MAUSAM, **50**, 3 (July 1999), 311-333

Weather in India

MONSOON SEASON (JUNE - SEPTEMBER 1998)*

1. Introduction

The seasonal rainfall was excess or normal in 33 meteorological sub-divisions and was marginally deficient in only two meteorological sub-divisions. No meteorological subdivision received scanty rainfall during the season. One very severe cyclonic storm over the Arabian Sea and a deep depression over the Bay of Bengal formed in the month of June. One land depression over west Madhya Pradesh and a depression over east-central Arabian Sea formed in the month of September. No depression/storm formed in the other two months of the season 1998. Off-shore troughs along different parts of west coast persisted on most days throughout the season. The seasonal rainfall departures, station wise and sub-divisionwise are given in Figs.1 and 2.

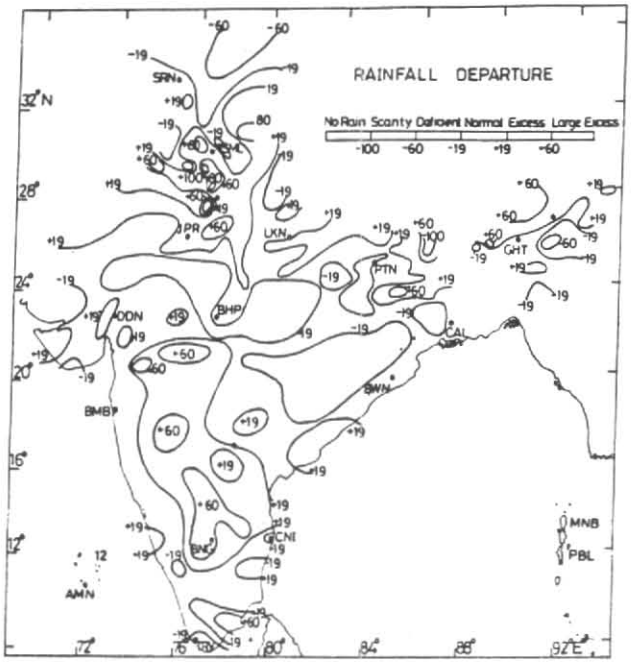

Fig.1. Stationwise seasonal rainfall departure (%) for the period of June - September 1998

2. Characteristic features of southwest monsoon 1998

2.1. The southwest monsoon set in over Kerala on 2 June as against the normal date of 1 June without any onset vortex over the Arabian Sea. Advance of Southwest monsoon over northeast India was earlier than Kerala as in the years 1972, 1995 and 1996. However, its further advance over the country was rapid in association with a cyclonic storm in the Arabian Sea and a depression in the Bay of Bengal.

2.2. The southwest monsoon covered the entire country by 30th June, 15 day earlier than the normal date similar to 1960 (29 June), 1961 (21 June) and 1980 (26 June). The advance of monsoon across the country was however rather quick.

2.3. One very severe cyclonic storm (4 - 10 June) in the Arabian Sea and three depressions (1 in June and 2 in September) formed during the season. No cyclonic storm formed over the Bay of Bengal during the season. One deep depression (30 September - 1 October) over the Arabian Sea, one deep depression (14 - 15 June) over Bay of Bengal and one land depression (14 - 18 September) over west Madhya Pradesh formed during the season. The very severe cyclonic storm which formed over Arabian Sea crossed Gujarat coast near Porbandar on 9 June morning. The deep depression which formed over west-central Bay and neighbourhood on 13 moved westnorthwestwards and crossed the north Andhra coast on 14 night very close to Vishakhapatnam and weakened as a well marked low pressure area over Vidarbha and neighbourhood. The land depression which formed over central parts of Madhya Pradesh on 14 close to Bhopal moved westnorthwesterly direction and weakened into a well marked low pressure area over north Gujarat and adjoining west Rajasthan. The third depression which formed over east central Arabian Sea on 30 June weakened into a well marked low pressure area over westcentral Arabian sea.

2.4 In addition to the above systems there were 9 low pressure areas (1 in June, 4 in July, 2 each in August and

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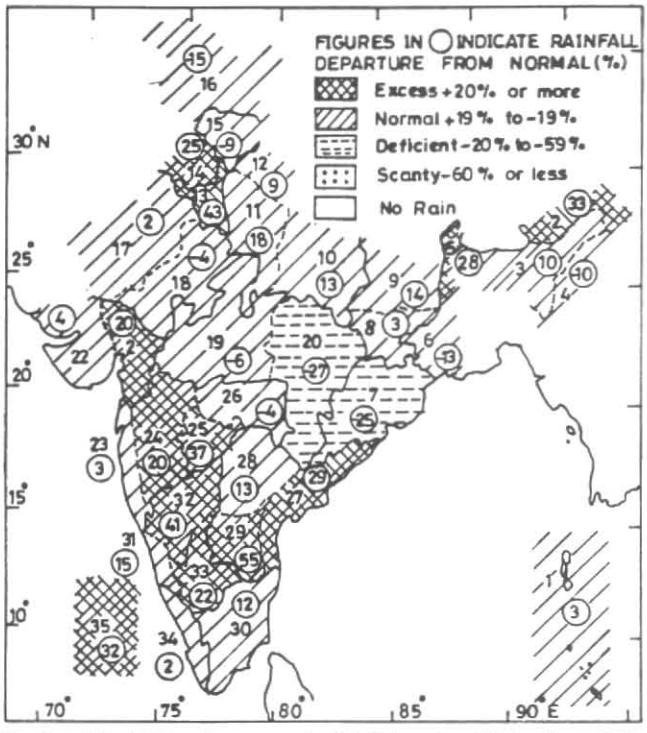


Fig.2. Sub-divisionwise seasonal rainfall departure (%) for the period June - September 1998

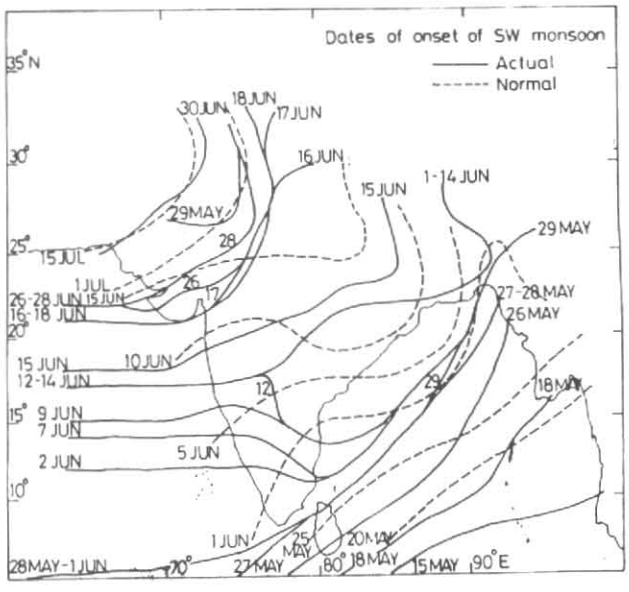


Fig.3. Advance of southwest monsoon 1998

September), 51 cyclonic circulations (8 in June, 13 in July, 15 each in August and September), 11 troughs (4 each in June and July, 3 in August) and 4 western disturbances (4 in September) which affected the monsoon.

2.5. Rainfall was well distributed in space and time during the season. From the week ending 8 July, 80% or more of the Meteorological sub-divisions received excess or normal rainfall.

2.6. In all the 17 weeks, rainfall was either deficient or scanty in Orissa and east Madhya Pradesh, over Nagaland, Manipur, Mizoram and Tripura, rainfall was either deficient or scanty during the first 11 weeks and thereafter it became normal in the last 6 weeks of the season.

2.7. Rainfall was excess or normal throughout the period in Arunachal Pradesh, Assam and Meghalaya, Sub-Himalayan West Bengal and Sikkim, Rajasthan, Gujarat state, Madhya Maharashtra and Lakshadweep.

2.8. Rainfall during the monsoon season was excess in 12, normal in 21 meteorological sub-divisions. It was marginally deficient only in 2 meteorological sub-divisions, *viz.*, Orissa (-25%) and east Madhya Pradesh (-27%).

2.9. The country received total rainfal of 105 % of its long period average.

2.10. Out of 35 meteorological sub-divisions, excess or normal rainfall was received 25 in June, 29 in July, 27 in August and 29 in September meteorological sub-divisions.

2.11. Monsoon trough and Tibetan Anti cyclone established early in the season. Monsoon trough got established on 15 June. It lay close to the foot hills of the Himalayas from 15 July to 26 July and from 21 August to 31 August.

2.12. Southwest monsoon withdrew from western parts of west Rajasthan on 7 September, 6 days after normal date of withdrawal. It further withdrew from Madhya Pradesh, Orissa, Maharashtra and northeast India by 9 October. It withdrew from the entire country by 20 October.

2.13. Off-shore trough on sea level chart was present 25 days in June, 21 days in July, 25 days in August and 27 days in September. Thus, off-shore trough along the west coast was almost a semi-permanent feature of the season.

2.14. Northeast monsoon rains commenced over Tamil Nadu, Kerala and adjoining states Karnataka and Andhra Pradesh on 28 October.

2.15. Northeast monsoon withdrew from Tamil Nadu & Pondicherry, Kerala and adjoining parts of Andhra Pradesh and of Karnataka on 22 December 1998.

3. Features of monsoon

3.1. *Advance of southwest monsoon*

The southwest monsoon set in over Kerala on 2 June as against the normal date of 1 June without any onset vortex over the Arabian Sea. Advance of Southwest monsoon over northeast India was earlier than Kerala as in the years 1972, 1995 and 1996. However, its further advance over the country was rapid in association with a cyclonic storm in the Arabian Sea and a depression in the Bay of Bengal. The southwest monsoon covered the entire country by 30th June,

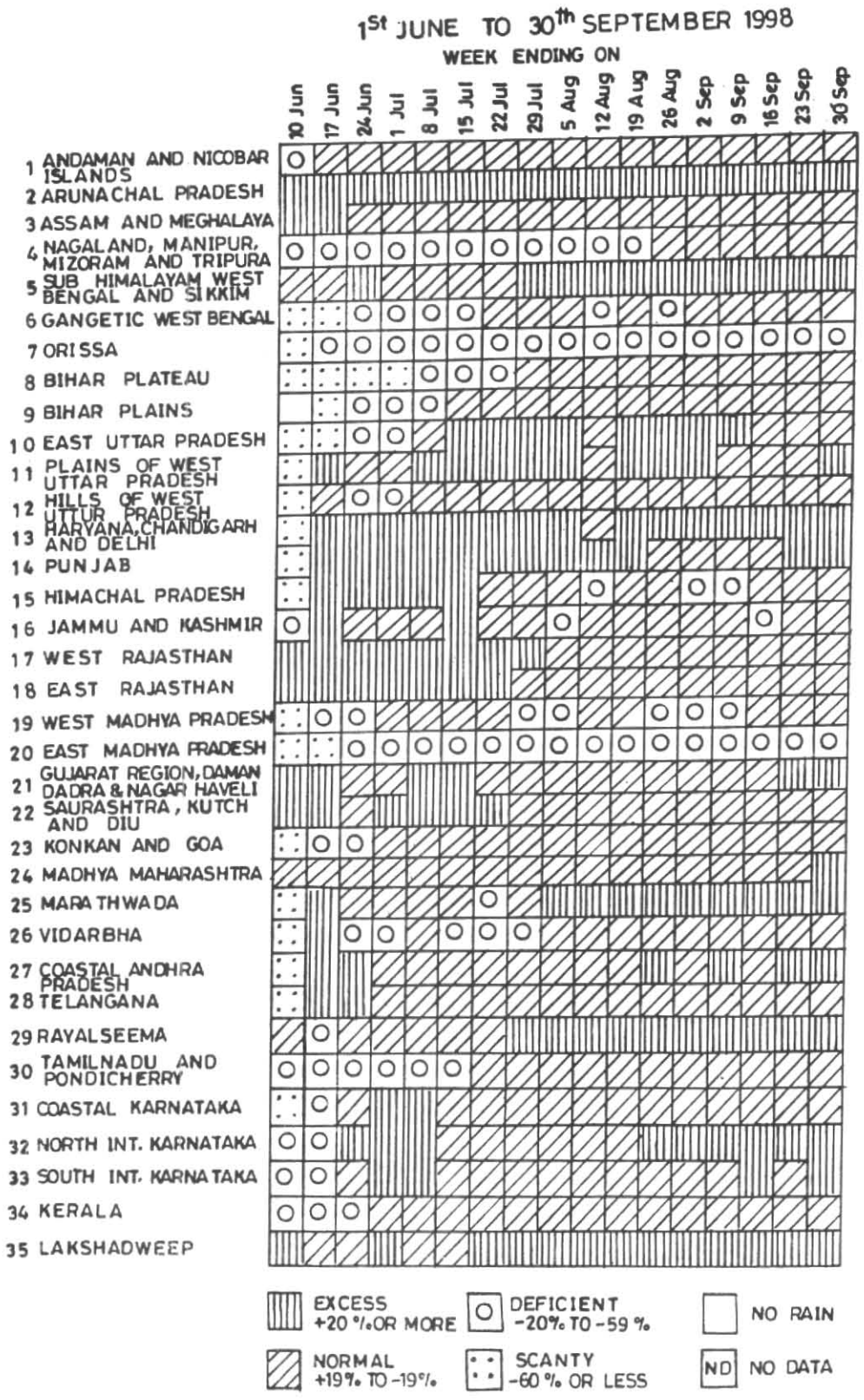


Fig.4 . Progress of southwest monsoon week- by -week (1 June to 30 September 1998)

TABLE 1

Rainfall figures (mm) for each month and season as a whole (June- September 1998)

S. No.	Meteorological sub-division	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	481	470	2	381	357	7	363	360	1	418	407	3	1643	1595	3
2.	Arunachal Pradesh	899	568	58	770	674	14	762	483	58	277	307	-10	2708	2035	33
3.	Assam & Meghalaya	640	598	7	656	528	24	549	450	22	243	325	-25	2088	1903	10
4.	Naga., Maini.,Mizo. & Tri.	224	387	-42	423	328	29	326	295	11	145	237	- 39	1118	1236	- 10
5.	SHWB & Sikkim	593	524	13	779	609	28	753	502	50	486	404	20	2611	2038	28
6.	Gangetic West Bengal	155	247	-37	296	312	- 5	235	308	-24	269	230	17	954	1096	- 13
7.	Orissa	162	221	- 27	261	357	- 27	189	356	- 47	271	243	12	882	1177	- 25
8.	Bihar Plateau	111	195	- 43	373	334	12	303	324	- 7	343	226	52	1104	1074	3
9.	Bihar Plains	109	168	- 35	464	311	49	355	303	17	211	220	- 4	1139	1003	14
10.	East U.P.	67	105	-36	429	303	42	394	299	32	127	191	- 33	1018	898	13
11.	Plains of west U.P.	72	80	- 11	333	264	26	393	269	46	114	162	- 29	912	775	18
12.	Hills of west U.P.	141	169	- 17	458	449	2	606	448	35	205	229	- 11	1409	1295	9
13.	Haryana, Chandigarh & Delhi	116	51	127	213	175	22	211	179	18	196	108	81	735	513	43
14.	Punjab	69	42	63	230	188	22	143	169	- 15	179	99	80	621	499	25
15.	Himachal Pradesh	163	97	69	235	347	- 32	236	321	- 26	206	157	31	841	921	- 9
16.	Jammu & Kashmir	48	55	- 12	132	171	- 23	123	170	- 27	62	86	- 28	408	483	- 15
17.	West Rajasthan	66	28	139	85	101	- 16	64	106	- 39	72	47	53	287	281	2
18.	East Rajasthan	76	57	33	219	226	- 3	177	226	- 22	131	117	11	602	627	-4
19.	West Madhya Pradesh	104	115	- 10	245	318	-23	254	316	- 20	257	174	48	864	920	- 6
20.	East Madhya Pradesh	93	166	- 44	259	385	- 38	282	385	-27	221	213	4	834	1149	-27
21.	Gujarat Region	162	145	12	372	433	- 14	283	301	- 6	455	181	152	1272	1060	20
22.	Saurashtra & Kutch	114	91	26	232	240	-3	155	129	20	67	85	-21	568	544	4
23.	Konkan & Goa	719	685	5	914	1106	-17	730	663	10	532	348	53	2896	2801	3
24.	Madhya Maharashtra	150	140	7	264	271	-3	221	179	24	256	155	65	890	745	20
25.	Marathwada	160	146	9	290	206	41	276	187	48	254	179	42	980	717	37
26.	Vidarbha	134	171	-22	291	228	-14	247	272	-9	267	194	37	939	975	-4
27.	Cot. Andhra Pradesh	114	109	4	181	168	7	215	160	35	275	170	62	784	608	29
28.	Telangana	143	135	6	239	243	-2	279	212	32	222	188	18	882	778	13
29.	Rayalaseema	47	59	-21	133	85	68	182	97	88	215	131	64	577	372	55
30.	Tamil Nadu	31	47	-34	76	72	6	120	76	57	109	103	6	337	299	12
31.	Coastal Karnataka	1124	923	22	1213	1214	0	637	715	-11	685	326	110	3659	3178	15
32.	N.I. Karnataka	124	90	38	129	132	-3	161	109	48	253	142	79	667	473	41
33.	S.I. Karnataka	161	139	16	282	256	10	224	172	30	186	132	41	853	699	22
34.	Kerala	724	697	4	600	765	-22	366	439	-17	516	252	105	2207	2153	2
35.	Lakshadweep	382	307	24	389	283	37	197	192	3	275	161	71	1242	944	32

TABLE 2

State-wise number of districts with excess, normal, deficient and scanty rainfall for the period 1 June to 30 September 1998 (Provisional)

State/UT	Excess	Normal	Deficient	Scanty	N.R.	**	Total
Andaman & Nicobar Islands (UT)	0	1	0	0	0	0	1
Arunachal Pradesh	3	1	0	0	0	1	5
Assam	6	5	2	1	0	2	16
Meghalaya	0	2	0	0	0	0	2
Nagaland	0	0	1	0	0	0	1
Manipur	0	1	0	0	0	0	1
Mizoram	0	0	1	0	0	0	1
Tripura	0	1	0	0	0	0	1
Sikkim	0	1	0	0	0	0	1
West Bengal	6	7	3	0	0	0	16
Orissa	0	5	8	0	0	0	13
Bihar	12	18	7	0	0	2	39
Uttar Pradesh	24	30	2	0	0	0	56
Haryana	12	4	0	0	0	0	16
Chandigarh (UT)	1	0	0	0	0	0	1
Delhi (UT)	1	0	0	0	0	0	1
Punjab	6	2	3	0	0	1	12
Himachal Pradesh	2	6	4	0	0	0	12
Jammu & Kashmir	1	3	3	1	0	4	12
Rajasthan	10	13	7	0	0	0	30
Madhya Pradesh	7	17	21	0	0	0	45
Gujarat	6	12	1	0	0	0	19
Dadra, Nagar Haveli & Daman (UTs)	0	1	0	0	0	0	1
Diu(UT)	0	0	1	0	0	0	1
Goa	0	1	0	0	0	0	1
Maharashtra	15	13	2	0	0	0	30
Andhra Pradesh	13	10	0	0	0	0	23
Tamil Nadu	8	9	5	0	0	0	22
Pondicherry (UT)	0	1	0	0	0	0	1
Karnataka	19	8	0	0	0	0	27
Kerala	1	11	2	0	0	0	14
Lakshadweep (UT)	1	0	0	0	0	0	1
Total	154	183	73	2	0	10	422
% Distribution of 412 dists. recd.	37	44	18	1	0		

Total No. of Districts from which data have been received = 412 ** = data inadequate.

15 days earlier than the normal date similar to 1960 (29 June), 1961 (21 June) and 1980 (26 June). Thus advance of monsoon across the country was rather quick.

Isochrones of advance of southwest monsoon 1998 are shown in Fig.3.

3.2. *Week by week cumulative rainfall distribution 1 June 1998 - 30 September 1998*

Meteorological Sub-divisionwise cumulative rainfall departures (percentage departures from normal) during the period 1 June to 30 September 1998 comprising of 17 weeks are given in Fig.4. Rainfall given in this figure are computed from the updated data. Rainfall activity was very well distributed in space and time throughout the season.

For the week ending 10, 17, 24 June and 1 July, the rainfall received was in excess or normal in about 29%, 57%, 63% and 71% of the meteorological sub-divisions respectively. From the week ending 8 July onwards, 80% or more of the meteorological sub-divisions received excess or normal rainfall.

In all the 17 weeks (from 1 June to 30 September 1998), weekly rainfall was excess or normal throughout the period in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Rajasthan, Gujarat State, Madhya Maharashtra and Lakshadweep. It was excess in 9 weeks or more in Andaman & Nicobar Islands, Gangetic West Bengal, Bihar, Uttar Pradesh, Haryana, Chandigarh &

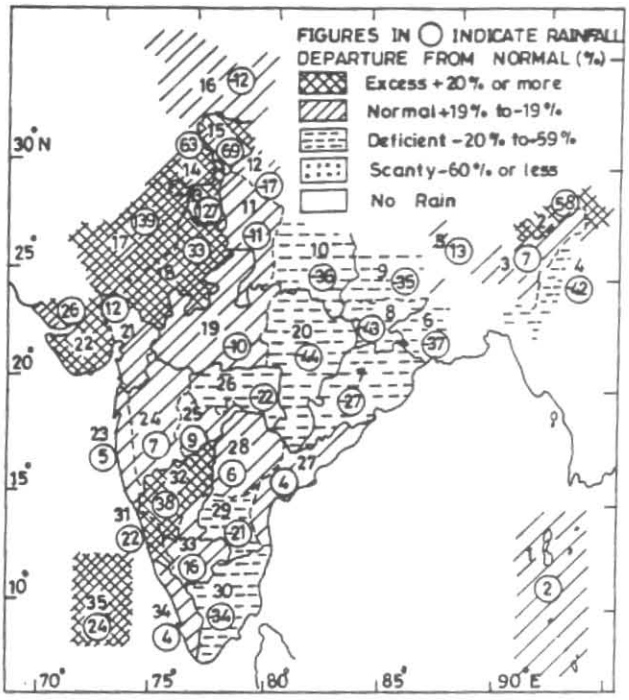


Fig.5. Rainfall for the month of June 1998 (Figures in square indicate rainfall percentage departure from normal)

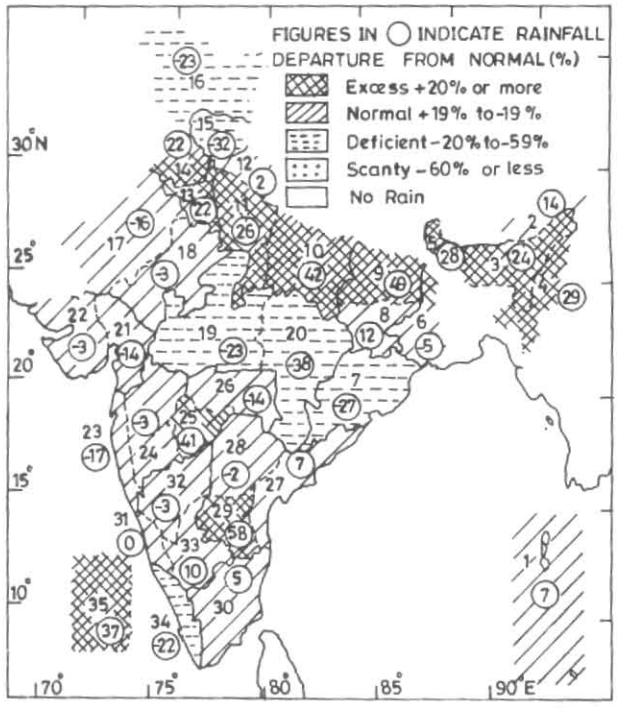


Fig.6. Rainfall for the month of July 1998 (Figures in square indicate rainfall percentage departure from normal)

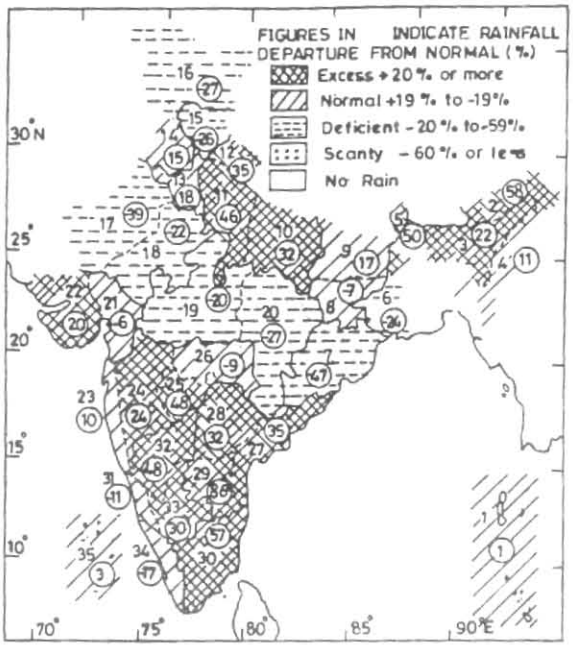


Fig.7. Rainfall for the month of August 1998 (Figures in square indicate rainfall percentage departure from normal)

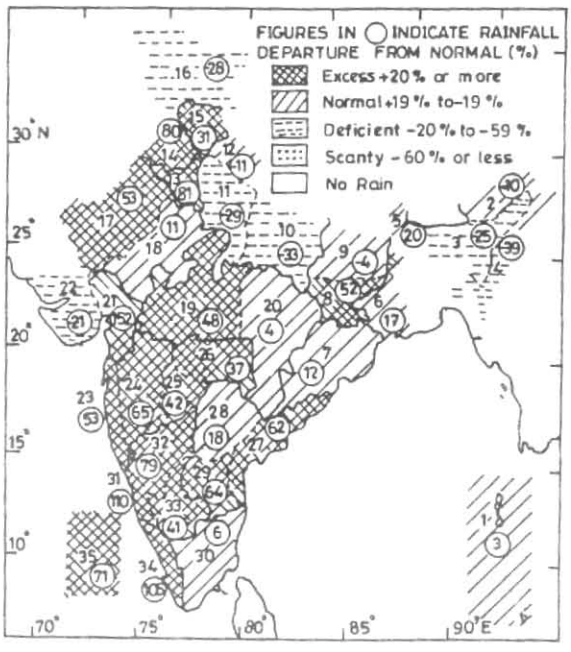


Fig.8. Rainfall for the month of September 1998 (Figures in square indicate rainfall percentage departure from normal)

Delhi, Punjab, Himachal Pradesh, Jammu & Kashmir, west Madhya Pradesh, Konkan & Goa, Marathwada, Vidarbha, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala. Weekly rainfall was either deficient or scanty throughout the period in Orissa and east Madhya Pradesh and over Nagaland, Manipur, Mizoram & Tripura during first 11 weeks and thereafter it became normal in the last 6 weeks of the season.

3.3. *Month-by-month performance of monsoon rainfall*

Figs.5-8 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 Appendix 1.

TABLE 3

Details of the weather systems during June 1998

S. No.	System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(A) *Storms/Depression*						
1.	Very severe cyclonic storm	4 - 10	Southeast Arabian Sea and adjoining Lakshadweep	Initially northnorthwesterly and then northnortheasterly	Punjab and adjoining parts of Himachal Pradesh	It was first seen as a low pressure area over southeast Arabian Sea and adjoining Lakshadweep area on 2. It became well-marked on 4. It concentrated into a depression on 4 and intensified into a deep depression on the same evening. It intensified into a cyclonic storm in the evening of 5. It further intensified into a severe cyclonic storm on 6. Moving in a northnorthwesterly direction it further intensified into a very severe cyclonic storm on 7. Then, it recurved and moved in a northnortheasterly direction and crossed Gujarat coast near Porbandar between 0200 and 0300 UTC of 9. After crossing the coast, it weakened into a severe cyclonic storm on 10 morning near Kandla and further weakened into a deep depression and into a depression over east Rajasthan. Moving further, it weakened into a low pressure area over Punjab and adjoining parts of Himachal Pradesh
2.	Deep depression	13 - 15	West-central Bay and neighbourhood	Westnorthwesterly	Plains of west Uttar Pradesh	It was first observed as a low pressure area over west-central Bay and neighbourhood. It concentrated into a depression and into a deep depression over north Andhra coast on 14, it crossed north Andhra Pradesh coast and lay as depression over Nagpur. It weakened into low pressure area over west Madhya Pradesh on 16
(B) *Low pressure area*						
1.	Low pressure area	23 - 24	Northwest Bay off West Bengal coast	Northerly	Gangetic west Bengal and neighbourhood	Associated cyclonic circulation extended upto mid tropospheric levels. It merged with the monsoon trough on 25
(C) *Embedded cyclonic circulations*						
1.	Lower levels	2 - 3	Gangetic West Bengal and adjoining parts of Bihar	Stationary	*In situ*	Merged with the trough from east Uttar Pradesh to east-central Bay
(D) *Other cyclonic circulations*						
1.	Lower levels	1 - 2	Southwest Rajasthan and adjoining Rajasthan	Stationary	*In situ*	
2.	Lower tropospheric levels	3 - 6	South Pakistan and neighbourhood	Northeasterly	West Rajasthan and adjoining parts of central Pakistan	Moved away northeastwards
3.	Lower levels	6 - 8	West Rajasthan and adjoining Pakistan	Stationary	*In situ*	
4.	Do	12 - 15	Southwest Rajasthan	Do	Do	
5.	Mid tropospheric levels	18 Jun-1 Jul	Coastal Karnataka and neighbourhood			Tilting southwards with height from 27 to 30
6.	Mid tropospheric levels	27 - 30	Bihar Plateau and adjoining parts of Orissa	Quasi-stationary	North Orissa and adjoining parts of Bihar Plateau	Titled southwards with height
7.	Lower tropospheric levels	27 Jun - 1 Jul	Southwest Rajasthan and adjoining Pakistan	Northeasterly	Haryana and neighbourhood	Merged with the monsoon trough
(E) *Troughs in westerlies*						
1.	Mid and upper troposphere	15 - 16	70°E, north of 20°N	Stationary	*In situ*	
(F). *Troughs in easterlies*						
(1.	*Lower tropospheric levels*	31 May - 2 Jun	Sub-Himalayan West Bengal & Sikkim to northwest Bay	Westerly	Bihar plains to north-west Bay	
2.	Lower tropospheric levels	10 - 13	North Bay to north Andaman Sea	Northwesterly	Sub-Himalayan West Bengal to Southeast Bay across east-central Bay	

TABLE 4

Details of the weather systems during July 1998

S.No.	System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(A) *Low pressure areas*						
1.	Well-marked low pressure area	1 - 6	Northwest Bay off north Orissa-West Bengal coast	Northwesterly	Central parts of Bihar	It was first observed as an upper air cyclonic circulation over Gangetic West Bengal and adjoining parts of north Orissa on 29 June. The trough was tilted southwards with height. Associated cyclonic circulation extended upto mid tropospheric levels ,tilted southwards with height The low pressure area became well-marked on 3
2.	Low pressure area	2 - 5	Saurashtra & neighbourhood	Northerly	Some parts of Kutch and adjoining parts of Saurashtra	Associated cyclonic circulation extended upto mid tropospheric levels, tilted southwards with height.
3.	Do	9 - 14	Northwest Bay off West Bengal-north Orissa coasts	Northwesterly	Central parts of Uttar Pradesh	It was first observed as a cyclonic circulation over north Andhra-south Orissa coasts Associated cyclonic circulation extended upto mid tropospheric levels, tilting south- wards with height. A trough from this system run to Gujarat. It became less marked on 17
4.	Do	28 Jul - 1 Aug	Off north Andhra - south Orissa coast	Northwesterly	West Madhya Pradesh adjoining east Rajasthan	Associated cyclonic circulation extended upto mid tropospheric levels
(B) *Cyclonic circulations*						
1.	Lower levels	5 - 7	Punjab and adjoining parts of Pakistan	Stationary	*In situ*	
2.	Mid tropospheric levels	9 - 14	West Rajasthan	Northeasterly	Punjab and adjoining parts of Himachal Pradesh	
3.	Do	10 - 12	North Gujarat and adjoining south Rajasthan	Southerly	Gujarat region and neighbourhood	
4.	Do	13 - 15	Kutch and adjoining parts of Saurashtra	Stationary	*In situ*	
5.	Lower tropospheric levels	14 - 15	South Pakistan and adjoining west Rajasthan	Stationary	*In situ*	
6.	Do	17 - 19	South Pakistan and neighbourhood	Do	*In situ*	
7.	Do	17-20	North Punjab and neighbour-hood	Southeasterly	Plains of west Uttar Pradesh	
8.	Mid tropospheric levels	19 - 21	South Tamil Nadu and neighbourhood	Stationary	*In situ*	
9.	Do	21 - 23	West-central Bay off south Andhra coast	Do	Do	
10.	Mid tropospheric levels	21 - 23	Northern parts of Kutch and adjoining parts of south Pakistan	Stationary	*In situ*	
11.	Do	24 - 25	North Kerala coast and neighbourhood	Do	Do	
12.	Do	26 Jul- 1 Aug	North Konkan and neighbourhood	Northerly	South Gujarat and north Maharashtra coast	
13.	Do	29 Jul - 2 Aug	Gulf of Siam and neighbourhood	Westnorth-westerly	Andaman Sea	It was first observed as a trough over Andaman Sea extending upto lower tropospheric levels
(C) *Troughs in the lower levels*						
1.	Lower levels	15 - 17	North Pakistan to Plains of west Uttar Pradesh	Stationary	*In situ*	
2.	Do	20 - 21	Northwest Punjab to Plains of west Uttar Pradesh	Do	Do	
3.	Lower tropospheric levels	23 - 25	West-central Bay to southwest Bay	Do	Do	

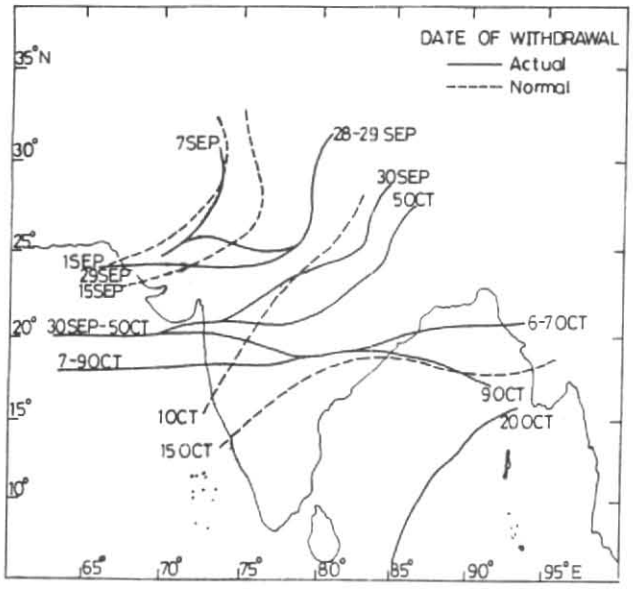


Fig.9. Withdrawal of southwest monsoon 1998

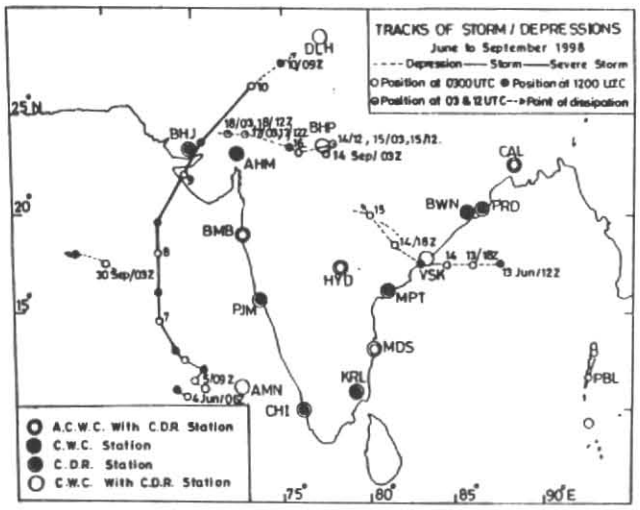


Fig.10. Tracks of storm/depressions (June to September 1998)

3.4. *Seasonal performance of monsoon rainfall*

The seasonal rainfall was excess in 12 and normal in 21 meteorological sub-divisions. It was deficient in only two meteorological sub-divisions namely Orissa (- 25%) and east Madhya Pradesh (- 27%). Seasonal total rainfall for the country as a whole was normal and received 105% of its long period average value.

3.5. *Districtwise distribution of rainfall*

Data received for 412 (out of 422) meteorological districts show that, 154 (37%) districts received excess rainfall and 183 (44%) districts received normal rainfall (Table 2) during the season. Statewise number of districts which received excess/normal rainfall is given in Table 2.

3.6. *Withdrawal of southwest monsoon*

Southwest monsoon withdrew from western parts of west Rajasthan on 7 September, 6 days after the normal date of withdrawal. It further withdrew from Madhya Pradesh, Orissa, Maharashtra and northeast India by 9 October. It withdrew from the entire country by 20 October. Withdrawal dates of southwest monsoon are given in Fig.9.

3.7. *El-Nino phenomenon*

El-Nino indicates the anomalous rise in sea surface temperature over the east Pacific. A see-saw relationship between sea level pressure over the southeastern Pacific ocean and the Indian ocean is known as Southern Oscillation (SO), which is the atmospheric response to the El-Nino. Thus, "El-Nino Southern Oscillation" or ENSO can be considered as a measure of Ocean-Atmospheric coupling. The phase and magnitude of the ENSO can be indicated either by the sea surface temperature anomalies (SST anomalies) over the Pacific or by the Southern Oscillation Index (SOI) expressed as the difference in atmospheric surface pressure between Tahiti (an island station in the southeast Pacific Ocean) and Darwin (Australia). Generally, inverse relationship between ENSO and Indian summer monsoon rainfall has been observed. However, magnitude and sign of this relationship shows epochal dependence.

TABLE 4.1

Pacific SST anomalies (°C)

Month	Nino 1+2 0-10°S 90°- 80°W	Nino 3 5° N- 5°S 150°-90° W	Nino 4 5° N-5° S 60°-150° W	SOI
Dec 97	4.5	3.9	1.1	-1.3
Jan 98	3.9	3.6	1.0	-3.3
Feb 98	3.2	2.7	0.8	-2.7
Mar 98	3.0	2.3	0.6	-3.5
Apr 98	3.3	1.8	0.2	-1.9
May 98	3.8	1.4	0.1	0.1
Jun 98	2.6	-0.2	0.1	0.7
Jul 98	2.0	-0.1	-0.4	1.3
Aug 98	1.2	-0.2	-0.6	1.0
Sep 98	0.7	-0.4	-0.4	1.2
Oct 98	0.6	-0.6	-1.0	1.0
Nov 98	0.0	-0.6	-1.0	1.1

The warm ENSO conditions which prevailed over tropical Pacific since 1997 reached its peak in December 1997 and thereafter started to show sign of weakening. The Table 4.1 depicts the monthly values of sea surface temperature anomalies at various geographical regions of tropical Pacific and SOI for the period December 1997 to November 1998. Along the south American coast, SSTs in the Nino 1+2 region from its peak value of December 1997, initially declined for a brief period upto March 1998.

After showing an increase in April and May 1998, the SSTs in this region decreased abruptly in June and then

TABLE 5

Details of the weather systems during August 1998

S.No.	System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(A) *Low pressure areas*						
1.	Extended low pressure	6 - 10	Gangetic west-Orissa and adjoining north Bay	Northwesterly	Southwest Uttar Pradesh and neighbourhood	It was first observed as a cyclonic circulation extending upto mid tropospheric levels, tilting southwards with height. The system merged with the seasonal trough. Associated cyclonic circulation extended upto mid tropospheric levels and became less marked on 12
2.	Low pressure area	23 - 24	Southwest Bay and neighbourhood	Stationary	*In situ*	It was first seen as a cyclonic circulation over south Andaman Sea off Tennessarim coast. Moving in a northwesterly direction, it lay as a trough over west-central Bay extending upto mid tropospheric levels on 22. Associated cyclonic circulation extended upto mid tropospheric levels, tilting westwards with height. It became less marked on 29 over Gulf of Cambay
(B) *Induced cyclonic circulations*						
1.	Lower levels	8 - 9	Punjab Haryana and adjoining Rajasthan	Stationary	*In situ*	
2.	Do	11-14	Central Pakistan and neighbourhood	Easterly	Punjab and neighbourhood	Merged with the seasonal trough
(C) *Cyclonic circulations*						
1.	Mid tropospheric levels	2 - 3	Northwest Madhya Pradesh and neighbourhood	Stationary	*In situ*	
2.	Lower tropospheric levels	2 - 3	Punjab and neighbourhood	Northeasterly	Himachal Pradesh	Moved away northeastwards
3.	Mid tropospheric levels	2 - 3	Saurashtra and neighbourhood	Stationary	*In situ*	It was first observed as a trough in the mid tropospheric levels over Bihar Plains to coastal Orissa on 11. Trough from the system to north Bay in the lower levels was observed on 13. It became less marked on 18
4.	Lower tropospheric levels	6 - 7	Central Uttar Pradesh and neighbourhood	Do	Do	
5.	Mid tropospheric levels	9 - 13	North Bay and adjoining central Bay off Gangetic West Bengal-Orissa coasts.	Northwesterly	East Madhya Pradesh and neighbourhood	
6.	Do	11 - 13	West Madhya Pradesh and adjoining Gujarat Region and north Madhya Maharashtra	Southwesterly	South Gujarat State and neighbourhood	Tilted southwards with height
7.	Lower levels	13 - 17	Gangetic West Bengal neighbourhood	Northwesterly	Haryana and neighbourhood	A trough from this system extended southwards upto north Tamil Nadu in lower levels. The system lay as a trough from 17 to 19
8.	Mid tropospheric levels	19 - 21	Bangladesh	Northwesterly	Gangetic West Bengal and adjoining Bihar Plateau	
9.	Do	19 - 22	North Pakistan and neighbourhood	Southeasterly	Punjab and neighbourhood	

Contd.

TABLE 5 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
10.	Lower tropospheric levels	23-25	Pakistan and adjoining parts of west Rajasthan	Northnortheasterly	North Pakistan and neighbourhood	
11.	Do	24-26	South parts of Haryana and neighbourhood	Eastarly	Southern parts of west Uttar Pradesh and neighbourhood	Merged with the monsoon trough
12.	Lower levels	26 - 28	East Rajasthan and neighbourhood	Northerly	Haryana and neighbourhood	A trough from this system was seen from southeast Rajasthan in lower levels. It became less marked on 29
13.	Mid tropospheric levels	29 - 30	Haryana and neighbourhood	Stationary	*In situ*	
(D)	*Western disturbance*					
1.	Upper air system	6 - 7	North Pakistan and neighbourhood	Northeasterly	Jammu & Kashmir and neighbourhood	Moved away northeastwards
2.	Do	7 - 10	Do	Eastnortheasterly	Do	Do
3.	Do	26 - 29	Do	Do	Do	Do
(E)	*Troughs*					
1.	Lower tropospheric levels	3 - 5	Marathwada to south Tamil Nadu	Easterly	Telangana to south Tamil Nadu	
2.	Lower levels	17 - 18	Sub-Himalayan West Bengal to northwest Bay	Stationary	*In situ*	
3.	Do	18 - 19	Central parts of Uttar Pradesh to coastal Andhra Pradesh	Do	Do	

declined steadily to reach its normal value in November 1998. In other two regions (Nino 3 and Nino 4) also the SSTs were warmest during December 1997. Thereafter the SSTs declined regularly and during the monsoon season weak cold episode (La-Nina) conditions prevailed over these regions. During October-November 1998, the cold episode conditions became moderate as SSTs more than 1.0°C below normal were observed over Nino 3 and Nino 4 regions. The SOI values also showed variations in consistent with the SST anomalies over central & east-central Pacific. During the warm episode, it reached its highest negative value of -3.5 in March 1998, which is three months later than the month when SST anomalies peaked over tropical Pacific. Subsequently, SOI showed abrupt increase to change its sign to positive in May 1998, one month before the SST anomalies over Nino 3 changed its sign. The positive values of SOI during May- November 1998 were consistent with the cold episode conditions which prevailed during the period.

4. Chief synoptic features during the monsoon

The synoptic disturbances which affected the Indian monsoon region in June, July, August and September are given in Table 3,4,5 and 6 respectively.

4.1. *Cyclonic storms/depressions*

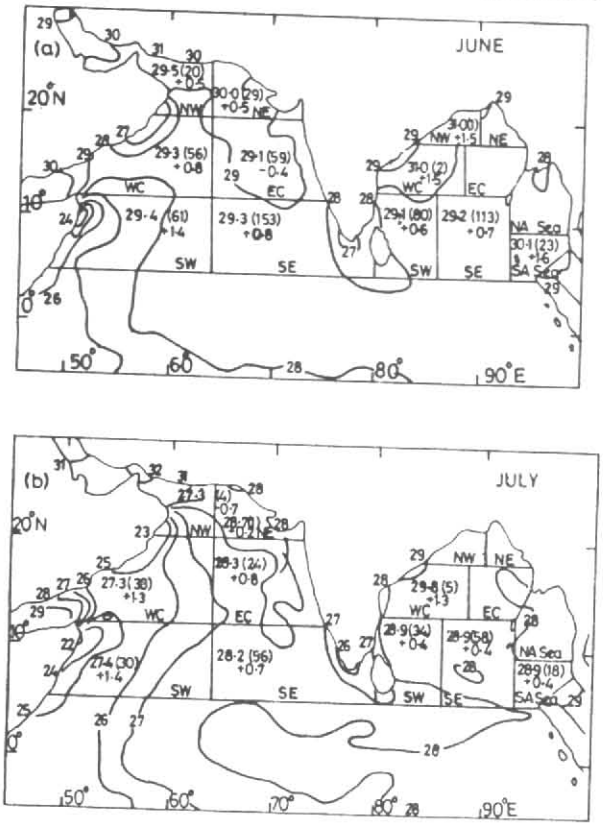
The tracks of storms/depressions are shown in Fig.10.

4.1.1. *Very severe cyclonic storm over the Arabian Sea (4 - 10 June 1998)*

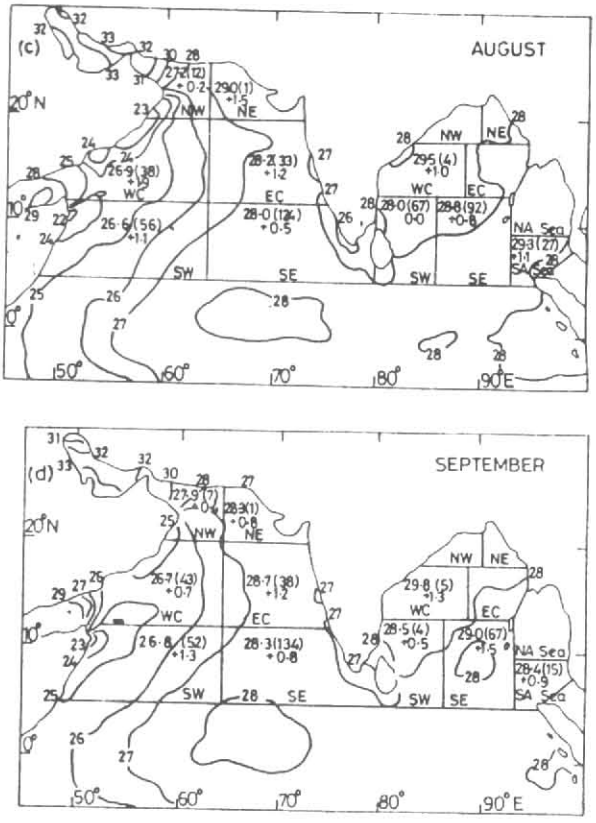
A low pressure area formed over southeast Arabian Sea and adjoining Lakshadweep area on 2 evening and became well-marked on 4 and its central region was near Lat. 11.0° N/Long. 71.0°E. It concentrated into a depression at 0900 UTC of 4 and further intensified into a deep depression at 1200 UTC of 4 June near Lat. 11.0° N/Long. 69.0° E. It further intensified into a cyclonic storm at 1200 UTC of 5 and lay near Lat. 12.0° N/Long. 70.5° E. It moved in a northnorthwesterly direction and at 0300 UTC of 6 it lay near Lat. 12.5° N/Long. 69.5° E, about 560 kms southwest of Goa. It further intensified into a severe cyclonic storm at 0900 UTC of 6 and moved in a northnorthwesterly direction and lay at 0300 UTC of 7 near Lat. 14.5° N/Long. 68.0° E, about 650 kms westsouthwest of Goa. It further intensified into a very severe cyclonic storm and lay at 1200 UTC of 7 near Lat. 16.0° N/Long. 68.0°E. At 0300 UTC of 8, it lay near Lat. 18.0° N/Long. 68.0°E, about 400 kms southwest of Veraval. Then, it moved in a northnortheasterly direction and crossed Gujarat coast near Porbandar on 9 morning and lay as a very severe cyclonic storm about 50 kms northnortheast of Porbandar on 9 morning. It moved in a northnortheasterly direction and weakened into a severe cyclonic storm and further weakened into a depression and lay at 0300 UTC of 10 near Lat. 26.5° N/Long. 73.5°E, about 50 kms northeast of Jodhpur. It further weakened into a low pressure area over Punjab and adjoining parts of Himachal Pradesh.

4.1.2. *Deep depression over Bay of Bengal (13 - 15 June 1998)*

A well-marked low pressure area formed over northern parts of west-central and adjoining east-central Bay on the morning of 13. It concentrated into a depression and was centred at 1200 UTC of 13 near Lat. 17.5° N/Long. 87.5°E.



Figs.11(a&b). Mean monthly (June-July 1998) SST anomalies of (°C) of Indian seas during southwest monsoon



Figs.11(c&d). Mean monthly (August - September 1998) SST anomalies (°C) of Indian Seas during southwest monsoon

It moved in a westerly direction and further intensified into a deep depression and was centred at 1800 UTC of 13 near Lat. 17.5° N/Long. 86.0°E. Continuing its westerly movement, it lay as a deep depression at 0300 UTC of 14 near Lat. 17.5° N/ Long. 84.5° E and 1200 UTC of 14 near Lat. 17.5° N/Long. 83.0°E. The deep depression, then, crossed north Andhra coast, very close to Visakhapatnam (little south of Visakhapatnam) between 1300 and 1400 UTC of 14 and weakened into a depression and lay centred at 1800 UTC of 14 near Lat 18.5° N/Long. 81.5°E. It then moved in a northwesterly direction and lay centred at 0300 UTC of 15 as a depression near Lat. 20.0° N/Long. 80.0°E. It further moved in a northwesterly direction and weakened into a low pressure area over Vidarbha by 15 afternoon.

4.1.3. *Land depression over west Madhya Pradesh (14 - 18 September 1998)*

A well-marked low pressure area moved over north Vidarbha and adjoining parts of west Madhya Pradesh on the evening of 13. It concentrated into a depression and lay centred at 0300 UTC of 14 near Lat. 23.0° N/Long. 77.5° E, about 50 kms north of Hoshangabad. The system did not show any appreciable movement and lay centred at 1200 UTC of 14 near Lat. 23.5° N/Long. 78.0°E. It then remained practically stationary and intensified into a depression and was centred near Lat. 23.5° N/Long. 78.0°E. The system then changed its direction of movement and moved in a westerly direction and lay centred at 0300 UTC of 16 as a depression near Lat. 23.0° N/Long. 76.0°E. It moved in a westnorthwesterly direction and weakened into a depression and lay centred at 1200 UTC of 16 near Lat. 24.3° N/Long. 75.5° E, near Ujjain. Continuing west north westerly movement, it lay centred at 0300 UTC and 1200 UTC of 17 near Lat. 24.0° N/Long. 73.0° E, close to Idar. Further moving in a west north westerly direction, it lay as a depression near Deesa at 0300 UTC and 1200 UTC of 18 near Lat. 24.0° N/Long. 72.0° E. It then moved in a westerly direction and weakened into a well-marked low pressure area over north Gujarat Region and adjoining parts of west Rajasthan.

4.1.4. *Deep depression, over the Arabian Sea (30 September 1998)*

A low pressure area moved into east-central Arabian Sea from peninsular India and became well-marked over east-central and adjoining west-central Arabian Sea on the evening of 29. It concentrated into a depression centred at 0300 UTC of 30 near Lat. 17.5° N/Long. 65.0° E. It moved in a westnorthwesterly direction and was centred at 1200 UTC of 30 as a depression near Lat. 18.0° N/Long. 63.5°E. It further moved in a westnorthwesterly direction and weak-

TABLE 6

Details of the weather systems during September 1998

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, probably deep	14 - 18	Central parts of Madhya Pradesh, close to Bhopal	Westnorthwesterly	Southwest Rajasthan	It lay as a low pressure area over northeast Madhya Pradesh and adjoining parts of Bihar on 10. It concentrated into a depression close to Bhopal on 15 and on 16 very close to Ujjain. On 17, it lay as a depression over north Gujarat region and adjoining parts of southeast Rajasthan, very close to Idar. It weakened into a well-marked low pressure area over north Gujarat region and adjoining west Rajasthan on 19. On 20, it became low pressure area over southwest Rajasthan and neighbourhood
2.	Do	30	East-central Arabian Sea	Westerly	West-central Arabian Sea	It was formed as a depression , in morning of 30 September over east-central Asabian Sea. Moving in a westerly direction it weakened into well marked low pressure area on 1 October over west. Central Arabian Sea and neighbourhood
(B) *Low pressure area*						
1.	Low pressure area	3 - 5	West-central Bay off North Andhra Pradesh coast	Stationary	*In situ*	Associated cyclonic circulation extended upto lower tropospheric levels, tilting southwestwards with height. It became less marked on 7 over north interior Karnataka and neighbourhood
2.	Do	20 - 21	West-central Bay off Andhra Pradesh coast	Do	Do	It was first observed as a cyclonic circulation off Orissa coast on 15. Associated cyclonic circulation extended upto mid tropospheric levels. It was tilted southwards with height on 28
(C) *Other cyclonic circulations*						
1.	Mid tropospheric levels	30 Aug-4 Sep	North Gujarat region and neighbourhood	Quasi-stationary	Gujarat Region and neighbourhood	
2.	Lower tropospheric levels	2 - 7	East Bihar and neighbourhood	Westerly	East Uttar Pradesh and adjoining Bihar Plains	
3.	Do	7 - 8	Northwest Madhya Pradesh and neighbourhood	Stationary	*In situ*	Merged with the monsoon trough
4.	Do	7 - 9	North Pakistan and neighbourhood	Do	*In situ*	
5.	Mid tropospheric levels	9 - 10	Vidarbha and neighbourhood	Do	Do	
6.	Lower tropospheric levels	10 - 11	Gujarat region	Do	Do	
7.	Do	11 - 14	Northwest Rajasthan and adjoining Pakistan	Do	Do	
8	Lower tropospheric levels	21 - 27	Southern parts of Thailand and neighbourhood	Westerly	South Andaman Sea and neighbourhood	
9.	Mid tropospheric levels	28 Sep-7 Oct	North Kerala coast and neighbourhood	Do	North interior Karuesteka and neighbourhood	
10.	Lower tropospheric levels	19 - 20	North Pakistan and neighbourhood	Northwesterly	Jammu & Kashmir	Moved away
11.	Lower levels	25 - 26	Plains of west Uttar Pradesh	Stationary	*In situ*	
12.	Lower tropospheric levels	27 - 30	West Rajasthan and neighbourhood	Do	Do	
13.	Mid tropospheric levels	29 - 30	Southwest Bay off north Tamil Nadu coast	Do	Do	Tilted southwestwards with height on 28
14.	Do	28 Sep-2 Oct	North Kerala coast and neighbourhood	Northerly	North Karnataka coast and neighbourhood	

TABLE 7

Tropical storms/depressions in the northwest Pacific in 1998

Month	TD	TS	Typhoons	Super typhoons	Total
June	0	0	0	0	0
July	2	1	0	0	3
August	0	1	1	0	2
September	1	1	4	0	6
Total	3	3	5	0	11

ened into a low pressure area over northern parts of west-central Arabian Sea.

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

During the season, 9 low pressure areas/well-marked low pressure areas formed. Most of these systems were associated with cyclonic circulations in the upper air. Monthwise break-up of these systems is 1 in June, 4 in July, 2 each in August and September. Details are given in Tables 3-6.

4.3. *Cyclonic circulations (CYCIR)*

In all, 51 cyclonic circulations (in lower and upper tropospheric levels) formed during the season and their contribution resulted in well distributed rainfall over the country. The monthwise break-up of cyclonic circulation is as under :

June 8, July 13 and August and September 15 each.

Details are given in Tables 3-6.

4.4. *Off shore trough*

From 11 June to 30 September 1998, off-shore trough along different parts of west coast (surface and lower levels), persisted on most of the days except on 11 to 15 June, 18-19 July, and 9-10 September. This is one of the significant features of southwest monsoon 1998.

4.5. *Low level troughs*

Details are given in Tables 3,4 and 5.

4.6. *Upper level troughs*

Detailed information is given in Table 3,5 and 6.

4.7. *Eastward moving circulation/western disturbance*

Details are given in Table 5 and 6.

5. Extra-Indian systems

5.1. *Cross equatorial flow*

Cross equatorial flow was nearly normal in June and July and more than normal by 5 kts during August and September along the equator. Over the Arabian Sea, the surface wind was slightly more than the normal (by about 5 kts) during June, August and September and in July, it was slightly less than the normal (by about 5 kts) and over the Bay of Bengal, the wind was slightly more than the normal by about 5 kts during June and September and it was nearly normal in July and August.

5.2. *Mid latitude troughs*

There were in all 29 mid and upper tropospheric westerly troughs which moved eastwards across 30.0° N latitude and affected the north India. Out of these, 15 were at 500 hPa level and 14 at 300 hPa level. The monthwise break-up is given below :

Levels	Jun	Jul	Aug	Sep	Total
500 hPa	3	4	4	4	15
300 hPa	3	4	4	3	14

5.3. *Systems in south China Sea/Northwest Pacific Ocean*

During June to September 1998, there were 11 disturbances , *viz*, 5 typhoons and 3 tropical storms. No super typhoon formed during the season. Their monthwise break-up is given in Table 7.

5.4. *Systems in southern hemisphere*

(a) There were 2 depressions in South Indian ocean during June to September 1998 (1 each in July and September)

(b) There were in all 23 upper air westerly troughs (7 in June, 5 each in July and September and 6 in August) that moved across Lat. 30° S during June to September 1998.

(c) the intensity of the Mascarene High during June to September 1998 (at 30° S/60°E) was slightly below normal (-1 hPa) during June and August, above normal (+ 3 hPa) in July and nearly normal in September 1998.

(d) The intensity of Australian high during June to September 1998 (at 30° S/140° E) was normal during July to September but was below normal by 1 hPa in June.

6. Semi-permanent systems

6.1. *Heat low*

Heat low over Pakistan and adjoining parts of west Rajasthan was seen on 1 June and remained in the same position till 25 September.

The lowest pressure values of heat low were 985.6 hPa on 12 July, 987.2 hPa on 7 July, 987.5 hPa on 21 June, 989.1 hPa on 30 June, 990.7 hPa on 4 August, 991.2 hPa on 2

TABLE 8

Main features of weekly wind anomalies during June to September 1998

Week Ending (1)	850 hPa (2)	500 hPa (3)	200 hPa (4)	Remarks (5)
		(a) June		
9 June	A trough off west coast from north Maharashtra to south Kerala and a ridge from north India to central Bay of Bengal through central India	An anticyclonic circulation centred ~ 21° N/82.5°E	An anticyclonic circulation centred ~ 17.5° N/84.0°E	Lower tropospheric westerlies and upper tropospheric easterlies near normal over southern peninsula
16 Jun	A cyclonic circulation over central India and associated northwest-southeast oriented trough from Jodhpur to north-central Bay of Bengal	Southwest-southeast oriented trough from northwest India to south Bay of Bengal	A ridge ~10°N and a trough ~19°N	Lower tropospheric westerlies stronger than normal and upper tropospheric easterlies weaker than normal
23 Jun	An east-west trough ~14°N and an east-west ridge ~20°N	A northwest-southeast oriented trough from northwest India to north Bay of Bengal and ridge ~19°N	Anticyclonic circulation over Tibetan region and associated ridge ~26°N	Easterly anomalies throughout the troposphere over central India
30 Jun	An east-west trough across central India ~22°N	A northwest-southeast trough across peninsula ~16°N and an anticyclonic circulation over Tibetan region	An anticyclonic circulation over Tibetan region and the associated ridge ~30°N	Lower tropospheric westerlies stronger than normal and upper tropospheric easterlies weaker than normal over southern peninsula
		(b) July		
7 Jul	A northwest-southeast trough from northwest India to north Bay of Bengal	A northwest-southeast trough across peninsula from Gujarat region to central Bay of Bengal and an anticyclone over west Tibetan region	An anticyclonic circulation over Tibetan region and associated ridge ~30°N	Lower tropospheric westerlies stronger than normal and upper tropospheric easterlies near normal lower peninsula
14 Jul	An east-west trough across north India ~26°N and a ridge ~15°N	An east-west trough ~25°N	An anticyclonic circulation over India and the ridge from this system extends to north Bay of Bengal	Monsoon circulation over peninsula weaker than normal
21 Jul	An east-west trough ~23°N	An east-west ridge ~20°N	An east-west trough ~ 11°N	Mainly easterly anomalies throughout the troposphere across the peninsula
28 Jul	An east-west ridge ~22°N	An east-west ridge ~20°N	An east-west ridge ~20°N	Mainly easterly anomalies throughout the troposphere across the peninsula
		(c) August		
4 Aug	A cyclonic circulation over Maharashtra and a northwest-southeast ridge over northwest to central India	A ridge across north India	A ridge ~25°N	Mainly easterlies above 700 hPa over Peninsula and central India
11 Aug	A northwest-southeast trough from northwest India to west-central Bay of Bengal and ridge ~15°N	A north- south trough in easterlies from central to south India	A ridge along the Himalayas and a northwest-southeast trough across the northern peninsula	Lower tropospheric westerlies at upper tropospheric easterlies weaker than normal peninsula
12 Aug	A east-west trough ~18°N	An east- west ridge ~19°N	An east-west ridge ~22°N	Mainly easterlies over peninsula and westerlies over central and north India throughout the troposphere
25 Aug	An anticyclonic circulation over northeast India with associated ridge ~23°N and a trough ~10°N	An east-west ridge ~22°N	An east- west ridge ~24°N	Mainly easterlies over peninsula and westerlies over central and north India throughout the troposphere
		(d) September		
1 Sep	An east-west ridge ~14°N	An east-west ridge ~16°N	An east-west ridge ~24°N	Mainly easterlies over peninsula and westerlies over central and north India throughout the troposphere

TABLE 8 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
8 Sep	A cyclonic circulation~15°N, 78°E	An anticyclonic circulation over central India and associated	An east-west ridge~20°N	Easterlies over peninsula and westerlies over central and north India above 500 hPa
15 Sep	A cyclonic circulation over central India with associated northwest-southeast trough extending from northwest India to north Bay of Bengal	A northwest-southeast trough from northwest India to north Bay of Bengal	An east-west ridge ~14°N	Stronger than normal lower tropospheric westerlies extending upto mid troposphere
22 Sep	A northwest-southeast trough from northwest India to west-central Bay of Bengal	A northwest-southeast trough from Gujarat to south Bay of Bengal and an anticyclonic circulation over Tibetan region	An anticyclonic circulation over Tibetan region and associated ridge ~30°N	Stronger than normal lower troposphere westerlies and weaker than normal upper tropospheric easterlies over peninsula
29 Sep	An east-west trough ~11°N	An anticyclonic circulation over east Tibetan region	An ridge ~32°N and a trough ~32°N and a trough ~17°N	Mainly easterlies over central and north India throughout the troposphere

August, 993.9 hPa on 3 September and 995.0 hPa on 2 September.

6.2. *Axis of the monsoon trough*

The axis of the monsoon trough on sea level chart was established in its normal position by 15 June. It persisted in it's normal position or south of it's normal position till 14 July. Afterwards, moving northwest, it lay close to the foothills of Himalayas from 15 to 26 July and resulted in Break Monsoon conditions. Then monsoon trough was seen at its normal position or south of it's normal position from 28 July to 20 August. Monsoon trough lay again close to foot hills of Himalayas from 21 to 31 August. It was again seen in it's normal position or south of it's normal position from 1 to 23 September. In late September, the presence of monsoon trough was due to the formation of a land depression over central India and it's slow westnorthwesterly movement along monsoon trough.

6.3. *Tibetan Anticyclone/high*

Tibetan Anticyclone/High got established on 13 June, at 300 and 200 hPa near Lat. 26.0° N/Long. 95.0° E and Lat. 27.0° N/Long. 90.0°E respectively. It was seen on a number of days during July, August and September at 300/200 hPa.

6.4. *Sub-tropical westerly let (STWJ)*

STWJ was seen over Delhi, Srinagar, Gorakhpur, Lucknow, Jodhpur and Gwalior during Ist week of June and became less marked by the end of 2nd week of June. It was not seen again till the last week of September suggesting the shifting of STWJ to the north during the season.

6.5. *Tropical easterly jet (TEJ)*

TEJ was observed over Minicoy from 6 June to the end of September (max. reported wind was of the order of 150 kts at 103 hPa on 5 August at 1200 UTC and 145 kts at 104 hPa on 18 August at 0000 UTC). It was seen over Thiruvananthapuram from 6 to 27 September (max. reported wind was 115 kts at 107 hPa on 22 July at 1200 UTC) and over Chennai from 5 to 7 September (max. reported wind was 120 kts at 100 hPa on 23 July at 0000 UTC and 115 kts at 117 hPa on 23 June). It was seen over Port Blair from beginning of the season till 16 September (max. reported wind was 130 kts at 103 hPa on 22 July at 1200 UTC). It was seen over Mumbai from 18 June to 2 September (max. reported wind was 130 kts at 100 hPa on 6 August at 1200 UTC).

7. Sea surface temperature (SST)

In the Arabian Sea and the Bay of Bengal isopleths of normal values and anomalies of SST for the months of June, July, August and September are given in Figs.11 (a-d).

The values of normal SSTs for calculating anomalies are estimated from the isopleths of normal values.

These statements are based on real time data which were sometimes not adequate in numbers.

8. Other features

8.1. *Weekly anomalies in monsoon circulation 1998*

Weekly anomaly charts are prepared for 850, 500 and 200 hPa levels and the corresponding anomaly troughs and ridges are marked. Weekly anomaly features are given in Table 8. Weekly wind anomalies for some stations are given in Table 9.

June-July -- Except for the third week, the lower tropospheric westerlies particularly over the southern peninsular India were normal/stronger than normal. The upper tropospheric easterlies in general remained weaker than normal.

TABLE 9

Weekly anomaly winds June-September 1998

Week ending dates	9 Jun	16 Jun	23 Jun	30 Jun	7 Jul	14 Jul	21 Jul	28 Jul	4 Aug	11 Aug	18 Aug	25 Aug	1 Sep	8 Sep	15 Sep	22 Sep	29 Sep
TRIVANDRUM (TRV)																	
850 hPa	17908	31205	27704	28414	33113	01605	08512	09703	08207	02101	10810	22005	12507	14905	25405	26203	29706
500 hPa	26606	01805	13303	30007	14201	09305	10015	09606	10011	15604	11110	15801	10613	15705	10102	36001	08906
200 hPa	26012	13807	21003	25104	16705	20609	22818	13410	25608	07905	23304	28108	07905	09520	09713	19810	09706
BOMBAY (BMB)																	
850 hPa	17511	31107	04305	24901	24612	25505	07110	05713	05107	32208	31334	07417	22303	04410	33512	25412	10307
500 hPa	19711	21817	06707	14803	23408	31402	10606	10113	11508	04807	12802	10013	22509	10503	29904	33313	19501
200 hPa	24818	16904	16615	26403	24104	10904	14915	15211	10017	25909	11615	12808	16707	28002	34910	06507	-
NAGPUR (NGP)																	
850 hPa	29007	21104	27907	21208	26523	26815	18710	11908	11709	19904	24707	12112	23640	06404	25710	17509	13108
500 hPa	21409	17313	05006	08706	10903	25409	26805	14103	10315	13403	24308	12110	20104	09306	26111	14212	11515
200 hPa	20811	15010	12313	09409	03908	08109	11814	19503	11811	16405	35611	07010	07526	05213	04825	08339	17625
MADRAS (MDS)																	
850 hPa	14905	27602	23407	24815	25712	16106	11221	12106	16607	20703	13611	11215	17510	22304	24113	19704	10008
500 hPa	06908	29505	17005	25004	25009	22306	09329	07710	14511	18706	10514	09223	10408	14408	19209	27905	08816
200 hPa	14407	18104	04506	01004	01808	35709	20007	13803	35907	34807	04807	28005	00912	02909	34913	30201	29901

Note: 1. Easterly anomalies at 850 hPa means that westerlies are weaker than normal, 2. Westerly anomalies at 200 hPa means that easterlies are weaker than normal.

During the first week of July, the monsoon circulation was near normal. During second week, the upper tropospheric circulation and during next two weeks, both the lower and upper tropospheric circulations were in general weaker than normal resulting in weak monsoon conditions.

August-September -- In the first two weeks, the lower tropospheric circulation was stronger than normal. During remaining period, it was weaker than normal. However, the upper air circulation was near normal throughout the month. During August, slightly weaker monsoon conditions were observed.

In the first week of September, the lower tropospheric monsoon circulation strengthened and during most of the remaining period, both the lower and upper tropospheric circulations were normal or stronger than normal.

Main features of weekly wind anomalies at three levels, *viz.*, 850 hPa, 500 hPa and 200 hPa are depicted in Table 8.

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*

Upper wind data of all available RS/RW stations over the country have been analysed during the monsoon period 1998.

10 hPa wind features

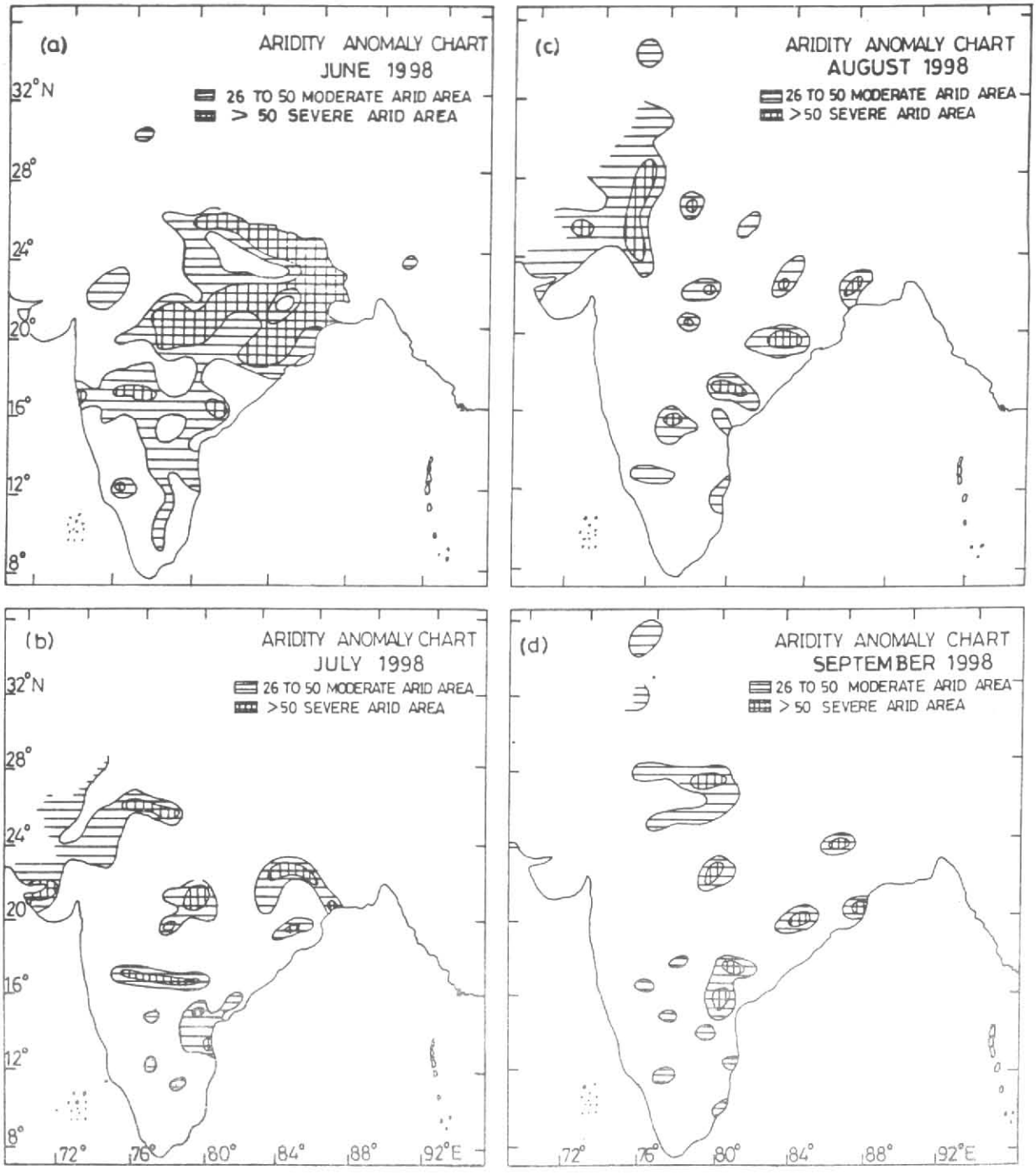
Based on the available data, it is inferred that the winds over the country were easterlies throughout the season with varying wind speeds. Monthwise variation of zonal wind was as detailed below :

June -- The easterly winds were strong over Minicoy and Thiruvananthapuram. The strength of zonal wind speed was of the order of 35 mps (based on data of Minicoy, 14th and Thiruvananthapuram, 4th). Towards north of this latitude belt, winds varied from 20 mps to 25 mps (based on data of Chennai, 8th, Port Blair, 1st, 7th and 28th, Machilipatnam 16th, Bhubaneswar, 30th and Balasore, 24th).

July -- Easterly strength of zonal easterlies over the country was of the order of 30 mps (based on data of Minicoy, 19th, Nagpur, 28th, Bhubaneswar, 30th and Balasore, 9th).

August -- The strong easterlies components between 45 & 50 mps were observed over southern India (based on data of Thiruvananthapuram, 28th and Port Blair, 2nd, 12th and 14th). Wind speeds of the order of 50 mps over Goa on 23rd were also observed indicating a double JET core. Over rest of the country, wind speeds were of the order 25 to 30 mps with greater number of observations.

September -- Easterlies of the order of 30 mps were recorded over central parts of India (based on data of Goa, 13th, Raipur, 9th, 10th, 18th and 26th). Towards north and south of central India, wind speeds were of the order of 15 mps.



Figs.12(a&b). Meteorological sub-divisions affected by moderate to severe aridity conditions during (a) June and (b) July 1998

Figs.12(c&d). Meteorological sub-divisions affected by moderate to severe aridity conditions during (c) August and (d) September 1998

30 hPa wind features during southwest monsoon 1998

When compared to 10 hPa regime, frequency of observations at 30 hPa over most of the upper air network was fairly good and easterlies prevailed throughout the season. Monthwise distribution of zonal component of wind speeds were as follows :

June -- Easterlies were of the order of 25 mps over southern parts of India and gradually reduced to the order of 10 mps towards north. Over western and northern parts of India, winds were below normal and over rest of the country, winds were above normal.

July -- Easterlies were of the order of 30 mps over central and southern India. Towards north, the speeds re-

TABLE 10

Statistics of spatial rainfall distribution (No. of days for monsoon season 1998 as a whole with heavy to very heavy rainfall)

S.No.	Sub-division	Vigorous	Active	V. Heavy	Heavy	W/Fw
1.	Andaman & Nicobar Isand	-	-	6	14	69
2.	Arunachal Pradesh	2	19	2	16	27
3.	Assam & Meghalaya	2	12	8	23	62
4.	Naga, Mani, Mizo & Trip.	-	4	-	-	41
5.	S.H.W.B. & Sikkim	3	33	19	22	48
6.	Gangetic west Bengal	4	13	4	10	21
7.	Orissa	-	3	5	29	39
8.	Bihar Plateau	-	-	2	5	44
9.	Bihar Plains	2	10	9	24	28
10.	East Uttar Pradesh	16	12	10	18	13
11.	Plains of west Uttar Pradesh	4	17	8	18	16
12.	Hills of west Uttar Pradesh	2	16	4	10	30
13.	Haryana, CHD & DLH	6	2	5	9	13
14.	Punjab	3	1	2	4	11
15.	Himachal Pradesh	4	4	2	11	24
16.	Jammu & Kashmir	1	2	1	3	6
17.	West Rajasthan	-	1	1	3	9
18.	East Rajasthan	-	1	-	1	15
19.	West Madhya Pradesh	6	13	4	32	14
20.	East Madhya Pradesh	2	12	2	10	24
21.	Gujarat region	8	9	20	33	19
22.	Saurashtra & Kutch	3	4	1	9	7
23.	Konkan & Goa	3	19	19	37	72
24.	Madhya Maharashtra	3	21	20	20	21
25.	Marathwada	11	20	3	11	8
26.	Vidarbha	7	3	9	7	31
27.	Coastal Andhra Pradesh	4	24	6	11	9
28.	Telangana	4	25	3	11	9
29.	Rayalaseema	10	13	-	-	2
30.	Tamil Nadu & Pondicherry	-	-	4	19	3
31.	Coastal Karnataka	6	29	14	50	64
32.	North interior Karnataka	3	25	4	14	4
33.	South interior Karnataka	1	25	15	29	8
34.	Kerala	4	29	5	18	58
35.	Lakshadweep	-	-	2	6	50

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 or at many places

duced gradually to the order of 20 mps. Wind speeds were above normal throughout the country.

August -- The strength of zonal easterlies were of the order of 40 mps over western and southern India. Towards north and east, the speeds reduced to 20 mps. Wind speeds were above normal throughout the country.

September -- The easterlies were of the order of 30 mps over southern India and reduced to an order of 10 mps towards north. Wind speeds were above normal throughout the country.

8.3. *Aridity conditions during monsoon 1998*

During the initial period of monsoon, large areas in central, northeastern and peninsular parts of the country were affected by moderate to severe arid conditions. With the progress of the monsoon, large areas of arid conditions appeared over northwestern parts and arid conditions in eastern parts were wiped out. However, small and isolated areas were noticed in northern, central and peninsular parts of the country in September and large moderate and severe arid area in northwestern parts was wiped out.

Aridity anomaly maps for June and July are given in Figs.12(a & b) and for the August and September are given in Figs.12 (c & d).

9. Damages due to floods etc. during monsoon season

As per newspapers and reports received from RMCs, in all about 617 people lost their lives due to heat wave in northern parts of the country. 2294 people died due to heavy rains and floods. Damages occurred to properties worth

APPENDIX I

Principal amounts of rainfall (cm) (June to September 1998)

Date (1)	June (2)	July (3)	August (4)	September (5)
1	Kokrajhar 9, Tadong 7	Bhira 33, Tijara & Veraval 19 each, Madikeri 17, Subramanya 15, Hardwar 11, Banbasa & Irrikkur 10 each, Miao Nawashahar, Sarkaghat & Khanapur 9 each, Long Island, New Delhi (PLM) & Vapi each, Gharmura & Kharidwar 7 each	Barobisha 21, Taloda 13, Kondul 9, Margherita & Mukerian 8 each, Nahan 7	Bahalpur 16, Rangagora & Sripalpur 12 each, Elginbridge & Kochi 11 each, Hasimara, Tekkali & Bangalore 9 each, Passighat & Jharsuguda 8 each, Kondul & Ranchi 7 each
2	Car Nicobar 15, Kokrajhar 11, Mangalore 9, Champasarai 8, Kailashahar 7	Varaval 31, Pali 28, Gaganbavda 14, Sirsa 12, Rajura 11, Perur 10, Nawashahar & Irikkur 9 each, Ghumarwin, Narsapur & Kollur 7 each	Hasimara 33, Taibpur 24, Palliakalan 18, Nancowry 14, Patti 13, Nandyal 11, Dehradun & Dharamsala 9 each, Rajkot & Bhira 8 each, R. S. Dam 7	Sikanderpur 15, Darjeeling, Jabalpur & Jagityal 11 each, Adirampattinam 8, Shillong & Wada 7 each
3	Silchar 11, Barobisha 10, Long Island 7	Pali 19, Agumbe 14, Mahabaleshwar 13, Pandharkawada & Siddapura 10 each, Puthimiri, Akhuapada, Ujjain & Manantghavady 9 each, Mukteswar 8, Ajmer & Porbandar 7 each	Satna 21, Passighat & Chanpatia 18 each, Sandheads & Mirzapur 11 each, Long Island & Muddanur 10 each, V.V. Nagar 9, Agumbe 8, Chauldhowaghat, Moradabad, Chabra & Perur 7 each	Cooch Behar 28, Bahalpur 15, Passighat 12, Chargharia 8, Thanesar 7
4	Nil	Agumbe 23, Sandheads 18, Mudibidre 17, Dharamsala 13, Amgaon 12, Narora & Kozhikode 11 each Danta Ramgarh 10, Jamshedpur, Bikaner, Vidisha & Mahabaleswar 8 each, Dibrugarh & Udhampur 7 each	Barobisha 37, Saralpara 13, Banda & Mohana, 12 each, Berhampore, Banbassa, Krishanganj, Bangalore & Aluva 9 each, Satna, Golkonda & Minicoy 7 each	Annapurnaghat 34, Mathabhanga 21, Jogindernagar 15, Bhagalpur 10, Tanuku 8, Miao 7
5	Chepan 10	Reodhar & Gokarna 18 each, Kakardarighat & Dehradun 13 each, Bali & Gaganbavda 12 each, Derol Bridge 11, Talaguppa 10, Sevoke 9, Pendra 8, Hardwar 7	Yellandur 17, Jagadhari & Jhansi 16 each, Ahwa 13, Darjeeling 12, Simulia, Chillaghat, Chittur & Bhatkal 7 each	Cooch Behar 18, Taibpur 15, Ibrahimpatnam 10, Passighat & Thiruvananthapuram 8 each, Kokrajhar & Mantralayam 7 each
6	North Lakhimpur 16, Passighat 13, Pune (LHG) 8	Dasuya 34, Mirzhapur 28, Champasarai 16, Mudibidre 13, Kalpi & Bangana 12 each, Quilandy 11, Pagladiya 10, Mahabaleshwar & Thirthahalli 8 each, Japla & Harangi 7 each	Hardwar 15, Koyna (Navaja) & Gargoti 11 each, Krishnanagar 10, Ankinghat, Uttar Kashi & Adirampattinam 8 each	Barsi 16, Bhagalpur 15, Taljapur & Kozhikode 13 each, Bhivpuri, Malda & Jammalamadugu 10 each, Nagpur 8, Manas & Bansi 7 each
7	Passighat 19, Chauldhowaghat 16, Chepan 9, Kozhikode 7	Basti 33, Vadodra 18, Garhi 17, Banbasa 14, Pagladiya 12, Keshod 11, Kurukshetra & Ludhiana 9 each, Kondul & Mahabaleshwar 7 each	Koyna (Navaja) 14, Lakhipur 12, Nidadavolu & Mudigeri 10 each, Mahabaleshwar & Kollur 9 each, Rudraprayag 8, Kharagpur 7	Akhupada 16, Tuljapur 13, Alibag 10, Digha 9, Paratwada 8, Sendwa 7
8	Tezu 22, Panbari 14, Hasimara & Dapole 8 each	Gandevi 25, Bhira 23, Regali 20, Darjeeling & Kollur 17 each, Peint 16, Kondul 8, Tajewale & Khamba 7 each	Chauldhowaghat 12, Sever & Gaganbavda 9 each, Bhubaneswar 8, Long Island, Gwalior, Goa (Panjim) & Panambur 7 each	Prathipadu 13, Rajghat 12, Dahanu & Udgir 8 each, Canning Town, Kushalgarh, Dabhoi & Igat puri 7 each
9	Matizuri 29, Hasimara 11, Kailashahar 10, Tezu 9	Kakrahi 33, Mahabaleshwar 18, Triveni 16, Pratapgarh 14, Chhachhrauli & Bhira 12 each, Ahwa 11, Haripur 10, Jamsolaghat 9, Malda & Kothagudem 7 each	Barobisha, Chhabi Dam & Shirali 17 each, Tamini 14, Koyna (Pophli) 12, Karimganj 8	Kozha 18, Contai 16, Sambalpur 15, Palghar & Ahwa 11 each, Bhavnagar, Mahabaleshwar & Tuljapur 8 each, Ranchi & Tanuku 7 each
10	Diana 31, Siwan 19, Bhuj 12, Kheda 11, Panbari 10, Mount Abu & Pondicherry 7 each	Dharamsala 38, Ambala 17, Ayodhya 14, Nangal, Kathua & Tadepalligudem 13 each, Balaghat 12, Passighat & Deoband 9 each, Sringeri 8, Wanakbari 7	Mumbai (CLB) 26, Tamini & Shirali 18 each, Agumbe 14, Nahan 12, Degloor 11, Diana & Narasapur 8 each, Joshimath, Jammu & Dungidal 7 each	Agumbe 21, Contai 20, Nanipalsan & Talasar 13 each, Jaipur 12, Bhoond 10, Honavar, Qui- Landy & Amini Divi 7 each
11	Cowari 14, Nawashahar 13, Kheda 12, Mathunga & Naraingarh 11 each, Mahabaleshwar & Ponnani 10 each, Jhunjhunu 9, Sandheads 8, Diana & Mani 7 each	Miao 15, Dharamtul & Sevoke 13 each, Bhopal 10, Naraingarh & Jagdalpur 9 each, Jamsolaghat & Kozhikode 8 each, Nahan & Kota 7 each	Gaganbavda 28, Shirali & Agumbe 13 each, Aurangabad 10, Passighat 9, Shahpurkandi, Bodeli & Pandharkawada 8 each, Imphal & Gudalur Bazar 7 each	Sandheads 25, Jharsuguda 17, Mumbai (SCZ) 14, Mayabandar & Vapi 11 each, Ludhiana 7

APPENDIX I *(Contd.)*

(1)	(2)	(3)	(4)	(5)
12	Gangtok 17, Beki Road Bridge 15, Passighat 14 , Jogindernagar 11, Goa (Panjim) & Panambur 8 each	Aluva 21, Sumail 18, Behrampore 14, Beki, Mathanguri & Ankinghat 13 each, Chepan, Hardwar & Sriganganagar 9 each, Gwalior 7	Haripur 25, Tamini 18, Naraingarh & Koyna (Navja) 11 each, Chauldhowaghat & Ayodhya 10 each, Sankheda 9, Thikri 8, Paonta, Kalwa & Shegaon each	Mani 14, Agumbe 13, Digha, Bilaspur & Vapi 11 each, Balimundali 10, Rangara, Thane Belapur, Kalingapatnam & Kopargaon 7 each
13	Sevoke 18, Panbari 11, Passighat & Kundapura 8 each	Paonta 17, Malda 14, Kakrahi 13, Suri 12, Manas 11, Agartala, Naraingarh & Mandawar 10 each, Basua & Dehradun 8 each	Mundawara 20, Ghazipur 15, Saralpara 12, Rewari 11, Agumbe 10, Cooch Behar, Canning Town, Lalbegiaghat & Dharampur 9 each, Marora, Amarwara & Shirali 8 each, Mohana 7	Mudibidre 18, Puri 14, Sringeri 12, Krishnanagar 10, Pendra 8, Matizuri 7
14	Sankalan 9, Nancowry 8, Waltair 7	Calgaon 20, Newari 15, Harnavweir 13, Passighat & Chepan 10 each, Kokrajhar & Subramanya 7 each	Goalpara 26,Chillaghat 20, Chanpatia & Chandigarh 11 each, Cuttack 10, Bhira 9, Gaganbavda 8, Berhampore, Haripur & Rahuwas 7 each	Betul 28, Shirali 17, Chotaundaipur 15 Pendra 11, Jogindernagar 8, Mayabandar & Amraoti 7 each
15	Ellamanchili 17, Deulgaonraja 16, Sreeramsagar 12, Vijapur 9, Naharkatia 7	Dehradun 11 Munger & Vellore 10 each, Panambur 9, Nangal 8, Jalpaiguri & Karauli 7 each	Sevoke 16, Sandheads 15, Bareilly 13, Dibrugarh & Satna 11 each, Banda, New Delhi (SFD) & Khajuraho 10 each, Bari & Khed 9 each, Buxar, Dehradun, Jammu & Jagatyal 8 each, Mahabaleshwar 7	Betul 31, Garudeshwar 24, Paratwada 17, Bhiwandi 14, Marora 11
16	Ambala 14, Jamner 11, Buldhana 10, Daman & Dahanu 8 each	Dengraghat 22, Namsai 17, Mathura 14, Kakrahi 13, Uttar Kashi 10, Surat 8, Champasarai, Harinkhola, Paonta & Bisalpur 7 each	Dabri 15, Ayodhya 14, Marora 13,Passighat & Mathabhanga 11 each, Darauli & Hindon 10 each, Khowang 7	Sankheda 18, Dahanu 9, Bhubaneswar, Indore & Vadakkancherry 7 each
17	Mathanguri 21, Passighat & Garhi 13 each, Tadong & Silvassa 12 each, Bareilly 10, Kasauli, Agra & Mani 8 each, Mangalvedha 7	Regoli 18, Shajapur 17, Chandigarh 13, Chauldhowaghat 12, Rosera 9, Suri, Kaso & Amini Divi 8 each	Goalpara 31, Champasarai 19, Jammalamadugu 11, Kakardarighat & Avanigadda 10 each, Hardwar & Thanesar 9 each, Seppa,Khadda Marora & Medak 7 each	Nanipalsan 41, Akkalkuwa 25, Malpura 13, Ratlam & Dahanu 11 each
18	Mathanguri & Hasimara 22 each, Mulki 21, Thalasserry & Malvan 9 each, Ambala 8, Ghamroor & Jamkhandi 7 each	Kakrahi 15, Hamirpur & Bangalore 12 each, Krishnanagar 8, Tikarpada, Kursela, Bhira, Avanigadda,Hyderabad, Pakala, Bhatkal & Chengannur 7 each	Kakrahi 30, Sikandarpur 18, Champasarai 14, Guler 12, Dadupur 7	Mehsana 25, Igatpuri 17, Kalvan 16, Mount Abu 11, Dewas 10, Kondul 9, Churu 8
19	Cooch Behar 24, Goa (Panjim) 21, Tadepalligudem & Mahabubnagar 11 each, Calcutta (DUM) & Kudulu 7 each	Tajewala 13, Passighat, Barobisha & Vadakkancherry 10 each ,Pamban 9, Gooty 8, Saralpara 7	Kakrahi 30, Dehradun 21, Balachaur 13, Sandheads & Tirupathi 9 each, Khagaria, Hardwar, Chodavaram & Perinthalmanna 8 each, Mandya 7	Kherwara 11, Sripalpur 10, Nangal 7
20	Chepan 18, Mathanguri 17, Kalamb 14, Kannur 10, Colgaon 9, Passighat 8, Porumamilla 7	Shillong & Puttur 17 each, Honnali 13, Silliguri & Taibpur 12 each, Karipur 11, Tezu & Ahmedabad 8 each, Ankinghat & Jat 7 each	Kondul & Saralpara 18 each, Anantpur 14, Una 12, Ayodhya 10, Chepan, Taibpur & Nandigama 9 each, Medak 8, Agumbe 7	Jalpaiguri 13, Basti 12, Dowlaiswaram 10, Valsad, Mahabubnagar & Karwar 7 each
21	Dengraparaghat 20, Taibpur 19, Honavar 11, Domohani 16,Khed & Khanapur 9 each Chandanpur 7	Sankalan 16, Haripur & Kundapura 11 each, Tezu & Dholai 10 each, Pathri 7	Baijnath 17, Tirupattur 16, Malda & Hardwar 11 each, Gudari, Sikanderpur & Idukki 9 each Dehradun, Kalka, Kotkasim, Ahmednagar, Gangapur & Amini Divi 7 each	Bhoond 15, Paonta 14, Triveni, Nanded 12, New Delhi (SFD) 10, Sevoke & Sikri 9 each, Raver 8, Agra 7
22	Malvan 19, Saralpara 11, Talipara Barrage 9, Jalpaiguri & Honavar 8 each, Agumbe 7	Cooch Behar & Bhira 8 each	Mancompu 16, Sagar 11, Ghamroor & Mangrulpir 9 each, Venkatagiri 8, Miao, Sardarnagar, Dehradun & Alampur 7 each	Khandwa 27, Nilokheri 26, Balachaur & Malkapur 19 each. Edlabad 15, Sardarshahar 12, Shardanagar & Kahu 10 each, Tonk 9, Nagrakata 8, Pathri 7
23	Ratnagiri 19, Chauldhowaghat 17, Bhatkal 13, Cuttack 8, Triveni, Alland & Khammardi 7 each	Matizuri 11, Jhawa 9, Bhira 8, Mani & Kunnamkulam 7 each	Birpur 17, Mancompu 15, Jalpaiguri 10, Visakhapatnam 9, Uttarkashi 8, Gorakhpur & Pune (LHG) 7 each	Todabhim 20, Shajapur 15, Palghar & Palamner 12 each, Kasauli 10, Hasimara, Mathura & Kalka 9 each, Basholi & Neyattinkara 8 each

APPENDIX I *(Contd.)*

(1)	(2)	(3)	(4)	(5)
24	Mani 24, Kasargod 19, Kammardi 12	Marmugoa 34, Hasimara 18, Kundapura 12, Jainagar 10, Balmikinagar, Bhubaneswar & Osmanabad 7 each	Karipur, 11 Chatia & Avanigadda 9 each, Silchar, Kumher & Ahwa 7 each	Sewara Head 17, Mandya 16, Narwana & Kozha 15 each, Hathmathiweir & Balachaur 14 each, Kahu & Kurnool 9 each, Venkatagiri Town 8, Nancowry, Jodhpur & Adirampattinam 7 each
25	Chiplun & Agumbe 12 each, Hatkangale, Mangalore & Vadakara 10 each, Tikrapara 9	Baghdogra & Khadda 15 each, Dhubri & Mani 13 each, Triveni 11, Kannur 10, Cuttack & Vengurla 9 each, Amini Divi 8, Udgir 7	Cooch Behar 12, Allahabad & Alibag 10 each, Banbasa & Ahmednagar 9 each, Annapurnaghat & Jalna 8 each , Sandheads,Taibpur, Dharamsala, Keshod & Kozhikode 7 each	Marora 19, Sangola 14, Jalpaiguri 10
26	Baghdogra & Aluva 10 each, Tikarpara & Kollur 9 each, Kargal 8	Chandradeepghat 16, Mhasala 13, Chepan 12, Kailashahar 11, Shirali 10, Kokrajhar & Gudivada 9 each, Mayabandar 8	Agumbe 23, Betul 18, Kankavali & Chodavaram 12 each, Jalpaiguri, Chargharia, Nadaun & Honavar 10 each, Dehradun 9, Saralpara 8, Sandheads, Lunkaransar & Ahwa 7 each	Mani 18, Lakkavalli 11, Byadgi & Ponnani 9 each, Hut Bay, Puthimari & Kurnool 8 each, Guda Dam 7
27	Chiplun 26, Karwar 14, Agumbe & Peermade 11 each, Gaganbavda 9	Taibpur 34, Shegaon 14, Jalpaiguri 11, Kundapura 10, Ambad 9, Long Island, Mhasala & Yellandu 7 each	Gaganbavda 19, Koyna (Navaja) & Tadepalligudem 15 each, Sandheads & Mukhlishpur 10 each, Ratlam Derol-Bridge & Bhagamandala 9 each, Passighat, Jogindernagar, Bhimapur & Gokarna 8 each, Sikanderpur, Mohana, Mukerian, Sagara & Nanded 7 each	Chiplun 13, Singlabazar 9. Hut Bay & Puthimari 8 each
28	Mumbai (CLB) 25, Mani 24, Vythiry 16, Hosanagara 13, Rewari 11, Mayabandar & Raipur 9 each, Darjeeling 8, Parola 7	Sharadanagar 27, Ratnagiri 13, Ausa 11, Mohana 10, Chanpatia & Pargi 9 each, Ahmednagar 8 , Honavar & Gulbarga 7 each	Veraval 25, Tamini 16, Thanesar 13, Passighat, Talcher & Ajmer 10 each, Mathabhanga & Gaganbavda 9 each, Berthin 8, Patiala 7	Goalpara 11, Kavali & Kurnool 10 each
29	Ratnagiri 20, Naraingarh 17, Ahwa 14, Mahabaleshwar 13, Sevoke & Nawashahar 11 each, Chottabekra 10, Port Blair, Digha & Uttar Kashi 9 each, Keshod Udgir & Srungarapukota 8 each	Nanded 19, Amraghat 18, Honavar 16, Ratnagiri, Vikarabad & Agumbe 15 each , Chottabekra, Champasarai & Paleru-Bridge 9 each, Mahabaleshwar & Thodupuzha 7 each	Champasarai 18, Ratnagiri 14, Passighat 12, Galgalia, Narora, Silvassa & Malkapur 10 each, Kasol & Porbandar 8 each, Suri, Gaganbavada & Shirali 7	Pakala 11, Lanja 10, Chitradurga, Khusiary, Daitary, Kakinada & Mundargi 8 each, Kollur & Paravur 7 each
30	Kokrajhar 30, Chiplun & Gaganbavda 25 each, Mani & Agumbe 23, each, Idukki & New Delhi (PLM) 19 each, Manchekere 18, Hosanagara 15, Taibpur & Mannar 14 each, Astha 9, Jalpaiguri & Veraval 8 each, Bhubaneswar & Kangra 7 each	Dindori 27, Pali 17, Ambad 14, Patur 13, Sringeri 11, Karwar 9, Gohar & Tilakwada 8 each, Mayabandar & Bharatpur 7 each	Saralpara 18, Narora 10, Medak 9, Kudal 8, Passighat & Paradip 7 each	Dharmavaram & Gulbarga 8 each
31	Nil	Bhoond 20, Bhira 19, Subramanya 14, Cooch Behar & Pathri 12 each, Agumbe 11, Nancowry & Ahmedabad 10 each, Mahabaleshwar 9, Uttar Kashi & Narsipatnam 8 each, Bridghat 7	Taibpur 19, Jalpaiguri, Rajapur & Mulbagal 10 each, Car Nicobar 9, Nadiad 8, Tezu & Basti 7 each	

crores of rupees and many people rendered homeless due to heavy rains, landslides, thunderstorms and strong winds during June to September 1998.

Damages due to floods and heavy rains in June, July, August and September are given in section 12.1, 12.2, 12.3 and 12.4 respectively.

10. Significant spells of heavy rains

10.1. *June*

During the month, widespread rains with isolated heavy to very heavy falls occurred in many sub-divisions in the second fortnight of the month. Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Orissa, Gujarat Region,

south interior Karnataka and Kerala experienced 7 to 13 days of heavy to very heavy spells during the month.

10.2. *July*

During the month, good number of heavy to very heavy falls occurred throughout the country outside Nagaland, Manipur, Mizoram & Tripura, Haryana, Punjab, Rajasthan and Rayalaseema.

10.3. *August*

Good number of heavy to very heavy falls occurred throughout the country outside Nagaland, Manipur, Mizoram & Tripura, Bihar Plateau, Punjab, Rajasthan and Rayalaseema during the month.

10.4. *September*

During this month also, good number of heavy to very heavy falls occurred throughout the country outside Nagaland, Manipur, Mizoram & Tripura, hills of west Uttar Pradesh, Jammu & Kashmir, east Rajasthan, Saurashtra & Kutch and Rayalaseema.

The statistics of spatial rainfall distribution of June-September is given in Table 10.

11. Significant monthly features

11.1. *June*

11.1.1. *Temperature*

Severe that wave conditions prevailed on 3 to 4 days in Gangetic West Bengal and Bihar Plains and on 1 to 2 days in Rayalaseema and interior Karnataka. Heat wave conditions also prevailed on one day in plains of west Uttar Pradesh. Highest day temperature of 47°C was recorded at Dholpur (Rajasthan) on 6 June.

11.1.2. *Monthly rainfall*

Monthly rainfall is given in Fig.5 and principal amounts of rainfall are given in Appendix I.

12. Disastrous weather events and damages during monsoon months

12.1. *June*

Heat wave took toll of 617 human lives, West Bengal (52), Bihar (237), Uttar Pradesh (169) and Andhra Pradesh (159) were the most badly affected states. It is reported that, in Gujarat State and Rajasthan 1265 people lost their lives (1256 in Gujarat and 9 in Rajasthan) because of very severe cyclonic storm in Arabian Sea. In addition, 76 people died due to heavy rain and floods in various parts of the country. Properties worth crores of rupees was damaged due to floods and heavy rains.

12.2. *July*

According media reports, 302 people lost their lives in the various parts of the country including 81in Assam and 50 in Kerala. Properties worth crores of rupees was damaged due to floods and heavy rains.

12.3. *August*

According media reports, 250 people lost their lives in the various parts of the country including 93 in Assam. Properties worth crores of rupees was damaged due to floods and heavy rains. More than lakhs of people were affected in Assam because of flood water. Value of crops damaged in the country was more than 8 crores.

12.4. *September*

About 401 people lost their lives due to heavy rains and floods in various parts of the country including 144 in Assam, 83 in West Bengal. Lakhs of people were rendered homeless. Properties worth crores of rupees got damaged due to floods.

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