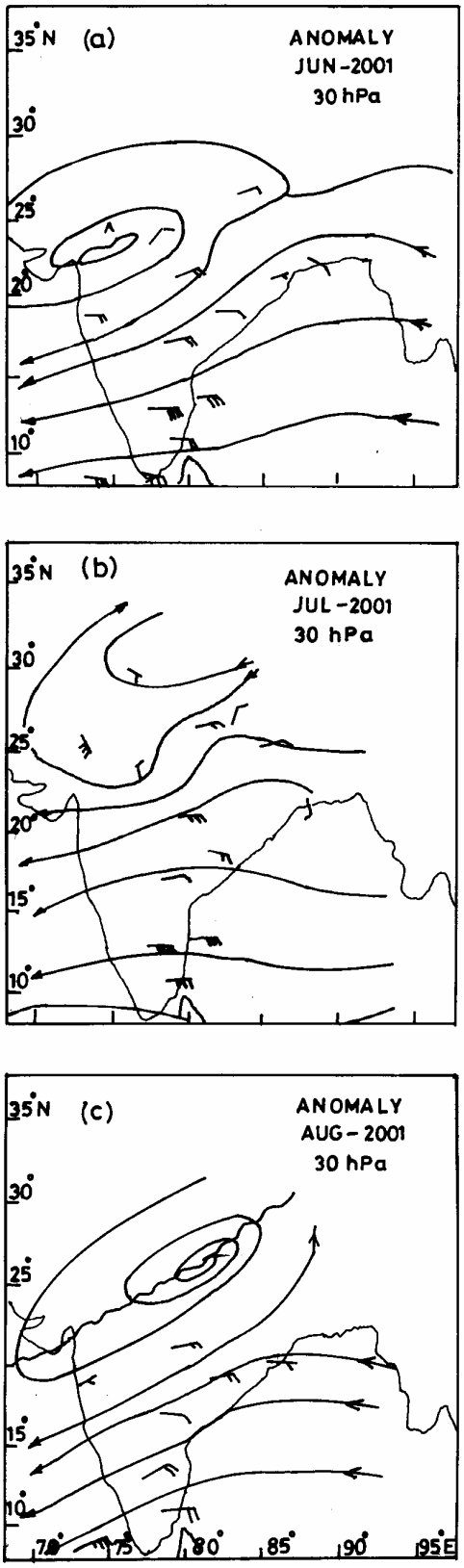
(1)	(2)	(3)	(4)	(5)
14	Armor 35, Bhiwapur 30, Gadchiroli 27, Kuhi 26, Mul & Bhadrawati 23 each, Chandur, Chamorshi & Rajura 21 each, Nagpur 17, Nangal & Raipur 13 each, Paonta, 12, Dhanera 11, Irikkur 10, Contai & Jammu 9 each, Kharidwar, Chikalwas & Jaisalmer 8 each, Mukerian, Vadali, Talaja & Ramgundam 7 each	Dasuya 7	Nahan 21, Nadaun 20, Hindon 19, New Delhi & Berthin 18 each, Una 17, Hardwar, Mukerian & Guler 14 each, Keonjhargarh, Marora & Kangra 13 each, Haripur, Dasuya & Kathua 12 each, Champua, Chandigarh & Jogindernagar 11 each, Ambala & Buwana 10 each, Thakurmunda, Nangal, Shimla, Jabalbet & Agumbe 9 each, Balchaur & Bhira 8 each, Sevoke, Balasore, Palliakalan, Dehra Dun, Nawgaon, Gohana, Jammu, Roha, Mandangad, Mahabaleshwar & Amgaon 7 each	Galgalia 14, Taibpur & Mukhlishpur 11 each, Baghdogra, Tantloi & Chandradeepghat 9 each, Rangarpet 8, Basti 7
15	Khandala 23, Kannod 19, Gandevi & Moregaon 18 each, Kalamb 17, Dahanu & Karanja 16 each, Silvasa, Vapi, Jafrabad, Khalapur, Mumbai & Washim 15 each, Hansot & Pareli 14 each, Yeotmal, Sringeri & Kasargode 13 each, Sehore, Chikkali & Virajpet 12 each, Ichhawar, Daman, Karjat, Alibag, Bhagamandala & Balehonnur 11 each, Canning Town, Sawarkundla, Pali & Napoklu 10 each, Indore, Dhari & Jalgaon 9 each, Tantloi, Shajapur, Bhopal, Surat, Valsad, Amreli, Radhanagari, Peint, Bhadravati & Sindewahi 7 each	Hardwar 25, Sultanpur 15, Bahraich 13, Gajol-doba 12, Karjat 10, Kangra 9, Dehra Dun & Ghamroor 8 each, Murti, Katerniaghat, New Delhi & Honavar 7 each	Vapi 33, Daman 24, Ahwa 21, Pardi 18, Songadh 17, Dharavi 11, Bihubar, Chouldhowaghat, Silvasa, Bhira & Panvel 10 each, Margherita, Ballabhgarh, Guna & Mumbai 9 each, Palmerganj, Valsad & Navsari 8 each, Diana, Nagrakata, Sundergarh, Mahabaleshwar & Nagpur 7 each	Kodaikanal 14, Munnar 11, Devanahalli 8
16	Khambalia 31, Navasari & Keshod 24 each, Palsana, Mahuva, Bhanitad & Ranawab 23 each, Bansda 22, Mandvi & Kalyanpur 21 each, Chikhali 20, Valsad & Porbandar 19 each, Dahanu 15, Jamnagar 13, Palghar 12, Sagar, Naliya & Veraval 11 each, Kammardi 9, Paonta, Surat, Okha, Bhuj & Akkalkuwa 8 each, Tilpara Barrage, Hissar, Taloda, Agumbe, Mudigeri, Hosanagara & Sringeri 7 each	Sharadanagar 28, Alipingal 22, Ambala 21, Kamakhyanagar 17, Nimapada, Khagaria & Bareilly 13 each, Triveni & Jagadhari 12 each, Sambalpur, Bausan & Ropar 11 each, Cuttack, Bansi & Moradabad 10 each, Lalbegiaghat, Rosera, Palliakalan, Sangrala, Nahan & Baijnath 9 each, Bhubaneswar, Patiala, Ludhiana & Kholar 8 each, Kharagpur, Sonbarsa, Katerniaghat, Hardwar, Chandigarh, Kataula, Paonta & Shivali 7 each	Daman,& Mandvi 31 each, Valsad 28, Chuda 18, Ahwa 17, Mahuwa 16, Nadiad 15, Bardoli, Vyara,& Sankheda 14 each, Badotti & Madhuban 13 each, Durra Colony, Khanpur, Panchola, Sawan Bhado & Aswan Bead 12 each, Botad, Bhira & Mahabaleshwar 11 each, Mysore 10, Bhalukpong 9, Sawai Madhopur, Palitana, Bhandup & Agumbe 8 each, Kota, Udaipur, Shajapur, Idar, Baroda, Babra & Jasdan 7 each	Chandur 7
17	Kaparad & Dhrangadhra 23 each, Madhuban 20, Silvasa 19, Mehsana, Wadhvan & Halwad 16 each, Talasari 14, Jawahar 13, Wada, Karjat & Mumbai 12 each, Dahanu 10, Ahmedabad, Gandhinagar & Kalyan 9 each, Thanesar & Surat 8 each, Naraingarh 7	Amraghat 20, Jharsuguda 17, Sambalpur 15, Sundergarh 14, Jogindernagar & Paonta 12 each, Dholai, Ankinghat & Nahan 11 each, Beki Road Bridge 10, Silchar, Darauli, Mukerian, Jhanjgir & Korba 9 each, Mukhlishpur, Regoli, Champa & Sakti 8 each, Bhalukpong, Beki Mathanguri, Paradip, Bhubaneswar, Phulbani, Sonbarsa, Nilokheri & Thanesar 7 each	Bhalukpong 14, Chouldhowaghat & Mahabaleshwar 12 each, Gajoldoba, Bhira & Agumbe 9 each, Gangtok, Quant & Kasargode 8 each, Tadong, Salumar, Mount Abu, Shajapur & Bhagamandala 7 each	Araria 15, Galgalia 14, Sangli 13, Ratnagiri & Jat 11 each, Hatkanangle & Kadiri 10 each, Khowang, Taibpur, Nagarjun Sagar Dam, Tadpatri, Gajendragad & Ramdurg 9 each, Jurala & Hungund 8 each, Kokrajhar, Hasimara, Baghdogra, Kolhapur,& Karkala 7 each

TABLE 11 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
18	Vyara 30, Mangrol 27, Sankheda 26, Quant 25, Mandvi 23, Sengadh 21, Dhadgaon 18, Pen 17, Dharavi & Taloda 14 each, Karjat 13, Itanagar, Kuresella, Bardoli & Mahabaleshwar 11 each, Banbasa & Bhira 10 each, Jhansi & Kalyan 9 each, Kalimpong, Palmerganj, Kolgaon, Alibag & Soegaon 8 each, Diamond Harbour, Bhagalpur, Mhow, Khandwa, Mumbai & Sindkheda 7 each	Chillaghat 12, Banda 11, Mahabaleshwar 9, Varanasi 8	Port Blair, Matridund, Kota & Agumbe 10 each, Boran, Kollur & Siddapura 8 each, Kolasib NH-31, Antra, Mahabaleshwar, Panambur & Kundapura 7 each	
19	Sankheda & Piravom 15 each, Harnaweir 13, Neemsar & Chotta Udaipur 11 each, Patna 10, Manas NH X-ing 9, Rojera, Panjim & Kollur 8 each, Cooch Behar, Jalpaiguri, Samastipur, Bani, Agumbe & Perumbudur 7 each	Rengali 17, Alipingal & Khalapur 15 each, Bhubaneswar 13, Cuttack 11, Haripur 9, Balasore, Keonjhargarh & Jabalpur 8 each	Bani 20, Karkala 15, Satna & Udupi 13 each, Maya Bandar & Rengali 10 each, Panposh, Benibad & Kamtaul 9 each, Sonbarsa, Chanpatia & Dehra Dun 8 each, Sikandarpur & Varanasi 7 each	
20	Gajoldoba 21, Sikandarpur 19, Domohani 18, Jalpaiguri & Chepan 13 each, Darjeeling, Lalbegiaghat & Chatia 8 each, Mathabhanga, Baghdogra,& Rewaghat 7 each	Haripur 19, Balimundali 15, Paonta 11, Jaipur, Chandanpur, Bausan, Mahabaleshwar & Soegaon 10 each, Baripada & Tajewala 9 each, Guna 8, Khilchipur 7	Jagdalpur 12, Bharwain 10, Nagrota Surian 9, Bangan 7	Diana 15, Thiruvananthapuram 13, Chepan & Vellore 8 each, Khanapura, Dillighat, Matijuri & Chiplun 7 each
21	Patna 9, Passighat & Nandgaon 8 each, Golaghat & Cherrapunji 7 each	Paonta 12, Panposh 11, Kathua, Nangal & Satna 9 each, Champua, Bangana & Nadaun 8 each, Chouldhowaghat, Chollabazar, Kalimpong, Balimundali, Pathankot, Ghamroor, Bhahwargarh Colony, Bhira,& Mahabaleshwar 7 each	Amraghat 10, Dholai 9, Golaghat 8, North Lakhimpur, Gorakhpur & Mukhlishpur 7 each	Gaganbavada 12, Siraguppa 11, Prakasam Barrage & Mantralayam 9 each, Nalbari & Gowribidnur 7 each
22	Kollur 18, Dharamtul 16, Karwar & Siddapura 14 each, Samastipur 11, Mudibidere & Agumbe 10 each, Darauli 9, Patna, Rosera & Dharmasthala 8 each, Chatia & Sringeri 7 each	Ajan 10, Kaman 8, Basti & Kathumar 7 each	Gorakhpur 16, Bausan 15, Jalpaiguri 13, Itanagar, Hasimara,& Bansi 12 each, Hardwar & Nagrota Surian 11 each, Guler, Geeler & Pendra 9 each, NH-31 & Ghamroor 8 each, Chouldhowaghat, North Lakhimpur, Kangra & Sagar 7 each	Varkala 9, Magadi 8, Bangarpet 7
23	Bokajan, Karipur, Agumbe & Kochi 7 each	Jaipur 16, Chhapidan & Bhira 11 each, Baijnath, Rahuwas & Khajuraho 10 each, Kangra 9, Barsar & Karali 8 each, Uttarkashi, Kadi, Songadh, Dholka & Mahabaleshwar 7 each	Domohani 17, NH-31 16, Dharamtul 14, Sriramsagar & Passighat 13 each, Armoor 11, Jammu 10, Kotdwar 9, Agumbe 8	Bangalore 10, Alapuzha 8, Karkala 7
24	Silchar 9, Amraghat, Ranchi, Bharatpur & Shahpura 7 each	Songadh 16, Sailan 15, Bhilwara & Shajapur 11 each, Palli & Surpura 10 each, Dillighat & Poladpur 9 each, Dehgam 8, Ropar, Arigucha, Mandal, Mejadam, Palanpur & Bhira 7 each	Barobisha 22, Islampur 21, Purnea 11, Safipur 10, Ambejogai 9, Mandasa & Mellabazar 8 each, Agumbe & Tensa 7 each	Thiruvananthapuram 12, Jalpaiguri & Haveri 8 each, Chepan, Alipurduar, Sangli, Hoskote,& Bangalore 7 each
25	Lakhipur 12, Gharmura 11, Guna 10, Margherita, Chottabekra, Basti & Jaunpur 9 each, Annapurnaghat, Digha & Indrapuri 8 each, Dabri, Sujanpur & Tira 7 each	Bhalukpong, Dhanera & Bawla 9 each, Beki Mathanguri, Chandrabhaga & Jawahar Sagar Dam 8 each, Panjim & Chennai 7 each	Dhumri 17, Bansi,& Williamnagar 10 each, Mahabaleshwar 8, Kashipur, Kantamal & Biharsarif 7 each	Karaikal 8, Neyyatinkara 7

TABLE 11 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
26	Kasargod 11, Kolasib, Bani & Hamirpur 9 each, Alapuzha 8, Bhalukpong & Kottayam 7 each	NH-31 25 & Jalpaiguri 13 each, Puri 12, Paradip 11, Bhalukpong, Chouldhowaghat, Domohani, Sikar, Salem & Mangalore 10 each, Hasimara & Dehra Dun 9 each, North Lakhimpur, Dabri, Deeg & Gopalpur 8 each, Diana, Tisara & Bidar 7 each	Williamnagar 13, Arambagh & Puri 8 each, Puttur & Kattumannarkoil 7 each	Sinor, C. R. Nagara, Kottayam & Magri 8 each, Upleta, Akola & Uppinangaddy 7 each
27	Tilpara Barrage 10, Dhollabazar 9, Lakhipur & Raipur 8 each, Palmerganj 7	Gajoldoba 29, Passighat 13, Narnaul 12, Diana 9, Hasimara, Galgalia, Bareilly, Dehra Dun, Jabalpur & Tiruchirapalli 7 each	Domohani 19, Durgachak 10, Palmerganj 9, Bansdih & Gingee 8 each, Jaipur 7	Visavadar 11, Gajoldoba & Agumbe 9 each, Khowang & Sholapur 7 each
28	Mangalore 21, Karwar 14, Sevoke 13, Hosdurg 12, Bhalukpong 10, Jai Bharati & Baghdogra 9 each	Beki Mathanguri 26, Varanasi & Ratnagiri 14 each, Panbari & Malwan 13 each, Shillong, Beki Road Bridge, Malda & Vengurla 11 each, Gannavaram 10, Sankalan 9, Tezu, Namsai, Kokrajhar, Phoolbagh, Pantnagar, Nahan & Tiruchirapalli 7 each	Sripalpur 15, Rewaghat & Darjeeling 12 each, Miao 9, Tikarpara 7	Jalpaiguri 9, Port Blair 8
29	Panjim & Karwar 11 each, Udupi 10, Mulki 9, Kundapura 8, Ratnagiri, Honavar & Mangalore 7 each	Shillong 22, AIE NH X-ing 20, Balrampur 18, Beki Road Bridge, Birdghat 16, Passighat & Kokrajhar 13 each, Kakardharighat & Panjim 12 each, Gajoldoba & Adampur 11 each, Turtipar & Honavar 10 each, Bhalukpong, Panbari, Nalbari, Suri, Chillaghat, Bari & Chennai 9 each, Dhubri, Beki Mathanguri, Sankalan, Hasimara, Basti, Nawrangpur, Kumta & Agumbe 8 each, Bansi, Banbasa, Nizamabad, Mangalore & Panambur 7 each	Basua 13, Gajoldoba 10, Bansdih 7	Sankeshwara 7
30	North Lakhimpur 13, Khajuraho 9, Bihubar & Dillighat 8 each	Triveni 31, Manas NH X-ing 23, Beki Road Bridge & Bharwain 13 each, Shillong 11, Beki Mathanguri, Kalimpong, Singlabazar, Gajoldoba, Darjeeling & Panjim 10 each, Sevoke, Lalbegiaghat & Allahabad 9 each, Bhalukpong, Kharagpur, Birpur, Balachaur, Amritsar & Sirsilla 8 each, Panbari, Matunga, Kokrajhar, Baghdogra, Jalpaiguri, Berhampore, Sikandarpur, Jainagar, Raya, Nagrota Surian, Jammu, Nizamabad, Karwar, Shirali & Agumbe 7 each	Swampatna 11, Bihubar & Chandbali 10 each, Talcher, Panposh & Dharamtul 9 each, Balrampur 8, Maya Bandar & Bantwal 7 each	Kakinada 15, Waltair & Karipur 11 each, Visakhapatnam & Kottayam 10 each, Kalingapatnam 9, Bihubar, Jalpaiguri, Narsapur & Alapuzha 8 each, Tuni & Kozhikode 7 each
31	-	Khadda 15, Chanpatia 11, Chatia, Triveni, Kamtul & Sikandarpur 10 each, Hasimara & Lalbegiaghat 9 each, Galgalia & Sonbarsa 8 each, Hut Bay, Jhanjharpur, Ahirwalia, Regoli, Vijayawada, Mangalagiri & Prakasam Barrage 7 each	Rangagora 22, Kharidwar 20, Jamshedpur 16, Simulia 14, Kangsabati Dam 12, Purulia 11, Tusuma 10, Dehra Dun 9, Mirzapur 8, Khowong, Tikarpara, Palmerganj & Gaya 7 each	-



Figs. 10(a-c). Anomalous wind flow during monsoon 2001 at 30 hPa

TABLE 12

Monthly values of SST anomalies for the period from October 2000 to September 2001

Month	Pacific SSTA (in °C) Nino 1+2 0°-10°S 90°-80°W	Nino 3 5°N-5°S 150°-90°W	Nino 4 5°N-5°S 160°E-150°W	SOI
Oct 2000	-0.5	-0.5	-0.2	1.0
Nov 2000	-1.1	-0.8	-0.3	2.0
Dec2000	-0.6	-0.7	-0.7	0.7
Jan 2001	-0.6	-0.6	-0.6	1.1
Feb 2001	-0.2	-0.3	-0.7	1.5
Mar 2001	1.0	0.1	-0.5	0.5
Apr 2001	1.1	0.1	-0.2	-0.1
May 2001	-0.5	-0.2	0.0	-0.8
Jun 2001	-1.1	0.0	0.2	-0.1
Jul 2001	-0.8	-0.2	0.5	-0.4
Aug 2001	-0.8	-0.3	0.5	-1.0
Sep 2001	-1.2	-0.6	0.6	0.2

TABLE 13

Statistics of mid-latitude troughs, Monsoon 2001

Levels	June	July	August	September	Total
300 hPa	2	0	2	6	10
500 hPa	3	0	3	5	11

TABLE 14

Statistics of systems in west Pacific Ocean/South China Sea, Monsoon 2001

Month	Tropical depression	Tropical storm	Typhoons	Total
June	0	0	1	1
July	0	0	6	6
August	1	2	3	6
September	0	1	4	5
Total	1	3	14	18

TABLE 15

Intensity of Mascarene High during monsoon season for the years 1996-2001

Year	June		July		August		September	
	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)
1996	1023	0	1025	0	1026	0	1023	-2
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

TABLE 16

Intensity of Australian High during monsoon season for the years 1996-2001

Year	June		July		August		September	
	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)	Pressure (hPa)	Departure (hPa)
1996	1017	- 3	1017	- 3	1017	- 3	1015	- 5
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

TABLE 17

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

Month/Year	1996	1997	1998	1999	2000
June	995 hPa (7^{th})	986 hPa (25^{th})	987.5 hPa (21^{st})	990 hPa (23^{rd})	989.0 (13^{th}, 14^{th}, 16^{th} & 25^{th})
July	990 hPa (11^{th})	986.8 hPa (6^{th})	985.6 hPa (12^{th})	988.0 hPa (2^{nd})	989.0 (7^{th})
August	991 hPa (5^{th})	990.5 hPa (4^{th})	990.7 hPa (4^{th})	988.5 hPa (6^{th})	990.0 (30^{th})
September	995 hPa (8^{th} & 14^{th})	996.8 hPa (2^{nd})	993.9 hPa (3^{rd})	994.0 (17^{th})	992.0 (1^{st})

The days Sub-Tropical Westerly Jet was observed in the past five years are given below :

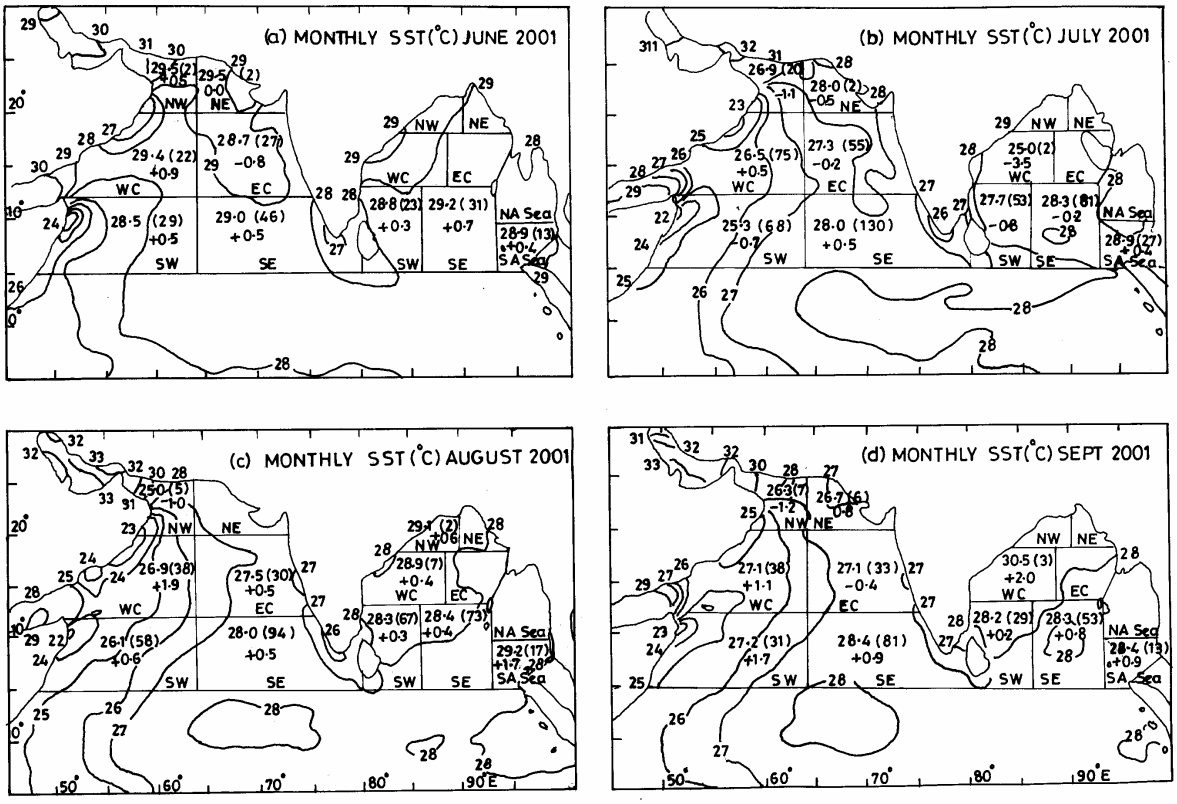
Year	*Sub-Tropical Westerly Jet (STWJ)*
1996	Seen till 1st week of June and 2nd fortnight of September
1997	Seen till first fortnight of June and last week of September.
1998	Seen only in first week of June.
1999	Seen only till 12 June.
2000	Made casual appearances on 5 June, 24 June & 16 July and further re-appeared in the last week of September.

6.5. *Tropical Easterly Jet (TEJ)*

TEJ was seen over Minicoy from 24 May to 15 July, 12 to 15 July, 27 July to 16 August, 28 August to 13 September. The maximum wind observed was 150 kts at 91.9 hPa on 0000 UTC of 5 June, 140 kts at 132 hPa on 0000 UTC of 6 August.

It was observed over Thiruvananthapuram from 24 May to 9 September. The maximum wind observed was 115 kts at 135 hPa on 1200 UTC of 2 August.

Over Chennai also it appeared on 28 May & was seen upto 15 September. The maximum wind observed



Figs. 11(a-d). Mean monthly (June-September 2001) SST anomalies (°C) of Indian seas during southwest monsoon

was 115 kts at 120 hPa on 1200 UTC of 23 June & at 160 hPa on 1200 UTC of 10 August.

Over Hyderabad TEJ was seen from 18 June to 1 July & 6 July to 4 September. The maximum wind observed was 150 kts at 115 hPa on 1200 UTC of 21 July.

Over Bhubaneshwar it was seen from 10 July to 14 July, 19 July to 5 August, 10 August to 21 August. The maximum wind was 95 kts at 126 hPa on 0000 UTC of 20 July. Details of TEJ in the last five years are as follows :

Year	*Tropical Easterly Jet (TEJ)*
1996	Appeared on 11 June. Less marked on 27 Sept. Max. wind 110 kts over MDS at 109 hPa on 14 July
1997	Appeared on 14 June. Less marked on 9 Sept. Max. wind 115 kts at 114 hPa on 25 July.
1998	Appeared from 1st week of June till the end of Sept. Max. wind 150 kts over MNC at 103 hPa on 5 Aug.
1999	Appeared on 3 June till the end of Sept. 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.

7. Sea surface temperature (SST)

Monthly mean SST values for the month of June, July, August and September 2001 for Arabian Sea, Bay of Bengal as well as Andaman Seas are presented in pictorial form in Figs. 11 (a-d). The normal values for each sector for calculating the anomalies have been estimated from the isotherms of normal values given in "Climatic Atlas of the Indian Ocean, Part I" by Stephen Hastenrath and Peter J. Lamb. Map showing the four months SST anomalies in each block is also given. The blocks in which the number of observations is less than 10, are not considered for the discussion. The WC & SE sectors of Arabian Sea and South Andaman sea remained warmer than normal throughout the season. EC Arabian Sea had negative anomalies except in the month of August. During the season as a whole, July was the coolest month for both the seas. The main features of monthly SSTs are given below :

7.1. *June*

WC and Southern sectors of Arabian Sea were warmer than normal, highest positive anomaly being +0.9° C in WC Arabian Sea. The mean temperature was below normal by 0.8° C in EC Arabian Sea. South Bay

and South Andaman Sea were warmer than normal and the highest positive anomaly was 0.7° C over SE Bay.

7.2. *July*

NW, EC and SW sectors of Arabian Sea were cooler than normal in the month of July. The NW had highest negative departure of –1.1° C. WC and SE sectors of Arabian Sea were warmer than normal by 0.5° C. South Bay was cooler than normal. SW sector had the largest anomaly, –0.8° C. South Andaman Sea was warmer than normal by 0.4° C.

7.3. *August*

Central and South Arabian Sea were warmer than normal, the highest anomaly being +1.9° C over WC Arabian Sea. The south Bay and South Andaman sea also had above normal temperature. South Andaman sea had the highest anomaly +1.7° C.

7.4. *September*

In the month September, WC and south Arabian Sea were warmer than normal. Maximum positive anomaly being+1.7° C in SW sector. EC Arabian Sea was cooler than normal by 0.4° C. South Bay and South Andaman Sea also were warmer than normal. South Andaman Sea had the highest anomaly; +0.9° C.

8. Other features

8.1. *Weekly upper wind anomalies in monsoon 2001*

The circulation anomaly features during the monsoon season (June-September) 2001 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-2001 are given in Table 8 and are discussed below :

8.1.1. *June wind anomaly features*

The circulation pattern for the week ending on 5th June was characterised by an anomalous E-W ridge over the peninsula indicating a weak monsoon. There were anomalous troughs along extreme south and north of the country in the lower tropospheric levels and anomalous easterlies were seen at the upper levels, showing stronger than normal easterlies. Next week, the ridge moved northward and an anomalous trough appeared over peninsula even at 200 hPa level, a sign of a good monsoon. In the week ending on 19th, the trough moved northward. Again a ridge appeared over the extreme peninsula indicating the weakening of monsoon circulation. In the last week of June, an anomalous trough was seen over northern India, while the anomalous ridge continued over extreme peninsula. Upper level easterlies were stronger than normal.

8.1.2. *July wind anomaly features*

In the week ending on 3 July also, the anomalous ridge line was seen over south peninsula in the lower tropospheric levels. In this week also the upper level easterlies were stronger than normal. The second week of July was characterised by an anomalous cyclonic flow in the lower tropospheric levels, showing a strong monsoon. In the upper level, an anomalous trough over north India, a ridge over central India, another trough and ridge over peninsula were also noticed.

During the week ending on 17 July, the lower tropospheric flow was mainly anticyclonic. NE India had an anomalous cyclonic flow. A N-S ridge was seen from Uttaranchal to south Andhra coast. An E-W ridge over south peninsula was also noticed. At 200 hPa, the anomalous flow was mainly cyclonic showing a weaker than normal easterlies. In the following week, the anomalous flow was cyclonic over north India, but over peninsula it was mainly anticyclonic. In the last week of July, it was seen that the lower level westerlies covered the entire country and hence was under the influence of anomalous anticyclonic flow. The upper level easterlies were more or less of normal strength.

8.1.3. *August wind anomaly features*

In the first week of August the monsoon regained the normal pattern. The anomalous flow over peninsula was cyclonic and that over north India was anticyclonic. Trough and cyclonic circulations were present over peninsula in the lower tropospheric levels during next week, but a ridge appeared at the extreme south peninsula indicating the weakening of monsoon. At 200 hPa level, NW-SE oriented trough and ridge were seen.

In the third week, even though, an anomalous cyclonic circulation was seen over Bay, the N-S ridge at 850 hPa level in the northern part of the country and E-W ridge at the extreme peninsula indicated one more week of subdued monsoon activity. At 200 hPa level, the easterlies to the northern latitudes gained strength. In the last week of August a N-S anomalous ridge line extended from Himachal Pradesh to Lakshadweep area in the lower tropospheric levels. An anomalous cyclonic flow was observed over NE parts of the country. The country was under the influence of anomalous anticyclonic

circulation. At upper levels, strong westerlies made appearance.

8.1.4. *September wind anomaly features*

Westerly winds prevailed over the entire country and hence an anomalous N-S ridge was present at 850 hPa indicating below normal monsoon activity in the first week of September. At 200 hPa level the anomalous flow was entirely anticyclonic.

During the second week, the lower level flow was purely anticyclonic and the monsoon was weak. At 200 hPa level, easterlies were stronger than normal. In the third week also the lower level anomalous flow was mainly anticyclonic. The upper level easterlies were weaker than normal and hence an E-W trough was seen across the peninsula. In the week ending on 25 September, the cyclonic circulation which moved across the peninsula caused the formation of an anomalous cyclonic circulation over Konkan and Goa. Other than that the flow was anticyclonic over the other parts of the country. The trough present at 200 hPa level in the previous week was seen in this week also.

In the last week of the season that is, week ending on 2nd October, the anomalous flow was cyclonic in the lower tropospheric levels. At 200 hPa, an anomalous anticyclone appeared with a N-S ridge.

Weekly wind anomaly values at three levels (850, 500 and 200 hPa) for a few representative stations over India are given in Table 9.

8.2. *Stratospheric features*

Stratospheric winds at 30 hPa and 10 hPa have been analysed based on balloon data received from Balasore till September 2001 upto 10 hPa level and RS data for 30 hPa level till September 2001. Rocket sonde data from Thumba and Balasore have already been discontinued since September 1993 and March 1995 respectively. Circulation patterns during monsoon 2001 are given below :

8.2.1. *Winds at 10 hPa*

The wind data of all available RS/RW stations over the country have been analysed during the monsoon period-2001. Rocket sonde observations from Thumba and Balasore have already been discontinued since September, 1993 and March 1995 respectively. Based on the available data, it is noted that on an average, over the country, the wind was mainly easterly through out the season. Monthwise wind data at 10 hPa level are given below.

Month	*Station*	*Date (Zonal wind speed in mps)*
June	Minicoy	3 (20)
	Nagpur	4 (25), 12 (32), 16 (19), 30 (32)
	Jagdalpur	5 (25)
	Hyderabad	5 (20)
July	Bhopal	11 (26)
	Ranchi	5 (30)
	Jagdalpur	31 (73)
	Kolkata	17 (27)
	Nagpur	3 (29), 29 (46)
	Agartala	23 (46)
August	Minicoy	1 (39)
September	Patiala	9 (12)

8.2.2. *Winds at 30 hPa*

Figs.10 (a-c) depicts the monthly anomalous wind flow during June, July and August of 2001 at 30 hPa level. The anomalous wind flow has been calculated from real time data and 30 years normals (1967-96).

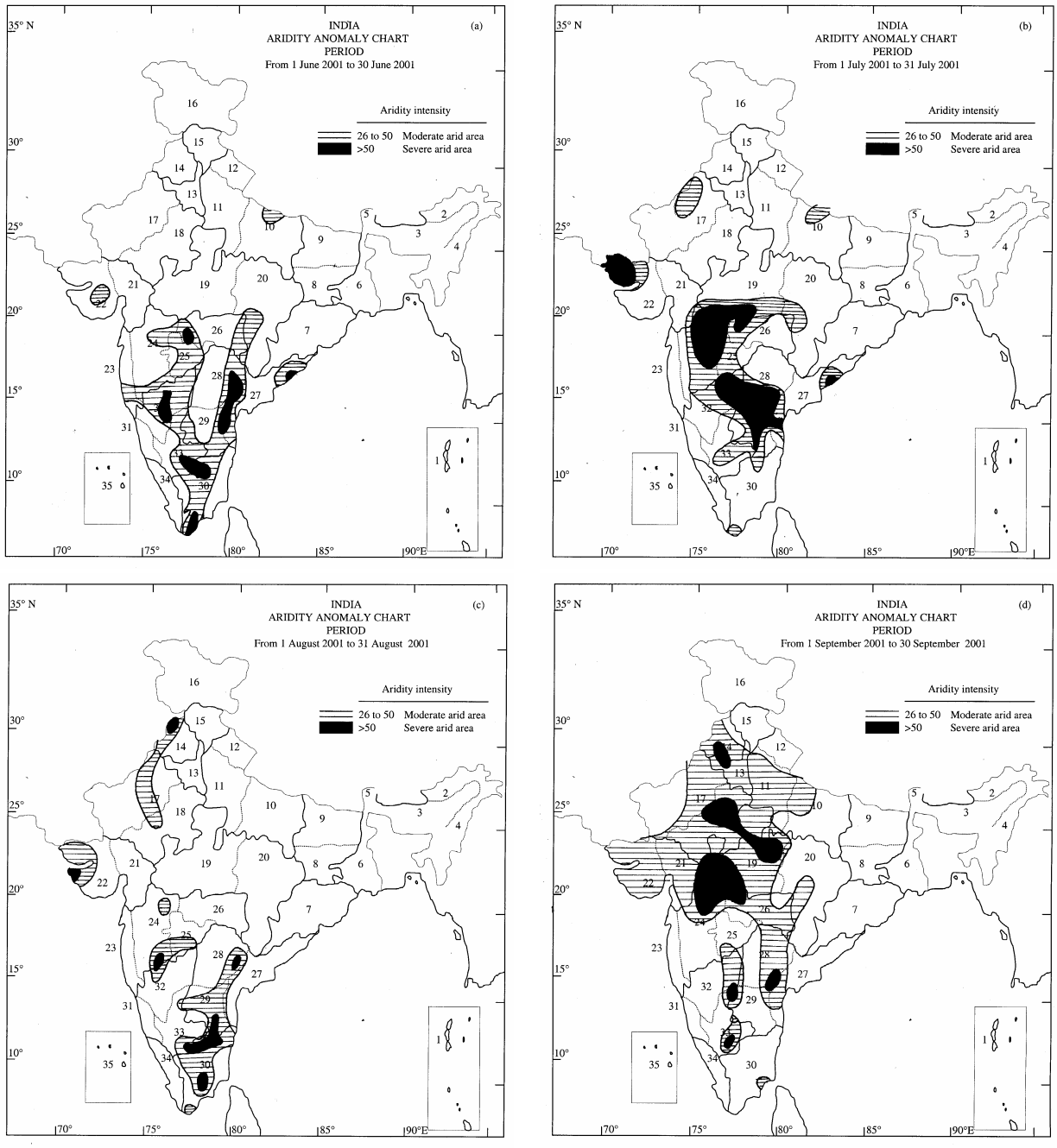
At 30 hPa the wind anomalies over the central and peninsular India were mainly easterly during June, July and August 2001, indicating stronger than normal (central India June 17 mps, July 24 mps, August 23 mps & September 19 mps; Peninsula June 18 mps, July 25 mps, August 26 mps & September 20 mps) easterly winds over these regions. In June, an anomalous anti-cyclonic circulation was observed over west Madhya Pradesh and adjoining areas with a ridge line oriented northeast-southwest. In August an anti-cyclonic circulation was observed over the east Uttar Pradesh region.

8.3. *Aridity conditions during Monsoon 2001*

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

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

Where, PE is potential evapotranspiration *i.e.* combined loss of water vapour to atmosphere in the form of evaporation from soil, water surfaces 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.



Figs. 12(a-d). Aridity anomaly chart – Drought research unit, Pune

The difference between actual aridity for the month and normal aridity *i.e.* the aridity anomaly is worked out. The aridity anomalies have been classified into the following classes :

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. 12(a-d) respectively.

Moderate to severe arid areas were noticed in the western, central and peninsular region of the country during June. These areas over western, central and in some peninsular regions persisted in July but those in the extreme southern parts disappeared. The arid areas decreased over the central parts of the country and

increased over eastern parts of the peninsular region during August. In September, the arid areas increased in the north, northwest and central parts of the country and decreased over Maharashtra, Andhra Pradesh and other parts of the peninsular India.

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

8.3.1. *June*

Severe arid areas

Small areas in southeastern parts of Madhya Maharashtra, Telangana and south Interior Karnataka, northwestern parts of North Interior Karnataka; northeastern parts of Rayalaseema and northwestern and southern parts of Tamil Nadu & Pondicherry and isolated areas around Buldhana (Vidarbha) and Vishakhapatnam (Coastal Andhra Pradesh).

Moderate arid areas

Large areas of Marathwada, Rayalaseema, north interior Karnataka, south interior Karnataka and Tamil Nadu & Pondicherry.

Small areas in eastern and western parts of Vidarbha and adjoining southwestern parts of east Madhya Pradesh; northeastern and southern parts of Madhya Maharashtra; central parts of Konkan; northern and central parts of Telangana and northern and southern parts of coastal Andhra Pradesh.

Isolated areas around Rajkot (Saurashtra & Kutch) and Bahraich (east Uttar Pradesh).

8.3.2. *July*

Severe arid areas

Large areas of Telangana, Rayalaseema and Madhya Maharashtra.

Small areas of southern parts of coastal Andhra Pradesh; northeastern parts of north interior Karnataka; northwestern parts of Marathwada; northwestern parts of Vidarbha; southern parts of west Madhya Pradesh and western parts of Saurashtra & Kutch.

Isolated area around Visakhapatnam (coastal Andhra Pradesh).

Moderate arid areas

Large area of Marathwada.

Small areas of northern and southern parts of coastal Andhra Pradesh; central parts of Telangana; central and western parts of north interior Karnataka; western and southern parts of Rayalaseema; central and southeastern parts of south interior Karnataka and adjoining northern part of Tamil Nadu & Pondicherry; southern and western parts of Madhya Maharashtra; southern parts of west Madhya Pradesh; central, southwestern and northeastern parts of Vidarbha and adjoining western parts of east Madhya Pradesh; northern parts of Saurashtra & Kutch and northwestern parts of west Rajasthan.

Isolated areas around Bahraich (east Uttar Pradesh) and Coimbatore & Kanyakumari (Tamil Nadu & Pondicherry).

8.3.3. *August*

Severe arid areas

Small areas in northwestern parts of Tamil Nadu & Pondicherry; southeastern parts of south interior Karnataka, southern parts of Rayalaseema and southern parts of Madhya Maharashtra.

Isolated areas around Khammameth (Telangana), Madurai (Tamil Nadu & Pondicherry), Dwarka (Saurashtra & Kutch) and Amritsar (Punjab).

Moderate arid areas

Large areas of Rayalaseema and Tamil Nadu & Pondicherry.

Small areas in central and eastern parts of west Rajasthan and adjoining northwestern parts of east Rajasthan; western parts of Saurashtra & Kutch; southeastern parts of Madhya Maharashtra and adjoining southern parts of Marathwada and northwestern parts of north interior Karnataka; southeastern parts of Telangana and northern & southeastern parts of south interior Karnataka.

Isolated area around Malegaon (Madhya Maharashtra), Kakinada (coastal Andhra Pradesh) and Kanyakumari (Tamil Nadu & Pondicherry).

8.3.4. *September*

Severe arid areas

Small areas in central parts of Punjab, central parts of east Rajasthan, northern and southern parts of west

Madhya Pradesh and adjoining northeastern parts of Madhya Maharashtra; southern parts of west Uttar Pradesh; western parts of Vidarbha; western parts of coastal Andhra Pradesh and adjoining eastern parts of Telangana.

Isolated areas around Bellary and Mysore (south interior Karnataka).

Moderate arid areas

Large areas of east Rajasthan, west Uttar Pradesh, Haryana, Punjab, west Madhya Pradesh, Gujarat Region, Saurashtra & Kutch, Vidarbha and Telangana.

Small areas in northern and eastern parts of west Rajasthan; northwestern parts of east Uttar Pradesh; southern parts of coastal Andhra Pradesh and adjoining northeastern parts of Rayalaseema; northern parts of Madhya Maharashtra and northern and southern parts of Marathwada; central and northern parts of south interior Karnataka and adjoining western parts of Rayalaseema and eastern parts of north interior Karnataka.

Isolated areas around Gopalpur (Orissa) and Tondi (Tamil Nadu & Pondicherry).

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-divisionwise extent of rainfall in number of days like *widespread* and *fairly widespread*. Monthwise description is given below :

9.1. *Heavy rainfall during June*

During the month, *very heavy* rainfall occurred on 6 to 8 days in Assam & Meghalaya, Konkan & Goa; coastal Karnataka and Kerala; on 4 to 5 days in Sub-Himalayan West Bengal & Sikkim, Orissa, Gujarat Region, Madhya Maharashtra and south interior Karnataka and on 1 to 2 days in Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Bihar, Uttaranchal, Himachal Pradesh, east Madhya Pradesh & Chattisgarh and Saurashtra & Kutch. *Heavy* rainfall also occurred on 7 to 10 days in Assam & Meghalaya, Gangetic West Bengal and south interior Karnataka; on 4 to 6 in Nagaland-Manipur-Mizoram-Tripura, Orissa, Bihar, Himachal Pradesh, Konkan & Goa and Kerala and on 1 to 3 days in Andaman & Nicobar Islands, Arunachal Pradesh, Sub-Himalayan West Bengal & Sikkim, Jharkhand, east Uttar Pradesh, Uttaranchal, Haryana, Punjab, Jammu & Kashmir, east Rajasthan, west Madhya Pradesh, east Madhya Pradesh & Chattisgarh, Gujarat Region, Madhya Maharashtra, Telangana and coastal Karnataka.

9.2. *Heavy rainfall during July*

During the month, *very heavy* rainfall occurred on 8 to 11 days in Orissa and Konkan & Goa; on 4 to 6 days in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, east Uttar Pradesh, Himachal Pradesh, east Rajasthan, Gujarat Region, Madhya Maharashtra, south interior Karnataka and Kerala and on 1 to 3 days in Gangetic West Bengal, Bihar, west Uttar Pradesh, Uttaranchal, Haryana, Punjab, west Madhya Pradesh, east Madhya Pradesh & Chattisgarh, Saurashtra & Kutch, Tamil Nadu and coastal Karnataka. *Heavy* rain also occurred on 12 to 13 days in Assam & Meghalaya and coastal Karnataka, on 7 to 9 days in Sub-Himalayan West Bengal & Sikkim, west Uttar Pradesh and Madhya Maharashtra; on 4 to 6 days in Orissa, east Uttar Pradesh, Uttaranchal, Punjab, Himachal Pradesh, east Rajasthan, east Madhya Pradesh & Chattisgarh, Konkan & Goa, Vidarbha, Tamil Nadu, north interior Karnataka, south interior Karnataka and Kerala and on 1 to 3 days in Andaman & Nicobar Islands, Gangetic West Bengal, Bihar, Haryana, Jammu & Kashmir, west Rajasthan, west Madhya Pradesh, Gujarat Region, Marathwada and Lakshadweep.

9.3. *Heavy rainfall during August*

During the month, *very heavy* rainfall occurred on 8 days in Gujarat Region; on 4 to 5 days in Sub-Himalayan West Bengal & Sikkim and Konkan & Goa and on 1 to 3 days in Arunachal Pradesh, Assam & Meghalaya, Gangetic West Bengal, Orissa, Jharkhand, Bihar, east Uttar Pradesh west Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, west Rajasthan, Madhya Maharashtra, Marathwada, Tamil Nadu, coastal Karnataka and south interior Karnataka. *Heavy* rain has also occurred on 10 to 12 days in Assam & Meghalaya, Orissa and south interior Karnataka; on 7 to 9 days in Sub-Himalayan West Bengal & Sikkim, Bihar, east Uttar Pradesh, Konkan & Goa, Madhya Maharashtra and coastal Karnataka; on 4 to 6 days in Gangetic West Bengal, Uttaranchal, Himachal Pradesh, Jammu & Kashmir, east Rajasthan, Marathwada, Vidarbha, Telangana, north interior Karnataka and Kerala and on 1 to 3 days in Andaman & Nicobar Islands, Arunachal Pradesh, Nagaland-Manipur-Mizoram-Tripura, west Uttar Pradesh, Haryana, Punjab, west Rajasthan, Gujarat Region, Saurashtra & Kutch and Tamil Nadu.

9.4. *Heavy rainfall during September*

During the month, *very heavy* rainfall occurred on 9 days in Bihar; on 3 to 4 days in Sub-Himalayan West

Bengal & Sikkim, east Uttar Pradesh, Tamil Nadu and Kerala and on 1 to 2 days in Assam & Meghalaya, Nagaland-Manipur-Mizoram-Tripura, Gangetic West Bengal, Konkan & Goa, Madhya Maharashtra, coastal Andhra Pradesh, Rayalaseema, north interior Karnataka, south interior Karnataka and Lakshadweep. *Heavy* rain also occurred on 10 to 12 days in Assam & Meghalaya, Gangetic West Bengal, Tamil Nadu and south interior Karnataka; on 7 to 9 days in Sub-Himalayan West Bengal & Sikkim and north interior Karnataka on 4 to 6 days in Orissa, Konkan & Goa, Madhya Maharashtra, coastal Karnataka and Kerala and on 1 to 3 days in Andaman & Nicobar Islands, Arunachal Pradesh, Bihar, east Uttar Pradesh, Uttaranchal, Himachal Pradesh, Gujarat Region, Marathwada, Vidarbha, coastal Andhra Pradesh and Rayalaseema.

10. Significant temperature during the season

Significant temperatures were noticed only in the month of June and in remaining three months of the season, the temperature were within reasonable limits.

Day temperatures were *appreciably* to *markedly above normal* on 4 days in some parts of Jammu & Kashmir and on 1 to 2 days in some parts of Saurashtra & Kutch, Konkan & Goa, coastal Andhra Pradesh and Telangana and were *above normal* on 4 to 6 days in some parts of Jammu & Kashmir, west Rajasthan, Saurashtra & Kutch and coastal Karnataka and on 1 to 3 days in some parts of Gangetic West Bengal, Orissa, east Rajasthan, Gujarat Region, Konkan & Goa, Madhya Maharashtra, Telangana, Rayalaseema, north interior Karnataka and south interior Karnataka. They were *appreciably* to *markedly below normal* on 11 to 17 days in some parts of east Uttar Pradesh, west Uttar Pradesh, Uttaranchal, Haryana, Punjab and west Rajasthan; on 4 to 7 days in some parts of Orissa, Jharkhand, Bihar, Himachal Pradesh, Jammu & Kashmir, east Rajasthan, west Madhya Pradesh, east Madhya Pradesh & Chattisgarh, Gujarat Region and Vidarbha and on 1 to 3 days in some parts of Saurashtra & Kutch, Madhya Maharashtra, coastal Andhra Pradesh and Telangana and were *below normal* on 9 days in some parts of west Rajasthan ; 4 to 5 days in some parts of Haryana, Punjab, east Rajasthan and west Madhya Pradesh and on 1 to 3 days in some parts of Orissa, Jharkhand, Bihar, east Uttar Pradesh, Uttaranchal, Himachal Pradesh, Jammu & Kashmir, east Madhya Pradesh & Chattisgarh, Gujarat Region, Saurashtra & Kutch, Madhya Maharashtra, Marathwada, Vidarbha and Rayalaseema. Highest day temperature of 45°C was recorded at Phalodi (Rajasthan) on 12 June.

11. Disastrous weather events and damages during monsoon months

11.1. *June*

Heavy rains, lightning and floods took a toll of 102 (65 in Maharashtra, 16 in Kerala, 11 in Gujarat, 5 in Bihar, 4 in Chattisgarh and 1 in West Bengal) human lives. Also six fishermen are reported missing in Mumbai. Normal life disrupted due to water logging in Kolkata city in the first week of the month.

11.2. *July*

In all, 284 (133 in Orissa, 63 in Madhya Pradesh and Chattisgarh, 42 in Gujarat, 33 in Kerala, 6 in West Bengal, 5 in Maharashtra and 1 each in Assam and Karnataka) people lost their lives due to *heavy* rains and floods. 40 persons died in Madhya Pradesh due to bus collapse in flood water on 11 July. Road communication was disrupted due to floods in Assam in the first and last week of the month.

11.3. *August*

Bihar experienced serious floods in the first week of the month. Water level of river Yamuna crossed danger mark in Delhi. Normal life disrupted due to *heavy* rain in Satna district of Madhya Pradesh. In Assam, the road and rail communication remained cut-off due to floods; more than 61 villages submerged due to rising flood water of Brahmaputra river and damaged the standing crops worth lacks of rupees in large area. *Heavy* rain also took a toll of 29 (8 each in Karnataka and West Bengal, 4 each in Assam and Maharashtra, 3 in Madhya Pradesh & Chattisgarh and 2 in Tamil Nadu) people in other parts of the country.

11.4. *September*

Heavy rains and flood took a toll of 166 (148 in Bihar, 9 in Karnataka, 5 in West Bengal, 2 in Maharashtra and 1 each in Assam and Kerala) people. Water logging disrupted public life for second time in the season in Kolkata city due to torrential rain in large parts of the city on 11 September. Thousands of people in Jalpaiguri district of West Bengal were affected by flood in the first week of the month. NH-31 was washed away leading to complete communication disarray. Eighty thousand people were stranded in rain water.

12. Damages due to floods etc. during monsoon season

According to press reports, *heavy* rains and floods and rain related accidents took a toll of 581 people in different parts of the country. Bihar and Orissa were the most affected meteorological sub-divisions where 153 and 133 people respectively died due to floods. Other affected areas are Maharashtra (76), Madhya Pradesh & Chattisgarh (70), Gujarat (53), Kerala (50), West Bengal (20), Karnataka (18), Assam (6) and Tamil Nadu (2). Water level of Yamuna river in Delhi crossed the danger level during mid August.

More details of damages 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.

Acknowledgements

Valuable inputs from the offices of (1) DGM (Hydromet), New Delhi, (2) DGM(Sat. Met.), New Delhi, (3) ADGM(R), Pune and (4) DDGM(WF), Pune are gratefully acknowledged. Thanks are due to Smt. M. G. Huprikar, M. V. Mande, Miss B. T. Kulkarni and K. G. Pardeshi for their help in bringing out this report.

APPENDIX

Definitions of the terms given in '*Italics*'

Rainfall

Excess - percentage departure from rainfall is + 20% or more.

Normal - percentage departure from rainfall is between –19 % to + 19 %.

Deficient - percentage departure from rainfall is between – 20 % to –59 %.

Scanty - percentage departure from rainfall is between – 60 % to –99 %.

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

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

Few places - 26 % to 50 % stations of a meteorological sub-division reporting at least 2.5 mm rainfall.

Isolated places - 25% or less 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 over one or two stations in the sub-division.

Very heavy rainfall - rainfall amount more than 12.5 cm over one or two stations in the sub-division.

Monsoon activity

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

Vigorous - Average rainfall of a sub-division is more than 4 times or more than the normal with minimum 7 cm along the west coast and 5 cm elsewhere in atleast two stations in the sub-division.

Maximum/day temperatures

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

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

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 to –4° C.

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

Minimum/night temperatures

Appreciably below normal - departure of minimum temperature from normal is between –3° C to –4 ° Cfor the regions where the normal minimum temperature is 10 ° C or more.