MAUSAM, 49, 3, (July 1998), 405-432

Weather in India

MONSOON SEASON (JUNE-SEPTEMBER 1997)*

1. Introduction

The monsoon seasonal rainfall, from June to September 1997, was excess or normal in 32 out of 35 meteorological sub-divisions of the country. During the season, one cyclonic storm and five monsoon depressions formed over the Bay of Bengal. No depression formed over the Arabian Sea. The seasonal rainfall departures stationwise and sub-divisionwise are given in Figs. (1 & 2). Inspite of strong El-Nino year, country received well-distributed and normal rainfall.

2. Features of monsoon

2.1 *Advance of southwest monsoon*

The southwest monsoon set in over Kerala on 9 June 1997 with a delay of 8 days. It also advanced over northeast India on the same day as that of Kerala. Monsoon advanced upto Gujarat, Madhya Pradesh, Orissa and West Bengal by 22 June with a delay of about 5 days. It further advanced over Bihar, Uttar Pradesh, Himachal Pradesh, Jammu & Kashmir by 26 June with a delay of about 5 days. Monsoon covered the entire country by the 19 July with a delay of 4 days. Isochrones of advanced of southwest monsoon 1997 are shown in Fig. 3.

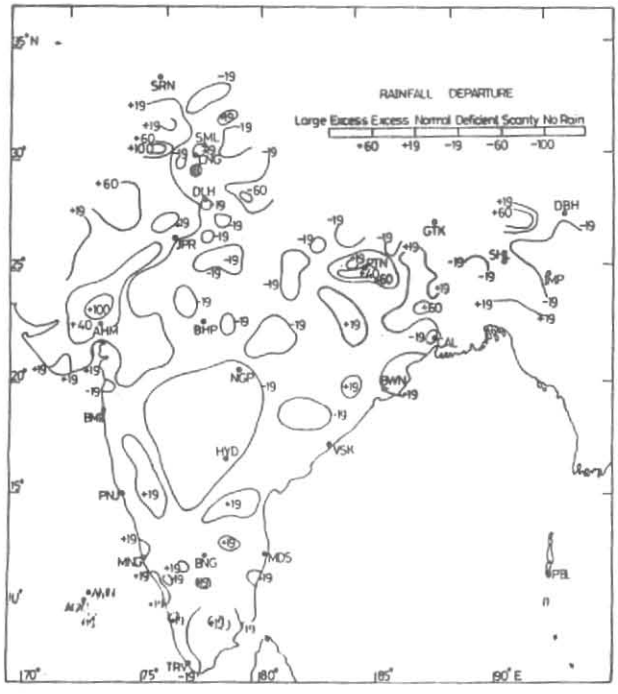


Fig. 1. Stationwise seasonal rainfall departure (%) for the period June-September 1997

2.2. *Week-by-week cumulative rainfall distribution (1 June-30 September 1997)*

Meteorological sub-divisionwise weekly cumulative rainfall departures (percentage departure from normal) during the period 1 June-30 September 1997, comprising of 17 weeks, are given in Fig.4. Rainfall activity was very well-distributed throughout the season. From the week ending 2 July onwards, nearly 70% or more of the meteorological sub-divisions received excess or normal rainfall. Weekly rainfall was either deficient or scanty in almost all the weeks in Marathwada, Vidarbha and Telangana. Weekly rainfall was either deficient or scanty over coastal Andhra Pradesh during the first 14 weeks and thereafter, it became normal in the last three weeks of the season.

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

Figs.5-8 show monthwise distribution of monsoon rainfall.

Rainfall figures and departures for each month sub-divisionwise are given in Table 1 and principal amounts of daily rainfall are given in Table 2.

2.4. *Seasonal performance of monsoon rainfall*

The season rainfall was excess in 7 and normal in 25 meteorological sub-divisions. It was deficient in only three meteorological sub-divisions, namely, Marathwada (-31%), Vidarbha (-22%) and Telangana (-26%). Seasonal total rainfall for the country as a whole was normal and received 102% of its long period average value.

Compiled by: S.K. Diskshit, D.S. Desai & V. Krishnan, Meteorological Office, Pune-411 005, India

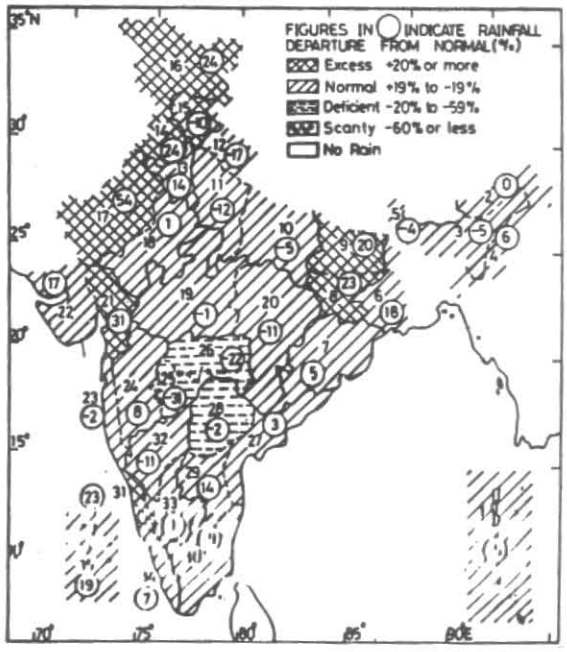


Fig. 2. Sub-divisionwise seasonal rainfall departure (%) for the period June-September 1997

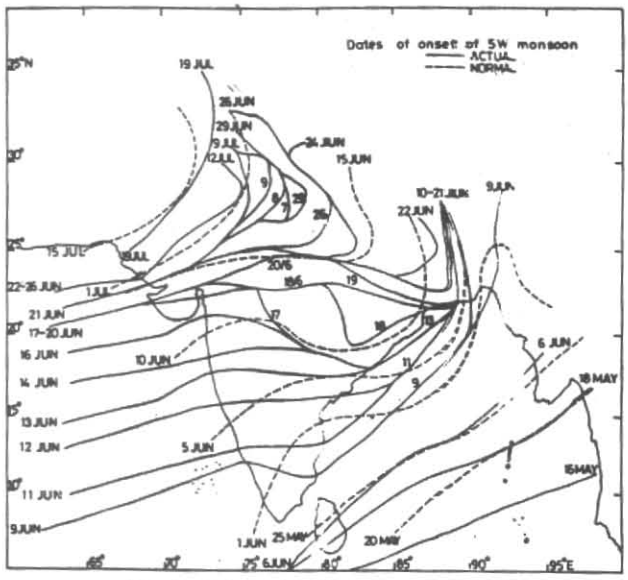


Fig. 3. Advance of southwest monsoon 1997

2.5. *Districtwise distribution of rainfall*

Data considered for 403 districts (out of 415 meteorological districts) show that, 23% districts received excess rainfall and 58% districts received normal rainfall (Table 3) during the season.

Statewise number of districts which received rainfall is also given in Table 3.

2.6. *Withdrawal of southwest monsoon*

Southwest monsoon withdrew from west Rajasthan on 18 September as against the normal date of 15 September. It further withdrew from rest of northwest India, Uttar Pradesh, west Madhya Pradesh, Gujarat and Marathwada by 3 October as against the normal date of 1 October. It withdrew from the entire country by 8 October. Northeast monsoon rains commenced over Tamil Nadu & Pondicherry, Kerala and adjoining parts of Andhra Pradesh and of Karnataka on 13 October. Withdrawal dates of southwest monsoon are given in Fig. 9.

2.7. *El-Nino phenomenon*

El-Nino is a term that is used for an oceanographic phenomenon and is the anomalous rise in sea surface temperature above its normal values off Peru coast. A see-saw relationship between sea level pressure over the eastern south Pacific Ocean and the Indian Ocean closely linked with El-Nino phenomenon is called the Southern Oscillation (SO). The index that measures the magnitude of the SO is known as Southern Oscillation Index (SOI) and is obtained by calculating the difference in atmospheric surface pressure between Tahiti and Darwin, Australia. There is a tendency of pressure over the Pacific and rainfall over India to increase while the pressure over the Indian Ocean decreases. The El-Nino phenomenon and SO are closely linked with each other and is often known as "El-Nino Southern Oscillation" or "ENSO".

Warm ENSO conditions prevailed over the tropical Pacific since March 1997. Table 14 depicts the monthly values of SOI and the Sea Surface Temperature Anomally (SSTA) values in Nino 1+2 region (0°-10°S, 90°W- 80°W), Nino 3 region (5°N- 5°S, 150°W-90° W) and Nino 4 region (5°N-5°S, 160°E- 150°W) for Jan-Dec 1997. It is observed that the SSTA value over the region off South American Coast was positive in February 1997 and continued to rise since then, reaching the peak value of 4.5°C in December 1997. The SSTA value over Nino 3 region turned to be positive in March 1997 and continued to rise thereafter till December 1997. The SSTA value over Nino 4 region was positive since August 1996, it rose sharply in April 1997 and thereafter, remained in the range of 0.9-1.0°C upto October 1997. In November and December 1997, this value further rose to 1.1°C. The global tropical SSTA value was positive and exhibited a steady increase since January 1997 till December 1997. It reached a record value of +1.3°C in December 1997. The value of SOI showed a sharp fall from its value of +1.6 in February 1997 to −1.1 in March 1997 and continued to be negative till December 1997, showing

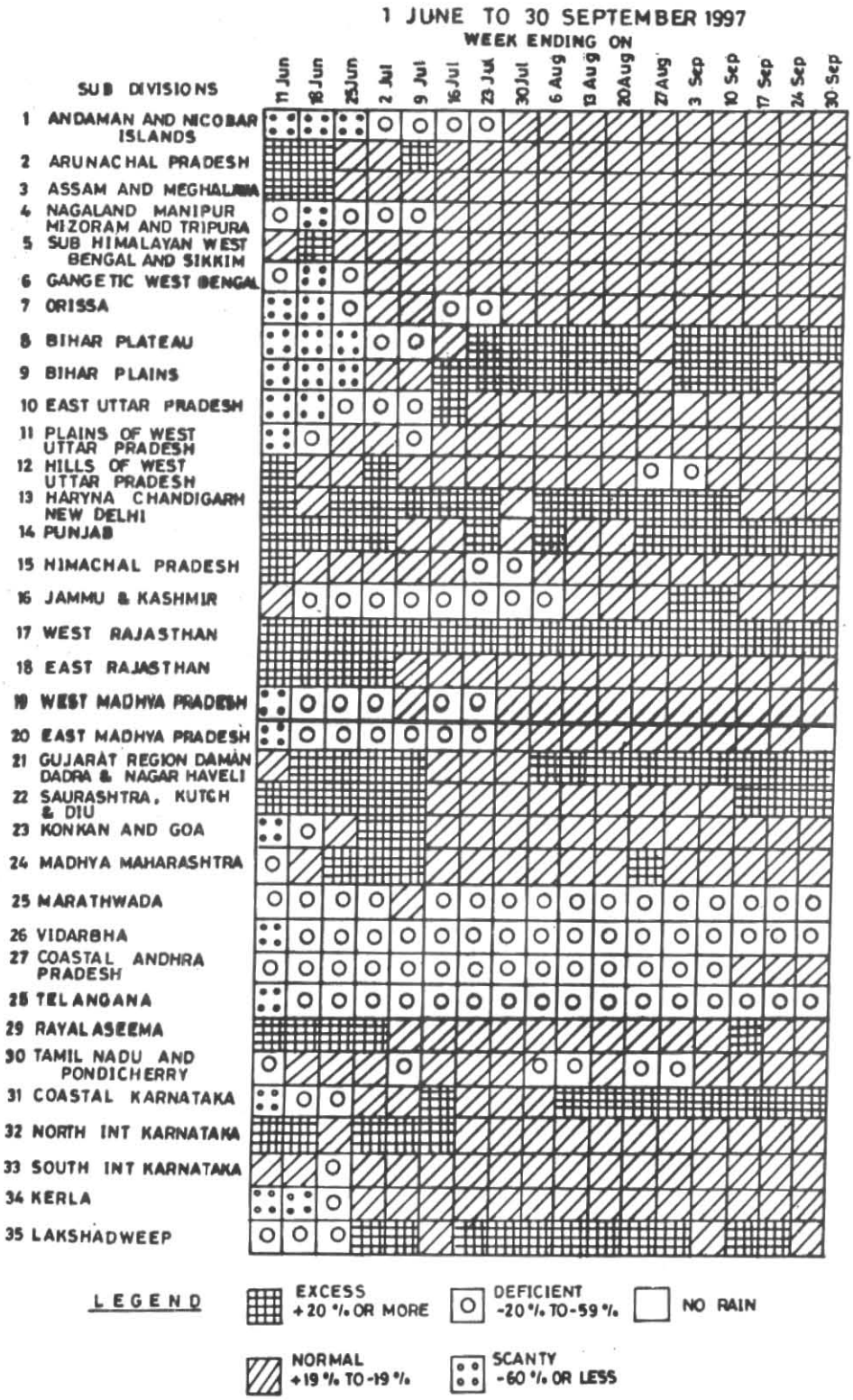


Fig. 4. Progress of southwest monsoon week-by-week (1 June to 30 September 1997)

TABLE 1

Rainfall figures (mm) for each month and season as a whole (June- September 1997)

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.	Andaman & Nicobar Islands	161	470	-66	558	357	56	377	360	5	416	409	2	1511	1597	-5
2.	Arunachal Pradesh	614	572	7	627	674	-7	274	483	-43	521	307	70	2036	2036	0
3.	Assam & Meghalaya	640	596	7	509	568	-10	305	453	-33	390	330	18	1844	1948	-5
4.	Naga., Mani., Miz. & Tripura	331	387	-20	469	329	43	241	295	-18	299	239	25	1320	1250	6
5.	SHWB & Sikkim	624	524	19	451	609	-26	481	502	-4	404	402	1	1960	2036	-4
6.	Gangetic West Bengal	204	247	-18	412	312	32	403	308	31	276	229	20	1295	1096	18
7.	Orissa	218	221	-1	291	357	-19	488	356	37	240	244	-2	1237	1178	5
8.	Bihar Plateau	246	195	26	440	333	32	421	324	30	213	224	-5	1320	1077	23
9.	Bihar Plains	224	168	33	482	311	55	321	303	6	176	220	-20	1204	1003	20
10.	East U.P.	79	105	-25	326	303	8	238	299	-20	214	191	12	858	898	-5
11.	Plains of west U.P.	85	80	6	239	262	-9	233	269	-13	116	162	-28	674	773	-13
12.	Hills of west U.P.	226	169	33	232	449	-28	334	448	-25	187	229	-18	1070	1295	-17
13.	Haryana, Chandigarh & Delhi	103	51	101	164	175	-6	273	179	53	47	108	-57	587	513	14
14.	Punjab	83	42	96	181	188	-4	318	170	87	38	100	-63	619	500	24
15.	Himachal Pradesh	91	97	-6	236	347	-32	379	321	18	126	157	-20	831	921	-10
16.	Jammu & Kashmir	45	55	-19	169	183	-8	342	183	87	65	80	-19	621	501	24
17.	West Rajasthan	96	28	244	121	104	17	180	106	70	42	48	-12	439	285	54
18.	East Rajasthan	95	57	66	194	227	-15	240	229	5	107	118	-9	636	630	1
19.	West Madhya Pradesh	90	115	-22	373	312	20	325	313	4	116	174	-33	904	914	-1
20.	East Madhya Pradesh	126	166	-24	428	386	11	326	385	-15	148	213	-31	1027	1149	-11
21.	Gujarat Region	404	158	156	348	433	-20	496	270	84	121	181	-33	1369	1042	31
22.	Saurashtra & Kutch	234	91	158	137	240	-43	94	129	-27	171	85	102	636	544	17
23.	Konkan & Goa	784	685	14	1004	1106	-9	771	663	16	199	348	-43	2759	2801	-2
24.	Madhya Maharashtra	182	140	30	242	271	-11	283	179	58	96	155	-38	804	745	8
25.	Marathwada	64	146	-56	147	206	-28	128	187	-32	153	179	-14	492	717	-31
26.	Vidarbha	110	171	-35	235	338	-30	259	272	-5	153	194	-21	758	975	-22
27.	Coastal Andhra Pradesh	56	109	-48	148	168	-12	110	159	-31	306	168	82	621	605	3
28.	Telangana	71	134	-47	185	231	-20	144	212	-32	164	188	-13	564	766	-26
29.	Rayalaseema	79	59	33	47	85	-44	85	98	-13	216	132	64	427	374	14
30.	Tamil Nadu	47	53	-10	61	73	-16	58	98	-41	131	103	28	298	326	-9
31.	Coastal Karnataka	864	871	-1	1528	1155	32	1172	680	72	124	301	-59	3688	3007	23
32.	N.I. Karnataka	115	98	17	133	149	-11	120	122	-1	111	150	-26	478	519	-8
33.	S.I. Karnataka	172	150	15	235	278	-16	236	185	28	117	138	-15	760	750	1
34.	Kerala	559	697	-20	942	765	23	521	439	18	290	252	15	2312	2153	7
35.	Lakshadweep	307	307	0	460	283	62	217	192	13	144	161	-11	1127	944	19

a brief decreasing trend during March to May and August to December. The minimum value of SOI was observed in August 1997.Thus, during the period of Indian summer monsoon (June-September) of 1997, strong warm ENSO conditions prevailed in tropical Pacific, as evident from SSTA values over various Nino regions of the Pacific and the SOI values. The analysis of SOI values shows that this warm ENSO episode was atleast as strong as 1982-83 episode. The SSTA values for June in Nino 1+2 and Nino 3 regions were the highest values since 1982-83 episode. The SSTA value in Nino 3 regions in July 1997 was the highest July value observed dating back to 1950. Also, the values in Nino 1+2 and Nino 3 regions were the highest in August and September observed in last 50 years.

3. Chief synoptic features during the monsoon

The synoptic distrubances which affected the Indian monsoon region in June, July, August and September are given in Tables 4,5,6 & 7 respectively.

3.1. *Cyclonic storms/depressions*

Five depressions and a cyclonic storm formed during the season (Fig. 10). All of them formed over the Bey of Bengal. Their monthwise distribution is given below.

One depression each in the months of June and July, three in August and the cyclonic storm in the month of September formed during the season.

TABLE 2

Principal Amounts of rainfall (cm) (June to September 1996)

Date (1)	June (2)	July (3)	August (4)	September (5)
1	Dhubri 10, Cooch Behar & Waltair 9 each, Varkal 8	Baltara 19, Sikandarpur 16, Chottabekra 10, Panbari 9, Beki Road Bridge & Berhampore 8 each, Poladpur 7	Raipur 24, Mana 22, Jamshedpur 19, Dungarwadi 12, Varansai 9, Panposh 8, Mohanpur 7	Dhubri 17, Bhind 16, Banbasa & Gazipur 15 each, Beki Mathanguri & Dowlaiswaram 13 each, Behar & Gwalior 8 each, Baltara 7
2	Sevoke 7	Beki Road Bridge 18, Dengraghat 14, Khalapur 13, Guwahati 9, Agartala & Bhavnagar 8 each, Gaganbavda 7	Kangsabati Dam 18, Koyna 14, Gaganbavda & Gohana 12 each, Auraiya & Yeotmal 8 each, Dabri & Mani 7 each	Bhind 14, Gooty & Kanpur 12 each, Tusuma 11, Garotha 10, Guntur 8, Dengraghat & Periyakulam 7 each
3	Kozhikode 7	Hasimara 18, Saralpara 15, Thane Belapur 9, Passighat 7	Gaganbavda 11, Jirka & Mahabaleshwar 9 each, Jamsolaghat, Moga & Vihar 7 each	Agra & Chibramau 13 each, Kattumannarkoil & Ramagundem 8 each, Jaipur & Jhansi 7 each.
4	Thiruvananthapuram 10, Thuklay 8, Maya Bandar 7	Nancowry 17, Beki Mathanguri 16, Galgaliya 13, Upper Vaitarna 10, Mumbai 8, Chintalapudi 7	Khand 10, Gaganbavda, Mahabaleshwar & Nawashahar 7 each	Taibpur 12, Dummagudem 11, Jharsuguda & Narsapur 8 each, Cuddapah 7
5	Itanagar 9, Minicóy 9, Alapuzha 8, Sevoke 7	Nagarkata 27, Pauni 14, Mellabazar 11, Purna 7	Jodhpur 29, Dehradun 10, Khand 9, Adoor, Agumbe, Dhollabazar, Guna & Koyna 7 each	Kakrahi 15, Berhampore 14, Nizamsagar 10, Kuhi, Sevoke & Uthangiri 9 each, Gadag & Mhasla 8 each, Kusiary 7
6	Hut Bay & Matizuri 7 each	Birpur & Purulia 9 each, Sevoke 8	Nawashahar 16, Mellabazar 15, Swampatna 13, Dohad 12, Mount Abu 11, Banswara, Dharamsala, Jhabua & Lanja 9 each, Minicoy 8, Agumbe, Ambone, Gazipur, Harinkhola, Nagaur & Ranchi 7 each	Sendwa 9, Banbasa, Durg & Tumkur 8 each, Passighat, Pathri & Sevoke 7 each
7	Kaikuntla 8, Gaganbavda 7	Guntur & Kondul 8 each, Guna & Latur 7 each	Kaharidwar 10, Ahmedabad & Subramanya 9 each, Chittradurga, Jamshedpur & Naraingarh 8 each, Banswara, Calcutta, Madikeri & Piravom 7 each	Pauni 19, Ottapalam 13, Rattia 12, Dohad & Narora 11 each, Ajmer & Kalingapattinam 9 each, Cooch Behar, Fetehgarh & R.S. Dam site 8 each, Alapuzha 7
8	Canning Town 8, Guhagar 7	Sindkheda 14, Almatti 12, Champasarai 10, Naraingarh, Paonta & Paravur 9 each, Amini Divi 7	Katerniaghat 15, Koyna 14, Haldwani 12, Sikandarpur 11, Nanipalsam & Peint 10 each, Chittorgarh 9, Chauldhowaghat & Koida 7 each	Colgaon & Jagadhari 14 each, Ayodhya 13, Alibag & Pathri 11 each, Cuddalore 10, Chottabekra & Madhuban 8 each, Banbasa, Moradabad & Raigarh 7 each
9	Bangalore & Panambur 8 each	Hasimara 10, Gwalior & Madurai 9 each, Akola 7	Suri & Bilari 15 each, Sevoke 13, Lalbegiaghat & Saralpara 11 each, Kashipur, Mahabaleshwar & Naraingarh 9 each	Kalka 18, Ukai 15, Dharampur 12, Amalapurama, Muddebihal & Udaipur 11 each, Shirol & Vellore 10, Pathri 9, Khadda & Triveni 8 each, Banpura & Dabri 7 each
10	Koyana & Panhala 8 each, Ghodegaon & Kondul 7 each	Dehradun 22, Barobisha 19, Ponnani 13, Malegaon 12, Panambur 10, Kozhikode, Maithan & Tezu 9 each, Ghamrur & Purulia 7 each	Jagadhari 16, Fatehpur, Nagrota & Suriam 15 each, Chotabekra 14	Sankheda 21, Manali 11, Balachaur & Vallabh Vidyanagar 10 each, Narnaul 8
11	Nagarkurnool 14, Panjim 13, Tiruvur 12, Itanagar 11, Atmakur 10, Karwar & Salem 9 each, Tiruchirapalli 7	Shardanagar 12, Kokrajhar & Sevoke 11 each, Kancheepuram, Karwar, & Nangal 10 each, Latur 9, Dungarwadi 8, Hut Bay, Idukki, Jagadhari & Umrer 7 each	Mudibigere 11, Car Nicobar, Sevoke & Fatehpur 10 each, Dabri, Katra & Koyna 8 each, Ambone 7	Savnur 9, Kalwakurthy 8
12	Malegaon 11, Chidambaram 9, Port Blair 8, Nagapattinam 7	Hasimara 19, Saralpara & Kakardarighat 18 each, Dharavi 16, Manchikere 12, Rangagora 10, Darabassi 8, Itanagar & Idukki 7 each	Cooch Behar 17, Bdatighat 15, Basa & Katra 13 each, Saralpara & Balarampur 10 each, Bangalore 9, Itanagar & Shrungavarapukotta 8 each	Chennai 17, Watrak Dam 13, M. Kotta 11, Bagewadi & Agumbe 10 each, Mangalvedha, Parenda & Hinganghat 9 each
13	Hosdurg 13, Panam Dam, Sinnar & Raichur 12 each, Chennai 11, Bhiwandi & Panambur 8 each, Nadaun 7	Sevoke 40, Saralpara & Kakardarighat 21 each, Rajapur 17, Nadaun 14, Bareilly 12, Tezu, Honavar & Kozhikode 10 each, Taibpur & Sirsilla 8 each, Gaganbavda & Tiruvuru 7 each	Khairi 20, Etawah & Jammu 19 each, Chanpatia 15, Gorakhpur & Mani 11 each, Sibsagar & Avanigadda 9 each, Bagdora & Melur 8 each, Koyna, Gaganbavda, Takapara & Nagarjunsagar Dam 7 each	Dabri & Panambur 10 each, Amalner 9, Karwar 8, Palliakalan 7

TABLE 2 (*contd.*)

(1)	(2)	(3)	(4)	(5)
14	Chennai 35, Mulki 33, Tada 23, Hosdurg 21, Panjim & Srikalahasti 11 each, Amritsar & Kargal 9 each, Berhampore 7	Taibpur & Kankavli 18 each, Gaganbavda 14, Karwar 9, Nancowry & Paderu 7 each	Neemsar 16, Baijnath 14, Chapra 13, Auraiya & Dholai 10 each, Dehradun 9, Baghdogra & Chandigarh 8 each, Mulug & Sidapur 7 each	Mumbai 17, Baijnath 12, Kheda 10, Gaganbavda 8, Pondicherry 7
15	Gokarna 38, Panjim 34, Kargal 24, Kannur 20, Chennai 19, Porumamilla 18, Udayagiri 15, Gaganbavda 11, Berhampore, Khanitari, Kollelur & Muddebihal 8 each, Jagadhari 7	Vengurla 17, Palliakalan 14, Kakinada 13, Mancherial 11, Kinwat 9, Dhbri 8, Kaithal & Karwar 7 each	Gorakhpur 13, Avanigadda 12, Sevoke 10, Indrapur 9, Raighgarh 8, Shahjina, Mahabaleshwar, Thanjavur & Kargal 7 each	Dungerwadi 14, Alibagh 12, Hardoi 10, Bodeli & Jagityal 9 each, Tuljapur 8, Shegaon & Gulbarga 7 each
16	Machilipatnam 20, Mudibagere 18, Rajapur 17, Chennai 11, Sevoke, Madikeri & Kannur 9 each, Kokrajhar & Gaganbavda 8 each	Kokrajhar & Barobisha 18 each, Rajapur 17, Passighat 16, Narsampet 14, Gaganbavda 13, Katangi 12, Eluru, Ankola & Derol Bridge 10 each, Agumbe 9, Kotraguda 8, Munnar 7	Hasimara & Sikandarpur 17 each, Beki Mathanguri 12, Vikarabad 10, Badaun & Rajampet 9 each, Digha, Sampla 8 each, Haripur & Parbhani 7 each	Tuljapur 15, Palliakalan 15, Mandsaur 10, Lonavala 7
17	Koida 67, Nidadavole 25, Piravom 16, Rajapur, Virajpet & Karwar 11 each, Karkarapur 8	Domahani 33, Galgalia 30, Beki Mathaguri 21, Passighat 18, Ambone & Bhatkal 16 each, Ratnagiri 14, Dabri & Agumbe 12 each, Palliakalan 11, Ellamanchali 9, Khuldabad & Pirovam 8 each, Kakrapar 7	Jogindernagar 17, Basholi & Tiruthuraipoondi 14 each, Sevoke 11, Bhagalpur 10, Lucknow & Narora 9 each, Dibrugarh 8, Chottabekara, Japla & Agumbe 7 each	Patan 9, Barwaha & Dungerwadi 7 each
18	Gaganbavda 19, Mulki & Sringeri 17 each, Idar 16, Mhasala & Kozhikode 11 each, Kaleswaram 9, Bikaner 8, Dharampur 7	Kokrajhar 33, Kollur 19, Galgalia 18, Mathabhanga 17, Kudal 12, Passighat & Kottigehara 11 each, Mahabaleshwar 8, Vidisha 7	Passighat, Baptla & Yercaud 13 each, Hasimara, Gorakhpur & Guler 12 each, Didwana 10, Dibrugarh 9, Arogyavaram 8, Kusiary, Nagpur & Bhongir 7 each	Neamatighat 7
19	Mahabaleshwar 28, Porbandar 15, Honavar 13, Rajnandgaon 12, Bhira & Kottigehara 11 each, Piravom 9, Suratgarh & Belgaum 8 each, Long Island 7	Chepan & Dungarwadi 24 each, Uran 22, Okha 17, Taibpur 16, Mani 13, Thalasarry 11, Passighat 10, Bobilli & Srisailam 9 each, Katghora & Koppa 7 each	Avanigadda 22, Gazipur 17, Durgachak 16, Birpur & Dehradun 13 each, Bihubar, Kanitar & Puri 8 each, Nahan & Durg 7 each	Kangra 8, Dharamsala 7
20	New Kandla 21, Port Blair, Veraval, Mahabaleshwar & Mulki 11 each, Chhotan & Mount Abu 10 each, Kannur 9	Dungerwadi & Mulki 19 each, Basti 15, Barobisha & Rajkot 13 each, Uran 12, Mehre 10, Surat 9, Madikeri 8, Hanamkonda & Qulandy 7 each	Sagar 13, Ranchi & Tenali 10 each, Dehradun 9, Dhubri & Tirupathi 8 each, Jaunpur, Deragopipur, Mul & Tambaram 7 each	Thirumanyam 5, Sriharikotta 4
21	Pokhran 17, Mount Abu 16, Cooch Behar, Jenapur, Amini Divi 11 each, Purulia 10, Haripad, Melabazar 8, Sarotary 7	Dahanu 20, Surat 19, Lonavala 14, Mulki 11, Kotputli 9, Kannur 8, Domohani, Dehradun, Kaleswaram, Somwarpet 7 each	Bhopal 29, Sandheads 13, Agumbe 12, Namakkal 11, Pendra & Ratnagiri 8 each, Chauldhowaghat, Naraingarh, Perur 7 each, Hut Bay 14, Neamatighat 10, Dapoli 7	
22	Phalodi 21, Talcher 18, Dengra Paraghat 13, Goalpara & Shimla 10 each, Dehradun & Amini Divi 9 each, Sankalan, Jamshedpur, Raigarh, Honavar & Hosdurg 7 each	Poladpur 27, Mahabaleshwar 23, Rengali & Veraval 18 each, Daman 15, Shirali 13, Mandsaur 10, Raigarh & Perur 8 each, Kishangarh & Sringeri 7 each	Kakrahi 21, Malda & Harinkhola 16 each, Jogindernagar 15, Udhampur 13, Jhajjar 11, Narora, Poladpur & Cuddapah 10 each, Bihubar, Sawai Madhopur & Agra 7 each	Parangipettai 14, Agartala 7
23	Nagaur 36, Srimadhopur 19, Purulia 15, Ranchi 11, Kathua 9, Bahraich 8, Khed 7	Veraval 36, Mahabaleshwar 28, Koyna 20, Kushalgarh & Agumbe 13 each, Silvasa 12, Dharamsala 11, Dharamasthala 10, Margherita & Khanapur 9 each, Perur & Raigarh 7	Udhampur 33, Nilokheri & Chamba 17 each, Malakpur 15, Vedaranniyam 14, Khanpur & Ramnagar 12 each, Sandheads & Gunupur 9 each, Basti 7	Bhagalpur 13, Kondut 10, Khowang 8
24	Kolputti 14, Hut Bay 12, Nurpur, Dapoli 10 each, Ranchi, Palmerganj 9 each, Rewari, Dungerwadi 8 each, Patiala 7	Banswara, Shirota 20 each, Dahanu 18, Kottighera 14, Karnal 13, Dharamsala 11	Jammu 16, Muktsar 15, Sambalpur 13, Chamba 12, Kozhikode 11, Hirekerur 10, Darauli, Jagadhari, Jagityal, Mani 9 each	Yercaud 9, Poladpur 8

TABLE 2 *(contd.)*

(1)	(2)	(3)	(4)	(5)
25	Bayana 23, Kakrahi 22, Rewari 13, Domohani 11, Maya Bandar 9, Harikhola 8	Balasore 19, Mahabaleshwar 15, Wada 12, Sonkutch & Sringeri 10 each, Kotari & Bijapur 9 each, Brahmpuri 8, Dharamsala Idukki 7 each	Udhampur 15, Sringeri 11, Malvan & Sangola 10 each, Purushottampur 9, Purna & Piduguraua 8 each, Bhopal & Pennagaram 7 each	Annigeri 16, Chitradurga 12, Sinner 10, Koderu & Kuppam 9 each
26	Chepan 17, Gheropara 11, Bharlipur 8, Car Nicobar & Usilampatti 7 each	Depalpur 34, Kotraguda 23, Bilaspur 12, Darjeeling & Mahabaleshwar 11 each, Ajmer 10, Kokrajhar 9, Dadupur & Dharamsala 8 each, Jamshedpur, Sringeri 7 each	Igatpuri 14, Shantiniketan & Mhasla 9 each, Long Island & Dummgudem 8 each, Kalamb 7	Dharamsala 13, Bhagamandala 11, Srikali 9, Sevoke 8, Kalapur, Dharwad, Thiruvananthapuram & Darjeeling 7 each
27	Goalpara 17, Ankinghat 14, Port Blair 11, Visakhapatnam 10, Chottabekra & Gohar 7 each	Bhopal 21, Mahabaleshwar 17, Passighat 16, Naharkatia 14, Banswara & Agumbe 13 each, Mani Dam & Gondia 12 each, Dharamsala 8, Sevoke & Nahan 7 each	Navapur & Vedadri 11 each, Bijapur 10, Eturunagaram 8, Port Blair, Shahabad, Sudhagad & Alur 7 each	Dapoli 9, Sankeswar & Tusuma 8 each, Shirali & Hut Bay 7 each
28	Chhatinag 13, Satna 12, Sevoke & Kahridwar 11 each, Kokarajhar 10	Banswara 21, Mahabaleshwar 19, Dohad 18, Indore 17, Nurpur & Sagara 9 each, Ratnagiri 7	Dehradun 16, Sangola 15, Naraingarh, Rajapur, Paleru Bridge & Hakimpet 13 each, Bijapur 9, Akhuapada 7	Dehradun 22, Peerumeau 17, Ranebennur 13, Malsiras 12, Amini Divi 11, Hulakere, Panambur, Kancheepuram & Motihari 8 each
29	Kakrahi & Nawashahar 13 each, Manas 11, Gaya & Ambala 9 each, Passighat & Imphal 7 each	Mahabaleshwar 14, Harnavweir 11, Agumbe 9, Tibri & Bhiwandi 7 each	Karjat 13, Latur 12, Passighat & Sandwa 11 each, Dungerwadi 10, Palliakalan & Shirali 9 each, Champasarai, Chamba, Jammu & Agumbe 8 each, Dhollabazar, Uttarkashi, Bemetara & Buldhana 7 each	Malda 23, Munnar & Agumbe 22 each, Puttur 19, Venkatagiri & Kota 11 each, Naduvattam 10, Hut Bay, Aizwal 9 each
30	Sikandarpur 24, Jogindernagar 13, Sevoke & Nilokheri 7 each	Mahableshwar 13, Bhira 12, Maya Bandar, Jogindernagar & Munnar 9 each, Belthangady & Agumbe 8 each, Shillong & Silvasa 7 each	Anibone 25, Kokrajhar & Barobisha 14 each, Galgalia, Jagadhari & Baroda 13 each, Passighat 12, Tarana 11, Bhira & Perur 10 each, Lansdawn & Sarangarh 9 each, Ahmedpur 8, Palliakalan & Shahpurkandi 7 each	Kakinada & Sunramayan 9 each
31	Nil	Pagladiya 33, Nadaun 13, Gwalior 10, Canning Town 9, Gurudaspur 8, Khed 7	Sevoke 32, Bhind 31, Jhanjharpur 21, Valsad 17, Paonta 14, Makhlilshpur, Dungerwadi 10 each, Car Nicobar 9, Jia Bharati 8, Bemetara, Thane & Belapur 7 each.	

3.1.1 *Deep depression over the Bay of Bengal (26-30 June 1997)*

A low pressure area formed over north Bay of Bengal and adjoining parts of Gangetic West Bengal and of Bangladesh on 23 and became well marked on 24 over northwest Bay of Bengal off West Bengal coast. It concentrated into a depression over the same area on 26 morning when it was centred near 21.0° N/89.5° E. Moving in a northwesterly direction, it intensified into a deep depression and crossed north Orissa- south West Bengal coast on 27. After crossing the coast, it moved in a westnorthwesterly direction initially, then in a northerly direction and weakened into a low pressure area on 30 over northern parts of Bihar Plains and adjoining parts of east Uttar Pradesh. It became less marked on 1 July over the same area.

3.1.2. *Deep depression over the Bay of Bengal (29 July-3 August 1997)*

A low pressure area formed in the evening of 28 July over north Bay. It concentrated into a depression on 29 morning near 21.0°N/89.0°E, about 220 km east- southeast of Balasore. Moving in a westerly direction, it intensified into a deep depression on 30 near 21.0°N/87.5°E, about 50km southeast of Balasore. It crossed north Orissa coast near Chandbali in the evening of 30. After crossing the coast, it moved in a west-northwesterly direction and weakened into a depression on 31 evening over Bihar Plateau and weakened into a well-marked low pressure area on 2 August over Haryana and neighbourhood.

3.1.3. *Deep depression over Bay of Bengal (4-9 August)*

A well-marked low pressure area formed over north Bay of Bengal on 4 morning and concentrated into a depression on the same evening near 21.5°N/89.0°E, about 150 km south-southeast of Calcutta. Moving in a northwesterly direction, it intensified into a deep depression on 5 and crossed West Bengal Coast slightly east of Sagar Islands around 1430 hr IST of 5. After crossing the coast, it moved in a northwesterly direction and lay about 50 km southwest of

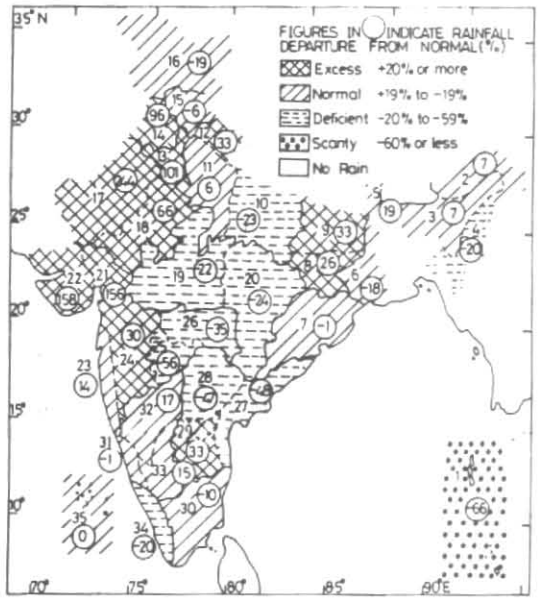


Fig. 5. Rainfall for the month of June 1997

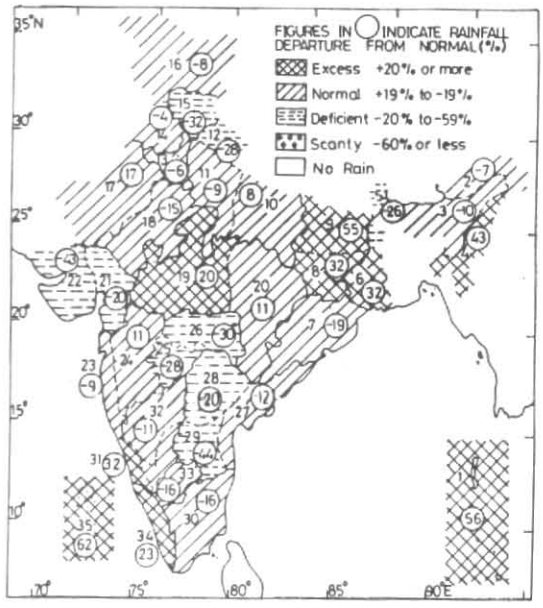


Fig. 6. Rainfall for the month of July 1997

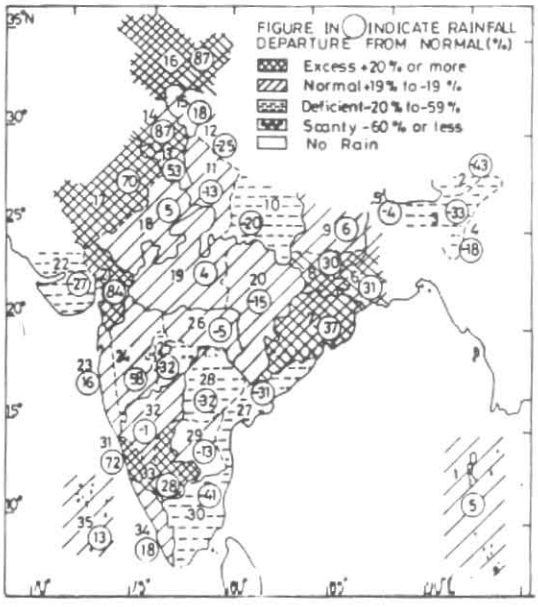


Fig. 7. Rainfall for the month of August 1997

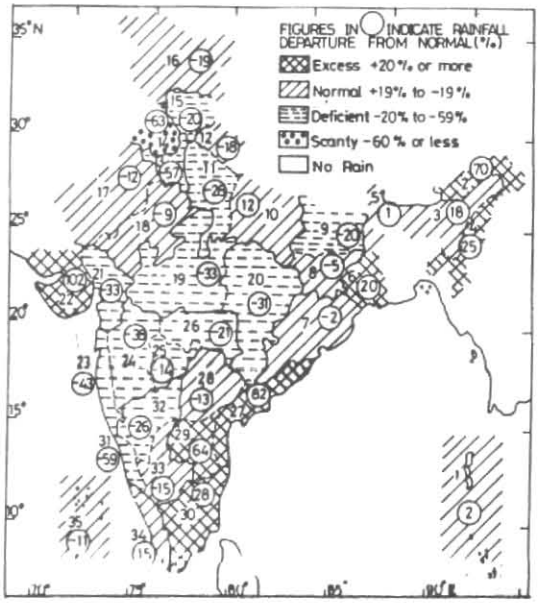


Fig. 8. Rainfall for the month of September 1997

Daltonganj on 6 and over northeast Madhya Pradesh (close to Satna) on the same evening. On 7, it weakened into a depression over northern parts of west Madhya Pradesh close to Shivpuri. It moved in a west- northwesterly direction and further weakened into a well-marked low pressure area on 8 over west Rajasthan and became less marked on 9.

TABLE 3

Statewise number of districts with excess, normal, deficient and scanty rainfall for the period 1 June to 30 September 1997

S. No.	State/UT	Excess	Normal	Deficient	Scanty	N.R.	Data inadequate	Total
1.	Andaman & Nicobar Islands (UT)	-	1	-	-	-	-	1
2.	Arunachal Pradesh	1	3	-	-	-	1	5
3.	Assam	-	11	2	-	-	3	16
4.	Meghalaya	-	1	1	-	-	-	2
5.	Nagaland	-	1	-	-	-	-	1
6.	Manipur	-	-	1	-	-	-	1
7.	Mizoram	-	1	-	-	-	-	1
8.	Tripura	1	-	-	-	-	-	1
9.	Sikkim	-	1	-	-	-	-	1
10.	West Bengal	6	9	1	-	-	-	16
11.	Orissa	3	9	1	-	-	-	13
12.	Bihar	16	20	2	-	-	1	39
13.	Uttar Pradesh	1	40	15	-	-	-	56
14.	Haryana	7	9	-	-	-	-	16
15.	Chandigarh (UT)	-	1	-	-	-	-	1
16.	Delhi (UT)	-	1	-	-	-	-	1
17.	Punjab	8	3	1	-	-	-	12
18.	Himachal Pradesh	3	4	5	-	-	-	12
19.	Jammu & Kashmir	3	1	1	-	-	7	12
20.	Rajasthan	12	16	2	-	-	-	30
21.	Madhya Pradesh	3	34	8	-	-	-	45
22.	Gujarat	13	5	1	-	-	-	19
23.	Dadar, Nagar Haveli & Daman (UT)	-	-	1	-	-	-	1
24.	Diu (UT)	-	1	-	-	-	-	1
25.	Goa	-	1	-	-	-	-	1
26.	Maharashtra	3	12	15	-	-	-	30
27.	Andhra Pradesh	3	13	7	-	-	-	23
28.	Tamil Nadu	1	14	7	-	-	-	22
29.	Pondicherry (UT)	1	-	-	-	-	-	1
30.	Karnataka	4	12	4	-	-	-	20
31.	Kerala	3	10	1	-	-	-	14
32.	Lakshadweep (UT)	1	-	-	-	-	-	1
	Total	93	234	76	-	-	12	415

Total no. of districts from which data have been received= 402

3.1.4. *Deep depression over the Bay of Bengal (20-28 August 1997)*

A low pressure area formed over northwest Bay of Bengal and adjoining parts of north Orissa-West Bengal Coast on 17. It became well-marked on 18 over the same region. On 20, it concentrated into a depression, probably deep, near 20.5°N/87.5°E, about 80 km east- southeast of Chandbali. Moving in a west-northwesterly direction, it crossed north Orissa coast between Paradip and Chandbali in the afternoon of 20. It lay over Orissa near 21.0°N/84.5°E, about 180 km northwest of Bhubaneswar on 21 and over east Madhya Pradesh, very close to Raipur (20.0°N/81.0°E) on 22. Continuing its west-northwesterly movement, it lay near 23.0°N/78.0 °E, very close to Hoshangabad on 23 and near 25.0°N/76.0°E, close to Kota in east Rajasthan on 24. It recurved and moved in a north- northwesterly direction and was centred near 26.0°N/76.0°E, about 60 km southeast of Jaipur on 25. It weakened into a depression and lay centred near 29.0°N/74.0°E, about 50 km south of Ganganagar on 27. It further weakened into a well-marked low pressure area over north Pakistan and neighbourhood on the same evening and merged with the seasonal trough on 28.

3.1.5. *Depression over the Bay of Bengal (28-30 August 1997)*

A low pressure area formed over north Andaman Sea on 25 and concentrated into a depression on 28 near 19.5°N/87.0°E, about 120 km southeast of Paradip. Moving in west-northwesterly direction, it crossed Orissa coast between Paradip and Puri by the noon of 28. It continued to move in a west-northwesterly direction and weakened into a well-marked low pressure area on 30 evening over Bihar and adjoining parts of east Uttar Pradesh and northeast

TABLE 4

Weather systems during June 1997

S. No. (1)	Weather system (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(A) *Depressions/low pressure areas*						
1.	Deep depression	26-30	Northwest Bay off West Bengal coast	Initially northwesterly, then west-northwesterly and finally northerly	Northern parts of Bihar Plains and adjoining parts of east Uttar Pradesh	First observed as a cyclonic circulation in the lower tropospheric levels over northern parts of Gangetic West Bengal and neighbourhood on 21. It became low pressure area on 23 over north Bay and adjoining parts of Gangetic West Bengal and of Bangladesh and well-marked low pressure area over northwest Bay off West Bengal coast. System concentrated into a depression over the same area on 26 with its centre near 21.0° N/89.5°E. Moving in a northwesterly direction, it intensified into a deep depression and crossed north Orissa-south West Bengal coast on 27. After crossing the coast, it moved in a westnorthwesterly direction initially and then in northerly direction and weakened into a low pressure area on 30 June over northern parts of Bihar Plains and adjoining parts of east Uttar Pradesh. It became less marked on 1 July over the same area
2.	Low pressure area	19-20	North Bay & neighbourhood	Stationary	*in situ*	First observed as a cyclonic circulation over northwest Bay off north Orissa-west Bengal coast on 18. Associated cyclonic circulation extended upto mid tropospheric levels. The trough from this system became less marked on 24
3.	Low pressure area	22-25	Northeast Arabian Sea off Gujarat coast (with a central region near 21° N/68°E)	Initially northwesterly and then northeasterly	North Gujarat Region & adjoining parts of Rajasthan	First observed as a cyclonic circulation over Gulf of Cambay and adjoining south Gujarat Region. Associated cyclonic circulation extended upto mid tropospheric levels
(B) *Induced cyclonic circulations*						
1.	Mid-tropospheric levels	31 May-4 June	Northwest Rajasthan and adjoining Pakistan	Northeasterly	West Uttar Pradesh & neighbourhood	Moved away northeastwards across Haryana and west Uttar Pradesh
(C) *Embedded cyclonic circulations*						
1.	Lower levels	7-8	Sub-Himalayan West Bengal & Sikkim	Stationary	*in situ*	
2.	Mid-tropospheric levels	13-17	Off Karnataka coast	Northerly	North Maharashtra coast & adjoining Gulf of Cambay	Merged with the off shore trough
(D) *Other cyclonic circulations*						
1.	Mid and upper tropospheric levels	1-2	Saurashtra & Kutch and neighbourhood	Stationary	West Madhya Pradesh & neighbourhood	
2.	Lower tropospheric levels	3-4	Southwest Rajasthan and neighbourhood	Do	*in situ*	
3.	Lower levels	5-6	Do	Do	Do	
4.	Do	6-7	Sub-Himalayan West Bengal & Sikkim	Do	Do	
5.	Lower tropospheric levels	7-9	Punjab & neighbourhood	Do	Do	
6.	Mid-tropospheric levels	10-12	Northwest Bay off Orissa coast	Southwesterly	West-central Bay off Andhra coast	

TABLE 4 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
7.	Lower tropospheric levels	13-15	Southwest Rajasthan & neighbourhood	Stationary	*in situ*	
8.	Lower levels	19-23	West Rajasthan & neighbourhood	East- northeasterly	Haryana & adjoining parts of west Uttar Pradesh	Moved away northeastward
(E) *North-South trough*						
1.	Lower tropospheric levels	31 May-2 June	Sub-Himalayan West Bengal & Sikkim to northwest Bay	Stationary	*in situ*	
(F) *Trough in the westerly*						
1.	Upper air	30 May-3 June	74°E north of 30°N	Easterly	73°E, north of 18°N	Moved away eastwards
(G) *Other troughs*						
1.	Lower tropospheric levels	4-7	East Madhya Pradesh to south Tamil Nadu	Stationary	*in situ*	
2.	Do	4-6	Sub-Himalayan West Bengal to northwest Bay	Do	Do	
3.	Do	7-18	Sub-Himalayan West Bengal to north Bay	Quasi- stationary	Sub-Himalayan West Bengal to Orissa	
(H) *Western disturbance*						
1.	Upper air system	30 May-3 June	Jammu & Kashmir and adjoining parts of Pakistan	Northeasterly	Jammu & Kashmir and neighbourhood	Moved away northeastwards

Madhya Pradesh and further weakened into a low pressure area on 31 August.

3.1.6. *Cyclonic storm over the Bay of Bengal (23-27 September 1997)*

A low pressure area formed over west-central Bay of Bengal off Andhra Pradesh coast on 21. It became well-marked on 22. On 23, it concentrated into a depression near 15.5°N/82.5°E. Moving in a northerly direction, it further concentrated into a deep depression near 16.5°N/82.5°E, about 72 km south-southeast of Kakinada on 24. It intensified into a cyclonic storm near 17.3°N/83.7°E, about 65 kms south-southeast of Visakhapatnam on 25 and then moved in a northeasterly direction. Skirting the coast, it crossed Bangladesh coast in the early morning of 27 and rapidly weakened into a deep depression near 24.0°N/92.0°E, close to Agartala on the same evening. It further weakened and lay as an upper air cyclonic circulation on 28 over Nagaland, Manipur, Mizoram & Tripura. It became less marked on 29 over the same area.

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

During the season, there were 5 LPA/WMLPA which also caused well- distributed rainfall over the country. Their monthwise break-up is as under:

2 in June and 1 each in July, August and September. Details are given in Tables 4-7.

3.3. *Cyclonic circulations (CYCIR)*

In all 47 CYCIRs (lower levels and upper levels; including induced CYCIRs) formed during the season and gave well- distributed rainfall in time and space over the country. The monthwise break-up is as under:

June 11, July 12, August 7 and September 17. Details are given in Tables 4-7.

3.4. *Offshore trough*

During 8 June to 1 October 1997, the off-shore trough along parts of west coast (surface and in low levels) persisted on most of the days and this was one of the characteristic features of the southwest monsoon 1997. Details are given in Table 8.

3.5. *Low level troughs*

In June, three low level troughs, north-south oriented from Sub- Himalayan West Bengal & Sikkim to north Bay formed. Two more troughs formed (4-6 June and 7-18 June) over northeast India and helped the early advance of southwest monsoon.

3.6. *Upper level troughs*

The westerly trough in mid and upper tropospheric levels which moved eastwards across north India are discussed here. One such trough during June (30 May-3 June),

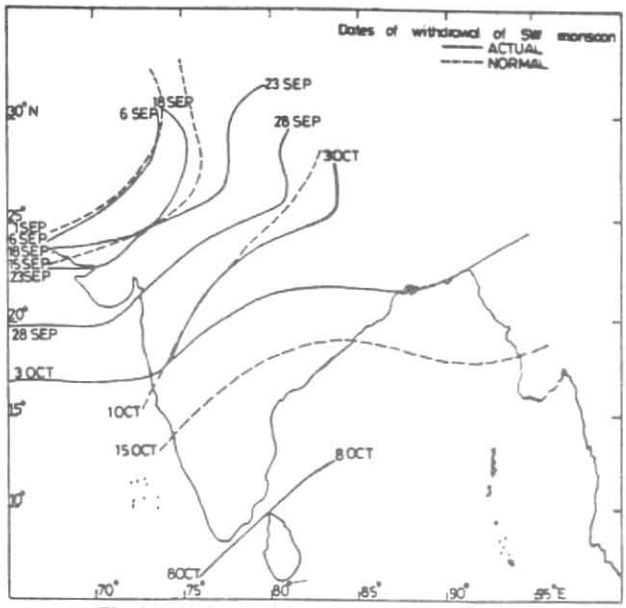


Fig. 9. Withdrawl of southwest monsoon 1997

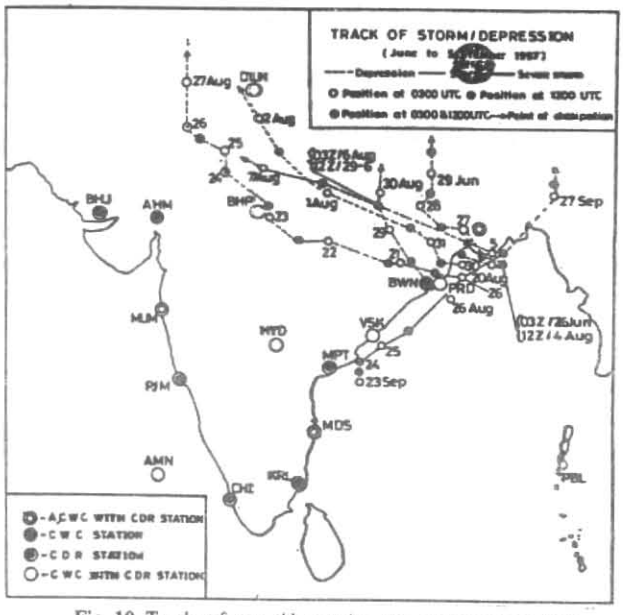
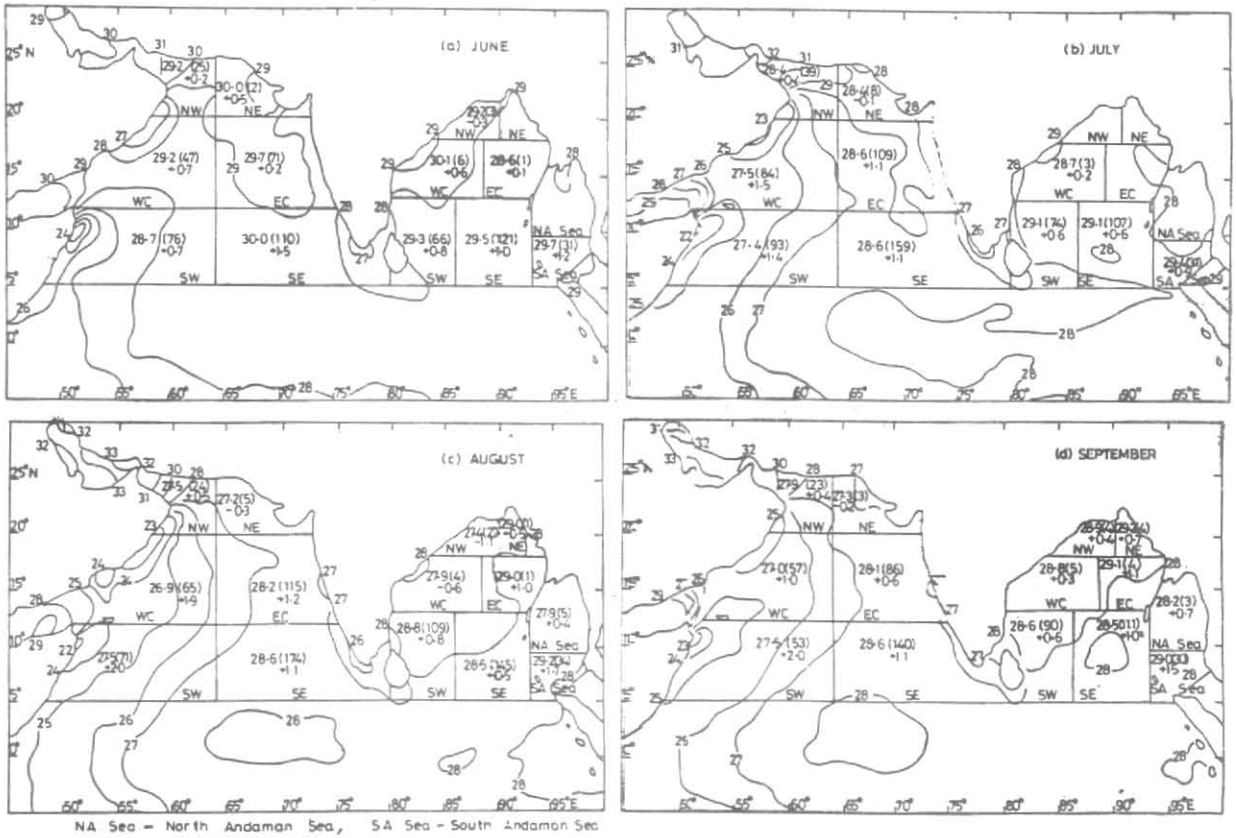


Fig. 10. Tracks of storm/depression (June-September 1997)



Figs. 11(a-d). Mean monthly (June-September 1997) SST anomalies (°C) of Indian seas during SW monsoon 1997

TABLE 5

Weather systems during July 1997

S. No. (1)	Weather system (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(A) *Depressions/low pressure areas*						
1.	Deep depression	29 Jul-3 Aug	North Bay	Initially westerly, then west-northwesterly	Haryana & neighbourhood	First observed as a trough of low on sea level chart over north Bay on 26, cyclonic circulation on 28 and as a low pressure area on 28 evening over the same area. It concentrated into a depression on 29 when it was 220 kms eastsoutheast of Balasore (21.0°N/89.0°E). Moving in a westerly direction, it intensified into a deep depression on 30 (Lat. 21.0°N/Long 87.5°E, about 50 kms southeast of Balasore). It crossed north Orissa coast near Chandbali in the evening of 30 July. Moving in a westnorthwesterly direction, it weakened into a depression on 31 evening over Bihar Plateau and became well-marked low pressure area on 2 August over Haryana and neighbourhood
2.	Well-marked low pressure area	17-28	Northwest Bay & adjoining north Orissa-West Bengal coast	West-northwesterly	Northwest Madhya Pradesh & adjoining parts of east Rajasthan and plains of west Uttar Pradesh	A low pressure area formed over northwest Bay and adjoining north Orissa-west Bengal coast on 17 and became well-marked on 21 over Gangetic West Bengal & neighbourhood. Associated cyclonic circulation extended upto mid-tropospheric levels. It merged with the monsoon trough on 29. (It was tilted southwestwards with height on 20, westwards with height on 21, 22)
(B) *Cyclonic circulations*						
1.	Lower levels	1-2	Northwest Rajasthan neighbourhood	Stationary	*in situ*	
2.	Mid-tropospheric levels	2-8	North Bay & neighbourhood	Northwesterly	Northeast Madhya Pradesh & adjoining parts of Bihar and east Uttar Pradesh	Merged with the trough No. 1
3.	Do	4-9	Gujarat Region & neighbourhood	Stationary	*in situ*	
4.	Lower levels	6-8	Southwest Rajasthan & adjoining Pakistan	Do	Do	
5.	Lower tropospheric levels	9-10	West Punjab & neighbourhood	Do	Do	
6.	Do	11-14	Punjab & adjoining Pakistan	Northeasterly	Punjab & adjoining Haryana	Moved away eastwards across Himachal Pradesh
7.	Do	12-17	Gangetic West Bengal & adjoining parts of Bangladesh	Stationary	*in situ*	Merged with the monsoon trough
8.	Lower levels	13-17	West Punjab and Pakistan	East-northeasterly	Punjab & adjoining parts of Himachal Pradesh	Moved away northwards across Himachal Pradesh
9.	Upper tropospheric level	18-22	Gujarat State & neighbourhood	Stationary	*in situ*	
10.	Lower tropospheric levels	18-22	Punjab & adjoining Pakistan	Northeasterly	Jammu & Kashmnir and adjoining Punjab	Moved away northeastwards

TABLE 5 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
11.	Mid-tropospheric levels	22-25	West Rajasthan & adjoining Pakistan	Do	Punjab & adjoining Jammu & Kashmir and Pakistan	Moved away northeastwards
12.	Lower tropospheric levels	25-31	Central Pakistan & adjoining west Rajasthan & neighbourhood	Do	Haryana & neighbourhood	
(C) *East-West trough*						
1.	Lower tropospheric levels	24-26	Across the country along Long. 22°N	Quasi-stationary	Across the country along Long. 23°N	
(D) *Troughs in the lower levels*						
1.	Lower tropospheric levels	6-9	Punjab to Gangetic West Bengal across south Uttar Pradesh and thence southeastwards to north Bay	Stationary	*in situ*	
2.	Do	10-12	Patna to Tezu across Malda	Do	Do	

one in August (3-4) and one in September (24-25). More details are given in Tables 4,6 and 7.

3.7. *Eastward moving circulation/western disturbance*

Two western disturbances; one each in August (6-8) and in September (21-23) moved across northwest India during the season. Details are given in Tables 6 and 7.

4. Extra-Indian systems

4.1. *Cross-equatorial flow*

Cross-equatorial flow over the Arabian Sea was slightly less than normal (by about 5 kt) in June, more than normal (by 5 kt) in July and normal in August and September. It was normal over the Bay of Bengal throughout the monsoon.

Cross-equatorial flow across the equatorial region was normal in June, more than normal by about 5 kt in July normal in August and September.

4.2. *Mid-latitude troughs*

There were 26 mid and upper tropospheric westerly troughs which moved eastwards across 30°N latitude in northern hemisphere and along 30°S in southern hemisphere. 17 troughs moved across north India and 9 troughs moved across south Indian Ocean in the southern hemisphere.

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

During four monsoon months of 1997, there were 12 typhoons (including 3 super typhoons) and 3 tropical storms making a total of 15 systems against 17 in the last year. Their monthwise break-up is given in Table 10.

4.4. *Systems in southern hemisphere*

(a) There were 9 mid and upper air westerly troughs in south Indian Ocean (2 each in June, July and September and 3 in August) which moved across 30°S latitude and also penetrated north.

(b) The intensity of Mascarene high was above normal (1024 hPa) during the monsoon season 1997. It was above normal by 4 hPa in June, and 3 hPa in August. During July and September, it was 1 hPa above normal. The normal value of pressure during June- September is 1024 hPa.

(c) During June to September, the Australian high was very intense compared to the normal values in all the months. It was above normal by 7 hPa in June, 10 hPa in July, 4 hPa in August and 4 hPa in September. 1024 hPa is the normal pressure value during June to August and 1018 hPa in September.

5. Semi-permanent systems

5.1. *Heat low*

Heat low over Pakistan and adjoining parts of west Rajasthan appeared on 7 June and persisted over the same region till last week of September except on 8 and 26 August

TABLE 6

Weather systems during August 1997

S. No. (1)	Weather system (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(A)*Depressions/low pressure areas*						
1.	Deep depression	4-9	North Bay	Initially north-westerly and then west-northwesterly	West Rajasthan	It was first observed as a Cyclonic circulation in mid-tropospheric levels over north Bay on 3. A well-marked low pressure area formed over the same region on 4 morning and it concentrated into a depression on the same evening (21.5°N/89.0°E, 150 kms southsoutheast of Calcutta). Moving in a northwesterly direction, it intensified into a deep depression on 5 and crossed West Bengal coast slightly east of Sagar Island around 1430 hrs. IST of 5. After crossing the coast it moved in a northwesterly direction, it lay on 6 about 50 kms southwest of Daltonganj and over northeast Madhya Pradesh (close to Satna) on the same evening. On 7, it weakened into a depression over northern parts of west Madhya Pradesh close to Shivpuri. After weakening, it moved in a westnorthwesterly direction and further weakened into a well- marked low pressure area on 8 over West Rajasthan and became less marked on 9 Associated cyclonic circulation extended upto mid-tropospheric levels. It titled southwestwards with height on 8. It was seen over Punjab and neighbourhood on 9 and became less marked on 11 over Jammu & Kashmir
2.	Do	20-28	Northwest Bay and adjoining parts of Orissa-West Bengal coast	Initially west-northwesterly, then northnorth-westerly and finally northwesterly	North Pakistan	It was first observed as a cyclonic circulation over northwest Bay and neighbourhood on 16. Under the influence, low pressure area formed over northwest Bay and adjoining parts of north Orissa-West Bengal coast on 17 it became well-marked on 18 over the same region. System concentrated into a depression probably deep near 20.5°N/87.5°E, about 80 kms eastsoutheast of Chandbali on 20. Moving in a westnorthwesterly direction, it crossed north Orissa coast between Paradip and Chandbali in the afternoon of 20. It lay over Orissa (21.0°N/84.5°E, about 180 kms northwest of Bhubaneswar) on 21 and over east Madhya Pradesh (22.0°N/81.0°E, very close to Raipur) on 22. Continuing its westnorthwesterly movement, it lay near 23.0°N/78.0°E, very close to Hoshangabad on 23 and near 25.0°N/76.0°E, close to Kota in east Rajasthan on 24. It recurved and moved in a northnorthwesterly direction and was centred near 26.0°N/76.0°E, about 60 kms southeast of Jaipur on 25. It weakened into a depression and lay centred within half a degreee of 29.0°N/74.0°E, about 50 kms south of Ganganagar on 27. It further weakened into a well-marked low pressure area over north Pakistan and neighbourhood on 27 and merged with the seasonal trough on 28

TABLE 6 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
3.	Depression	28-30	North Bay & neighbourhood	West- northwesterly	Bihar and adjoining parts of east Uttar Pradesh and northeast Madhya Pradesh	First observed as a low pressure area over north Andaman Sea on 25 and concentrated into a depression on 28 (19.5°N/87.0°E, about 120 kms southeast of Paradip). Moving in a westnorthwesterly direction, it crossed Orissa coast between Paradip and Puri by noon of 28. It continued to move in a westnorthwesterly direction and weakened into a low pressure area over Bihar and adjoining parts of east Uttar Pradesh and northeast Madhya Pradesh. Associated cyclonic circulation extended upto mid-tropospheric levels. It merged with the another cyclonic circulation on 8 Sept.
2.	Low pressure area	12-13	North Bay	Stationary	*in situ*	First observed as a cyclonic circulation in upper tropospheric levels over northwest Bay off Orissa coast on 8. It was titled southwestwards with height on 10
(B) *Cyclonic circulations*						
1.	Mid-tropospheric levels	2-3	Gangetic West Bengal & adjoining Bangladesh	Stationary	*in situ*	
2.	Do	5-8	Gujarat Region & neighbourhood	Do	Do	
3.	Do	12-17	Bihar & neighbourhood	Northeasterly	Bangladesh & neighbourhood	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 levels	18-19	Punjab & neighbourhood	Stationary	*in situ*	
5.	Upper tropospheric levels	20-23	Gujarat Region & neighbourhood	Quasi-stationary	Northwest Madhya Pradesh	Merged with the deep depression on 23
6.	Mid-tropospheric levels	25-26	North Bay	Stationary	*in situ*	Merged with the low pressure
7.	Do	30 Aug-2 Sept	Saurashtra & Kutch	Do	Do	
(C) *Western disturbance*						
1.	Upper air system	6-8	North Pakistan & adjoining Jammu & Kashmir and Punjab	Northeasterly	Jammu & Kashmir	Moved away northeastwards across Jammu & Kashmir
(D) *Trough in the westerlies*						
1.	Mid and upper tropospheric levels	3-4	72°E, north 25°N	Stationary	*in situ*	Moved away northeastwards

and 9 September when it shifted either westwards or was not seen at all.

On 8 and 26 August, monsoon depression was seen over west Rajasthan and adjoining Pakistan and the heat low could not be located separately.

The lowest pressure values of heat low were 985.4 hPa on 10 July, 986.0 hPa on 25 June, 986.6 hPa on 28 June, 987.0 hPa on 6 July, 991.0 hPa on 4 and 11 August and 997.0 hPa on 2 September.

5.2. *Axis of the monsoon trough*

Axis of the monsoon trough (at surface and at 0.9 km asl) extending from Anupgarh to northeast Bay of Bengal across the plains of north India was established by 16 July. It was almost over the same position till 21 August. On 22

TABLE 7

Details of the weather systems during September 1997

S. No. (1)	System (2)	Period (3)	Place of first location (4)	Direction of movement (5)	Place of dissipation (6)	Remarks (7)
(A) *Cyclonic storm*						
1.	Cyclonic storm	23-27	West-central Bay off Andhra Pradesh coast	Initially northerly and then northeasterly	Nagaland, Manipur, Mizoram & Tripura	It was first observed as a trough in the lower tropospheric levels over southwest Bay on 19. It was seen as a cyclonic circulation west-central Bay on 20. A low pressure area formed over west-central Bay off Andhra Pradesh coast on 21. It became well-marked on 22. It concentrated into a depression (15.5°N/82.5°E) on 23. Moving in a northerly direction, it further concentrated into a deep depression (16.5°N/82.5°E, about 75 kms southsoutheast of Kakinada) on 24. It intensified into a cyclonic storm (17.3°N/83.7°E, about 65 kms southsoutheast of Visakhapatnam) on 25 and then moved in a northeasterly direction. It crossed Bangladesh coast in the early morning of 27 and rapidly weakened into a deep depression (24.0°N/92.0°E, close to Agartala). It further weakened into an upper air cyclonic circulation on 28 over Nagaland, Manipur, Mizoram & Tripura. It became less marked on 29 over the same area
(B) *Low pressure area*						
1.	Low pressure area	4-5	Northeast Bay & neighbourhood	Stationary	*in situ*	Associated cyclonic circulation extended upto mid-tropospheric levels
(C) *Induced cyclonic circulations*						
1.	Lower levels	22-24	Central Pakistan & adjoining parts of west Rajasthan	Northeasterly	North Pakistan and Punjab and Jammu & Kashmir	Moved away northeastwards across Jammu & Kashmir
2.	Lower tropospheric levels	25-27	Punjab & adjoining parts of Jammu & Kashmir and north Pakistan	East-northeasterly	Jammu & Kashmir & neighbourhood	Moved away eastnortheastwards across Jammu & Kashmir
(D) *Embedded cyclonic circulation*						
1.	Lower tropospheric levels	13-14	North Kerala & adjoining Karnataka	Stationary	*in situ*	
(E) *Other cyclonic circulations*						
1.	Lower levels	4-6	West Punjab & neighbourhood	Stationary	*in situ*	
2.	Mid-tropospheric levels	6-9	North Bay & neighbourhood	Northwesterly	Gangetic West Bengal & adjoining parts of Bihar Plateau and Orissa	Merged with the monsoon trough
3.	Do	6-11	Gulf of Cambay & neighbourhood	Stationary	*in situ*	It was tilted southwards with height on 9th
4.	Lower tropospheric levels	8-11	Northwest Madhya Pradesh & neighbourhood	Northnorthwesterly	Northeast Rajasthan and adjoining Haryana	
5.	Do	12-15	North Bangladesh & neighbourhood	Stationary	*in situ*	
6.	Mid-tropospheric levels	13-17	North Gujarat region & neighbourhood	Do	Do	
7.	Do	16-18	North Andaman Sea & neighbourhood	Do	Do	

TABLE 7 (*Contd.*)

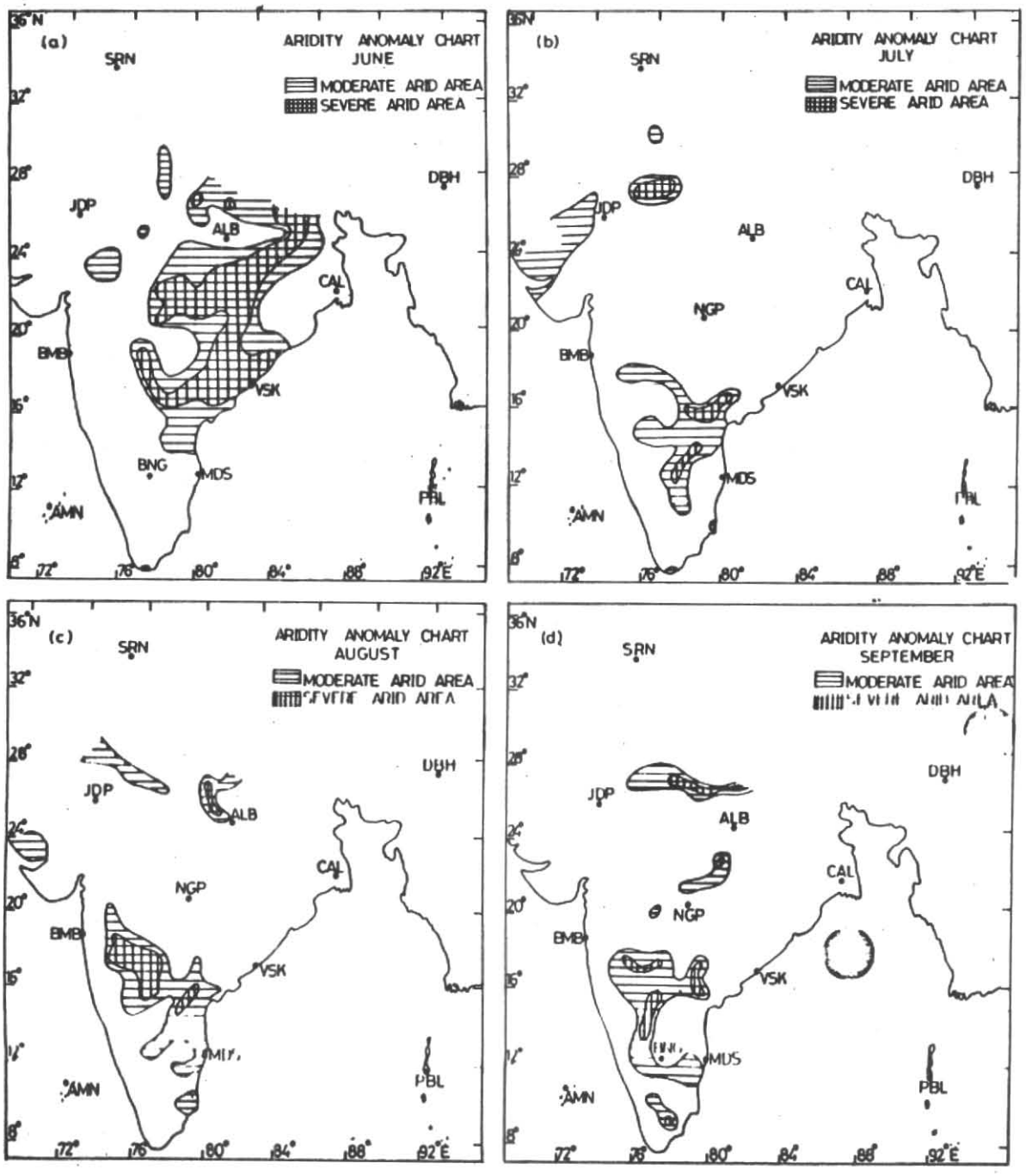
(1)	(2)	(3)	(4)	(5)	(6)	(7)
8.	Lower tropospheric levels	17-19	East Uttar Pradesh & neighbourhood	Do	Do	
9.	Do	18-19	Vidarbha & neighbourhood	Do	Do	
10.	Do	18-25	Gulf of Thailand & neighbourhood	Northwesterly	East-central Bay & adjoining north Andaman Sea	Merged with the cyclonic storm
11.	Do	21-22	Saurashtra & Kutch & neighbourhood	Stationary	*in situ*	
12.	Do	25-26	East-central Arabian Sea & adjoining Coastal areas of south Konkan and Goa and north Karnataka	Do	Do	
13.	Lower levels	27-30	North Pakistan & adjoining Jammu & Kashmir and Punjab	East-northeasterly	Moved away east-northeastwards across Jammu & Kashmir	
14.	Mid-tropospheric levels	28-30	Maharashtra State & neighbourhood	North-northeasterly	Northwest Madhya Pradesh & neighbourhood	
15.	Lower levels	30 Sept-3 Oct	Northwest Rajasthan & adjoining Pakistan	East-northeasterly	Punjab & neighbourhood	
(F) *Western disturbance*						
1.	As a cyclonic circulation in lower levels	21-23	Jammu & Kashmir	Northeasterly	Jammu & Kashmir	Moved away northeastwards
(G) *Trough in westerly*						
1.	Mid and upper tropospheric level	24-25	81°E, north of 21° N	Easterly	Moved away eastwards	
(H) *Troughs in the lower and mid-tropospheric levels*						
1.	Lower tropospheric levels	3-4	Sub-Himalayan West Bengal to north Bay	Stationary	*in situ*	
2.	Do	5-6	South Orissa to south Tamil Nadu	Do	Do	
3.	Mid-tropospheric levels	11-12	Saurashtra & Kutch	Do	Do	Merged with the trough no. 4
4.	Do	12-14	Southern parts of Haryana to Saurashtra	Do	Do	
5.	Do	15-17	Sub-Himalayan West Bengal to north Bay	Do	Do	
6.	Lower tropospheric levels	17-18	Saurashtra	Do	Do	
7.	Do	19-21	Bihar Plateau to north coastal Andhra Pradesh	Do	Do	
8.	Mid-tropospheric levels	30 Sept-1 Oct	Sub-Himalayan West Bengal and Sikkim to north Bay	Do	Do	

and 23 August, it shifted southwards. It was never seen to the foot hills of the Himalayas.

Datewise position of axis of the monsoon trough is given in Table 9.

5.3. *Tibetan anticyclone high*

Tibetan anticyclone/high got established during the last week of June at 300 hPa and 200 hPa. Its position during the last week of June at 300 hPa was near 26°N/93°E and at 200 hPa near 26°N/90°E. Its mean position during the month of



Figs. 12 (a-d). Meteorological sub-divisions affected by moderate to severe aridity conditions during (a) June, (b) July, (c) August & (d) September 1997

July at 300 hPa and at 200 hPa were near 29°N/90°E and near 29°N/86°E respectively. During August, it moved westwards at 300 hPa where its mean position was near 29°N/85°E and at 200 hPa, it was near 29°N/89°E. It further moved westwards during 1 to 16 September both at 300 hPa and at 200 hPa. The mean position were near 31°N/80°E and 30°N/84°E respectively. It became less marked at both the levels after 16 September. Tibetan anticyclone got established and was seen at 500 hPa from 19 July to 9 September with its mean position near 31°N/95°E.

5.4. *Westerly Jet*

Strength of westerly winds at 200 hPa were more than 60 kt on many days during the first fortnight of June and also

TABLE 8

Positions of the off-shore troughs during the monsoon period 1997 (on sea level chart)

Date	Position	Remarks
8 June	Off Kerala coast & adjoining Lakshadweep	
9-16 June	South Maharashtra coast to south Kerala coast	It became well-marked from 14 June
17-21 June	South Gujarat coast to south Kerala coast	Well- marked
22-24 June	Centre of the low pressure area (21.0°N/68.0°E) to south Kerala coast	
25-27 June	Southeast Rajasthan to south Maharashtra coast	
30 June-9 July	South Maharashtra coast to Kerala coast	More marked from 2 July
10-14 July	Off Kerala-Karnataka coast	Well-marked
25-27 July	South Konkan & Goa to Lakshadweep-Maldives area	
28-29 July	South Gujarat coast to Lakshadweep area	
30-31 July	South Maharashtra coast to Kerala coast	
1-5 August	Kerala-Karnataka coast	Became less marked on 5 August
7-8 August	Konkan & Goa to Lakshadweep area	
9-15 August	South Maharashtra coast to Lakshadweep area	
15-16 August	Lakshadweep area	Less marked on 16 August
2-5 September	South Maharashtra coast to Kerala coast	Less marked on 5 September
9-12 September	Karnataka coast	
13-15 September	North Kerala and adjoining Karnataka	
16-26 September	South Maharashtra coast to south Kerala coast	
27 September-1 October	North Konkan to Kerala	

during last week of September over Delhi, Srinagar, Lucknow and Gorakhpur. Otherwise, strength of westerly winds was less than 60 kt over Jodhpur, Delhi, Gwalior, Lucknow, Calcutta and Guwahati during the remaining days of the season at upper levels, suggesting the shift of the westerly jet further to the north.

5.5. *Tropical Easterly Jet (TEJ)*

Tropical easterly jet was observed over Minicoy from 14 June to 8 September (maximum reported wind was of the order of 115 kt at 141 hPa on 25 June, at 115 hPa on 3 July and 131 hPa on 21 August respectively). It became gradually less marked afterwards. It was seen over Thiruvananthapuram from 16 June till 9 September (maximum reported wind was 100 kt at 114 hPa on 20 July) and over Chennai from 14 June to 6 September (maximum reported wind was 95 kt at 110 hPa on 10 August). It was seen over Port Blair from 8 July to 20 August (maximum reported wind was 85 kt on 22 July at 143 hPa) and over Mumbai from 26 June to 13 August (maximum reported wind was 90 kt at 105 hPa on 8 July).

6. Sea surface temperature (SST)

Monthly mean SST values over 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.

7. Other features

7.1. *Weekly anomalies in monsoon circulation 1997*

Weekly anomaly charts are prepared for 850, 700 and 200 hPa levels and the corresponding anomaly troughs and ridges are marked. Weekly wind anomalies for some stations are given in Table 10 and weekly anomaly features are given in Table 12.

(a) *June-July* — The lower tropospheric westerlies and upper tropospheric easterlies were in general weaker than normal in June over the Indian region, particularly over the peninsular India, south of 15°N.

During the first fortnight of July, the lower tropospheric westerlies were stronger than the normal over the Indian region. In the next two weeks (*i.e.* the weeks ending on 15 and 22 July), these westerlies were weaker than normal over the peninsular India, south of 15°N. However, during the week ending on 29 July, the westerlies once again became stronger than normal. The upper tropospheric easterlies were weaker than normal over the peninsular India, south of 20°N, for the week ending on 15 July. Thereafter, they were weaker than the normal during the remaining period of July.

(b) *August-September* — The lower tropospheric westerlies were stronger than the normal over the Indian region during the first and the last week of August. They were

TABLE 9
Axis of the monsoon trough
(on sea level chart)

Date	Position
16 July	Anupgarh, Agra, Daltonganj, Balasore and thence southeastwards to northeast Bay
17 July	Ganganagar, Delhi, Varanasi and to the centre of the low pressure area (northwest Bay and adjoining Orissa-West Bengal coast) and thence to southeastwards to northeast Bay
18 July	Anupgarh, Aligarh, Allahabad, Ranchi and to the centre of the low pressure area (-do-) and thence southeastwards to northeast Bay
19 July	Ganganagar, Gwalior, Rewa, Ranchi and to the centre of the low pressure area (Gangetic West Bengal and adjoining Bihar Plateau and Orissa) and thence southeastwards to northeast Bay
20 July	Ferozepur, Agra, Varanasi, to the centre of the low pressure (-do-) and thence southeastwards to northeast Bay
21 July	Ganganagar, Gwalior, Satna, Jharsuguda, to the centre of the low pressure area (-do-) and thence sotheastwards to northeast Bay
22 July	Ganganagar, Gwalior, Rewa, Ambikapur and centre of the low pressure area (Bihar Plateau and adjoining east Madhya Pradesh and Orissa) and thence southeastwards to northeast Bay
23 July	Ganganagar, Alwar, Satna to the centre of the low pressure area (east Madhya Pradesh and adjoining Orissa and Bihar Plateau) to northeast Bay
24 July	Ganganagar, Gwalior to the centre of the low pressure area (-do) and thence southeastwards to Northeast Bay
28 July	Anupgarh, Dholpur, Ambikapur and thence centre of the cyclonic circulation (north Bay)
29 July	Anupgarh, Agra, Ranchi and to the centre of the depression (21.0°N/89.0°E) and thence southeastwards to east-central Bay
30 July	Bikaner, Gwalior, Ambikapur and to the centre of the depression (21.0°N/87.5 °E)
31 July	Bikaner, Gwalior, Ambikapur and the centre of the depression (22.5°N/85.5°E) and thence southeastwards to east-central Bay
1 August	Bikaner, centre of the depression (close to Satna), Tibias and nrothwest Bay
2 August	Ganganagar, centre of the depression (50 kms west of Aligarh), Sind and northwest Bay
3 August	Ferozepur, Bareilly, Patna and thence southeastwards to north Bay
4 August	Amritsar, Najibabad, Kheri, Motihari and thence southeastwards to centre of the low pressure area (north Bay)
9 August	Patiala, Bareilly, Patna and thence southeastwards to northwest Bay
10 August	Amritsar, Najibabad, Gorakhpur and thence southeastwards to northwest Bay
14 August	Anupgarh, Agra, Gorakhpur, Purnea and thence to Khonsa
15 August	Ferozepur, Najibabad, Gonda, Gaya and thence southeastwards to northeast Bay
16 August	Ferozepur, Bareilly, Calcutta and thence southeastwards to northeast Bay
17 August	Ferozepur, Najibabad and Gorakhpur and thence southeastwards to the centre to the low pressure area (northwest Bay and adjoining north Orissa-West Bengal coast)
19 August	Ganganagar, Agra, Ambikapur and thence to the centre of the well-marked low pressure area (-do-) (It was tilted southwards with height)
20 August	Bikaner, Satna, Jharsuguda, centre of the depression (20.5° N/87.5° E) and thence southeastwards to northeast Bay
21 August	Ganganagar, 25° N/80°E, 22.5° N/80.0°E, centre of the deep depression (21.0°N/84.5°E) and thence southeastwards to east central Bay
22 August	Deesa, Hoshangabad, centre of the deep depression (22.0°N/81.0°E), Bhubaneswar and thence southeastwards to east-central Bay
23 August	Deesa, centre of the deep depression (23.0°N/78.0°E), Jharsuguda and northwest Bay
24 August	Centre of the deep depression (25.0°N/76.0°E), Jharsuguda and northwest Bay
26 August	Phalodi, centre of the deep depression (27.0°N/74.0°E), Ambikapur and centre of the low pressure area
28 August	Amritsar, Jaipur, (25°N/80°E) and thence to the centre of the depression (19.5°N/87.0°E)
3 September	Ferozepur, Lucknow, Calcutta and thence southeastwards to northeast Bay
6 September	Patiala, Aligarh, Varanasi, centre of the cyclonic circulation (north Bay and neighbourhood) and thence southeastwards to east-central Bay
7 September	Bikaner, Jhansi, Satna, Balasore and thence southeastwards to east-central Bay

weaker than the normal over the peninsular India, south of 15°N, during the week ending on 19 August. The upper tropospheric easterlies were weaker than the normal particularly over the peninsular India, south of 20°N.

The lower tropospheric westerlies were weaker than the normal over the peninsular India, south of 15°N during the week ending on 9 and 16 September. However, they were stronger than the normal for the later period of September. The upper tropospheric easterlies were weaker than the normal, particularly over the peninsular India, south of 20°N.

7.2. *Stratospheric features*

Meteorological rocket launchings at Shar, Thumba and Balasore are suspended since June 1982, September 1993 and March 1995 respectively. As such, the available wind data of RAWIN stations over the country during June to September 1997 have been considered for the analysis of winds in the stratosphere. RAWIN flights have rarely

TABLE 10

Tropical storms/depressions in the northwest Pacific 1997

S.No.	Weather systems	June	July	August	September	Total
1.	Depression	0	0	0	0	0
2.	Tropical storms	0	1	1	1	3
3.	Typhoons	3	1	3	2	9
4.	Super Typhoons	0	1	1	1	3
5.	Total	3	3	5	4	15

TABLE 11

Weekly anomaly winds June-September 1997

Station & level	3 Jun	10 Jun	17 Jun	24 Jun	1 Jul	8 Jul	15 Jul	22 Jul	29 Jul	5 Aug	12 Aug	19 Aug	26 Aug	2 Sep	9 Sep	16 Sep	23 Sep	30 Sep
The easterly anomaly winds imply that the westerlies are weaker than normal																		
TRV																		
850 hPa	09206	11612	13712	07604	26706	21305	32505	02010	23706	29707	27901	05105	31010	34208	12106	14415	16706	22102
700 hPa	10517	09819	13812	08708	32205	23602	05602	05517	24207	31613	18901	10408	30912	30805	11412	10717	30907	28008
BMB																		
850 hPa	27409	24203	10110	22115	28713	29303	21311	10703	31306	28714	27205	28904	26111	21005	17601	22709	28701	26107
700 hPa	27510	22905	11212	23419	30310	28802	28213	01106	31303	28314	22305	35304	26509	14902	16807	23508	13104	22905
NGP																		
850 hPa	30118	33004	18506	23611	25910	22604	25314	02904	26614	28417	29706	32609	32820	33208	23205	23407	09207	02107
700 hPa	24514	24209	19203	24408	25912	27406	23613	12103	23515	28808	25206	28504	23125	25906	24203	23611	09608	33606
The westerly anomaly winds imply that the easterlies are weaker than normal																		
MDS																		
200 hPa	24228	24012	01606	32310	22005	31306	08510	23315	28511	28906	28906	22906	28713	25701	33708	28813	29112	25907
TRV																		
200 hPa	26334	26314	29807	34509	27313	34406	15107	21522	28109	12702	10010	15409	15409	18109	18107	29117	24112	15310

reached upto 30 hPa during the season. So the data at 10 hPa are not available. At 50 hPa level, winds were easterlies throughout the season with varying wind speeds from the month to month. Flow pattern of winds were much weaker than the normal (say by 20 mps) throughout the season. At 30 hPa level, the winds were easterly throughout the season. Circulation pattern of winds at 30 hPa level also were much weaker than the normal (say by 20 mps) throughout the season over the country.

7.3. *Aridity conditions during monsoon 1997*

During initial phase of monsoon, moderate to severe arid conditions prevailed mostly over Andhra Pradesh, Marathwada, Vidarbha, central and eastern parts of Madhya Pradesh, northern parts of east Uttar Pradesh, Bihar and over some isolated areas in plains of west Uttar Pradesh and west Madhya Pradesh. With the progress of monsoon, this condition improved considerably and by end of the season, most parts of the country except interior Karnataka and some isolated parts of Uttar Pradesh, east Rajasthan, Madhya Pradesh and Tamil Nadu came under non-arid to mild-arid conditions.

Aridity anomaly maps for June and July are given in Fig. 13 (a) and for August and September are given in Fig. 13 (b).

8. Characteristic features of southwest monsoon 1997

(*i*) The southwest monsoon set in over Kerala without any onset vortex over the Arabian Sea on 9 June. It was delayed by 8 days from the normal date.

(*ii*) Monsoon also advanced over northeast India on 9 June on the same day as that of Kerala. It was delayed by 5 days from the normal date.

(*iii*) Monsoon advanced upto Gujarat, Madhya Pradesh, Orissa and West Bengal by 22 June with a delay of about 5 days. It advanced over Bihar, Uttar Pradesh, Himachal Pradesh, Jammu & Kashmir by 26 June with a delay of about 5 days. Monsoon covered the entire country by 19 July with delay of 4 days.

(*iv*) Five depressions and a cyclonic storm formed during the season over Bay of Bengal. No depression formed over the Arabian Sea. One deep depression each in June (26-29 June) and in July (29 July-2 August) two deep depressions (4-8 & 20-27 August) and one depression (28-30 August) in August and one cyclonic storm (23-27 September) formed in September. All the five depressions during the season formed over northwest Bay. Three of them moved northwest or westnorthwestwards and dissipated over Punjab and neighbourhood. Remaining two moved northwestwards and then to north and dissipated. While one

TABLE 12

Weekly anomaly features of monsoon 1997

Week ending on (1)	Lower tropospheric features 850 hPa (2)	700 hPa (3)	Remarks (4)	Upper tropospheric features 200 hPa (5)	Remarks (6)
June					
3 June	Ridge along 15°N between 65°-80°E	(1) N-S oriented trough along 75°E, between 25°-30°N (2) Ridge between 13°-18°N	The monsoon westerlies were weaker than normal over the peninsular India, south of 15°N, at 700 hPa	Anomaly winds were westerlies over India	The upper tropospheric easterlies were weaker than normal
10 June	(1) NW-SE oriented trough between 25°- 30°N and 73°-80° E (2) Ridge between 21°-25°N	(1) Trough along 30°N between 65°-80°E (2) Ridge between 15°-19°N	The monsoon westerlies were weaker than normal over the peninsular India, south of 20°N	Trough along 30°N between 65°-80°E	Do
17 June	Ridge between 25°-19°N	(1) Ridge between 20°-25°N (2) Cyclonic circulation centred at 14°N/72°E	The monsoon westerlies were weaker than normal over the Indian region, south of 25°N	Anomaly winds were westerlies over India	Do
24 June	Ridge between 12°-15°N	Ridge between 12°-16°N	The monsoon westerlies were weaker than normal over the peninsular India, south of 15° N.	Do	Do
July					
1 July	Trough between 21°-24° N	Trough between 21°-24°N	An anomaly trough in the region of monsoon trough was observed. The monsoon westerlies were stronger than normal	Anomaly winds were mainly westerlies	The upper tropospheric easterlies were weaker than normal
8 July	(1) Trough along 19°N between 70°-90°E (2) Cyclonic circulation centred at 25°N/85° E (3) NE-SW oriented ridge between 10°- 20°N and 70°-100°E (4) Ridge along 25°N between 65°-72°E	(1) Trough between 22°-30°N (2) Ridge along 10°N (3) Ridge along 28° between-80°E	—	(1) Trough between 13°-19°N (2) Ridge between 25°-29°N	—
15 July	(1) Anticyclonic circulation centred at 14°N/74°E (2) Anomaly winds were mainly westerlies	Ridge between 11°- 14°N	The monsoon westerlies were weaker than normal over the peninsular India, south of 15°N at 700 hPa	Ridge along 20°N between 65°-90°E	The upper tropospheric easterlies were stronger than normal over the peninsular India, south of 20°N
22 July	Ridge between 26°-28°N and 65°-85°E	Cyclonic circulation centred at 22°N/86° E	The monsoon westerlies were weaker than normal over peninsular India south of 28°N at 850 hPa and south of 20°N at 700 hPa	Anomaly winds were mainly westerlies	The upper tropospheric easterlies were weaker than normal
29 July	(1) Trough between 20°-30°N with two embedded cyclonic circulation centred at 25°N/79°E and 21°N/90°E (2) Cyclonic circulation centred at 12°N/75°E	Trough between 18°-26°N with two embedded cyclonic circulations centred at 25° N/78°E and 20° N/86°E	An anomaly trough in the region of monsoon trough was observed at both, 850 hPa and 700 hPa levels. The monsoon westerlies were stronger than normal	An anti- cyclonic circulation centred at 7° N/76°E	The upper tropospheric easterlies were weaker than normal

TABLE 12 (*Contd.*)

(1)	(2) (3)	(4) (5)	(6)	(7)	
August					
5 August	Trough between 20°-23°N and 85°-100°E with an embedded cyclonic circulation centred at 23°N/86°E	Trough between 20°-25°N with an embedded cyclonic circulation centred at 23°N/87°E	The monsoon westerlies were stronger than normal	Ridge between 12°- 15°N	The upper tropospheric easterlies were weaker than normal
12 August	(1) Ridge between 20°-25°N with two embedded anticylonic circulation centred at 25°N/74°E And 22°N/91°E (2) Trough between 11°-17°N and 80°- 100°E (3) A cyclonic circulation centred at 21°N/72°E	(1) NE-SW oriented ridge between 15°-25°N and 75°-100°E with an embedded anticyclonic circulation centred at 23° N/92°E (2) Trough along 15°N between 85°-100°E (3) A cyclonic circulation centred at 8° N/74°E	—	(1) A cyclonic circulation centred at 28°N/78°E (2) Three anticyclonic circulations along the east coast, centred at (a) 25°N/90°E (b) 19°N/87°E (c) 12°N/77°E	—
19 August	Ridge between 10°-14°N and 65°-85°E with an embedded anticyclonic circulation centred at 15°N/70°E	Ridge along 20°N between 65°- 85°E with an embedded anticyclonic circulation centred at 20° N/70°E	The monsoon westerlies were weaker than normal over peninsular India, south of 15° N at 850 hPa and south of 20°N at 700 hPa	Anomaly winds were westerlies	The upper tropospheric easterlies were weaker than normal
26 August	Trough between 18°- 24°N with two embedded cyclonic circulations centred at 25°N/75°E and 22°N/87°E	Trough between 20°-23°N with two cyclonic circulations centred at 25°N/75°E and 22°N/90°E	An anomaly trough was observed in the region of monsoon trough. The monsoon westerlies were stronger than normal	The anomaly winds were mainly westerlies	The upper tropospheric easterlies were weaker than normal
September					
2 September	(1) Cyclonic circulation centred at 25° N/84°E and 20° N/85°E (2) An anticyclonic circulation centred at 12° N/85°E	(1) Two cyclonic circulations centred at 26°N/83° E and 20°N/84°E (2) An anticyclonic circulation centered at 9 °N/70°E	—	The anomaly winds were mainly southerlies over Indian region, south of 20°N. They were mainly westerlies over Indian region within the latitude belt of 20°-35°N	—
9 September	(1) An anticyclonic circulation centered at 24°N/84°E (2) NE-SW oriented trough between 15°-27°N and 70°E-85°E	(1) An anticyclonic circulation centred at 20°N/80° E (2) A cyclonic circulation centred at 25° N/78°E	The monsoon westerlies were weaker than normal over peninsular India, south of 20°N	(1) Trough between 23°-26° N (2) An anticyclonic circulation centred at 10°N/77°E	The upper tropospheric westerlies were weaker than normal over the central and peninsular India, south of 22°N
16 September	(1) Ridge between 10°-15°N with an embedded anticyclonic circulation centred at 15°N/87°E (2) NE-SW oriented trough between 24°-30°N and 65°-80° E N-S oriented trough along 86°E between 20°- 26°N	(1) Ridge between 10°-15°N with an embedded anticyclonic circulation centred at 16° N/85°E (2) NE-SW oriented trough between 22°-30°N and 65°-80°E	The monsoon westerlies were weaker than normal over the peninsular India, south of 15° N	(1) Trough between 16°-23°N with an embedded cyclonic circulation centred at 23°N/82°E (2) An anticyclonic circulation centred at 10°N/75° E	The upper tropospheric easterlies were weaker than normal over the Indian region, south of 20°N
23 September	(1) Trough between 15°-20°N with an embedded cyclonic circulation centred at 17°N/84°E (2) Ridge between 21°-29°N with an embedded anticyclonic circulation centred at 27° N/79°E	(1) Trough between 15°-20°N with an embedded cyclonic circulation centred at 16°N/85°E (2) Ridge between 20°-30° N with an embedded anticyclonic circulation centred at 26° N/80°E	The monsoon westerlies were stronger than normal over the peninsular India, south of 15°N	An anticyclonic circulation centred at 10° N/76° E	The upper tropospheric easterlies were weaker than normal

TABLE 12 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
30 September	(1) Trough along 16°N between 82°-95°E with an embedded cyclonic circulation centred at 15° N/92°E (2) Trough along 25°N between 90°-100°E with an embedded cyclonic circulation centred at 25° N/90°E (3) Ridge along 12°N between 65°-75°E (4) NE-SW oriented ridge between 20°-32°N and 70°-85°E	(1) Trough between 13°-18°N and 80°- 95°E with an embedded cyclonic circulation centred at 18° N/80°E (2) N-S oriented ridge along 75°E between 22° to 30°N	—	Ridge between 10°-20°N with an embedded anticyclonic circulation centred at 11°N/83°E	The upper tropospheric easterlies were weaker than normal

dissipated over Bihar and adjoining east Uttar Pradesh, the other over north Bihar Plains.

(*v*) All the depressions initially formed as low level cyclonic circulations and then descended to the mean sea level as low pressure areas.

(*vi*) The cyclonic storm (23-27 September) formed over the west- central Bay Off Andhra coast and moved northwestwards skirting the Andhra-Orissa-West Bengal coasts. It finally crossed the Bangladesh coast. Because of its peculiar behaviour, this requires further study. A storm during 7-9 November 1986 had similar track, skirting the Andhra-Orissa-West Bengal coast.

(*vii*) In addition to the depressions, there were 11 well-marked low pressure areas (2 in June, 3 in July, 4 in August and 2 in September) and 47 cyclonic circulations (11 in June, 12 in July, 7 in August and 17 in September) which affected the monsoon season.

(*viii*) Rainfall was well-distributed in space and time during the season. From the week ending on 2 July, nearly 70% or more of the meteorological sub-divisions received normal/excess rainfall.

(*ix*) In all the 17 weeks (except week ending on 9 July), rainfall was deficient in Marathwada Vidarbha, Telngana and coastal Andhra Pradesh (except for weeks ending on 17,24 and 30 September).

(*x*) Rainfall was excess or normal throughout in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Haryana, Punjab, Rajasthan, Gujarat and Rayalaseema.

(*xi*) Rainfall during the monsoon season was excess in 7, normal in 25 and deficient in 3 meteorological sub-divisions [Marathwada (-31%), Vidarbha (-22%) and Telangana (-26%)].

(*xii*) Out of 35 meteorological sub-divisions, excess or normal rainfall was received in 25 meteorological sub-divisions in June, 26 in July and August and in 22 meteorological sub-divisions in September.

(*xiii*) Axis of the monsoon trough on sea level chart was established on 25 June and became less marked on 9 September. The monsoon trough was active in its normal position almost on all the days except on 10 July, 9 & 15 August; when it was close to the foot hills of the Himalayas.

(*xiv*) Off-shore trough on sea level chart was present in June on 18 days, in July on 21 days, in August on 15 days and in September on 22 days.

(*xv*) Tibetan anti-cyclone/High was established in the last week of June and was active and south of its normal position in the month of July and August. The movement of the three depressions in August in a west-northwesterly direction was because of the southerly positions of Tibetan anticyclone.

(*xvi*) Though 1997 was a strong El-Nino year and there was a general apprehension that monsoon rainfall will be below normal leading to drought conditions in India, but there was a well- distributed and normal monsoon rainfall over India.

(*xvii*) Southwest monsoon withdrew from west Rajasthan on 18 September as against the normal date of 15 September. It further withdrew from rest of northwest India, Uttar Pradesh, west Madhya Pradesh, Gujarat and Marathwada by 3 October as against the normal date of 1 October. It withdrews from the entire country by 8 October.

(*xviii*) Northeast monsoon rains commenced over Tamil Nadu & Pondicherry, Kerala and adjoining parts of Andhra Pradesh and Karnataka on 13 October.

(*xix*) Northeast monsoon withdrew from Tamil Nadu & Pondicherry, Kerala and adjoining parts of Andhra Pradesh

TABLE 13

Statistics of spatial rainfall distribution (No. of days for monsoon season 1997 as a whole with heavy to very heavy rainfall)

S. No.	Meteorological Sub-division	Vigorous	Active	Very Heavy	Heavy	W/Fw
1.	Andaman & Nicobar Is.	-	-	5	12	65
2.	Arunachal Pradesh	-	12	4	3	45
3.	Assam & Meghalaya	1	17	12	30	47
4.	Naga., Mani., Miz. & Tripura	2	10	1	12	41
5.	S.H.W.B. & Sikkim	2	20	13	41	55
6.	Gangetic West Bengal	7	20	5	30	30
7.	Orissa	3	13	11	34	31
8.	Bihar Plateau	2	7	2	7	53
9.	Bihar Plains	2	4	8	6	34
10.	East Uttar Pradesh	4	10	7	15	13
11.	Plains of west Uttar Pradesh	3	5	7	11	9
12.	Hills of west Uttar Pradesh	3	13	3	9	16
13.	Haryana, CHD & DLH	6	4	3	10	5
14.	Punjab	7	6	4	8	3
15.	Himachal Pradesh	3	7	6	10	26
16.	Jammu & Kashmir	1	-	2	5	18
17.	West Rajasthan	2	-	2	6	2
18.	East Rajasthan	2	5	7	5	10
19.	West Madhya Pradesh	4	15	9	18	7
20.	East Madhya Pradesh	3	14	9	20	29
21.	Gujarat Region	9	10	13	8	12
22.	Saurashtra & Kutch	6	3	5	6	10
23.	Konkan & Goa	6	16	22	18	65
24.	Madhya Maharashtra	3	18	14	19	9
25.	Marathwada	-	11	-	7	11
26.	Vidarbha	-	3	3	10	28
27.	Coastal Andhra Pradesh	4	13	3	10	2
28.	Telangana	1	15	1	11	15
29.	Rayalaseema	7	4	1	9	3
30.	Tamil Nadu & Pondicherry	-	-	4	12	1
31.	Coastal Karnataka	3	26	19	22	57
32.	North interior Karnataka	1	8	2	12	4
33.	South interior Karnataka	2	14	13	7	13
34.	Kerala	5	24	13	36	48
35.	Lakshadweep	-	-	-	5	38

Very heavy rainfall — more than 12.5 cms. Heavy rainfall — more than 6.5 cms, W/Fw— Almost at all the places or at many places

and Karnataka on 31 December. Northeast monsoon was active on a number of days leading to excess rainfall activity over the region.

9. Damages due to floods etc. during monsoon season

As per the newspapers and reports received from Regional Meteorological Centres(RMCs), in all, about 750 people lost their lives, damages occurred to properties worth crores of rupees and many people rendered homeless due to heavy rains, landslides, thunderstorm and strong winds during June to September 1997.

Damages reported due to floods and heavy rains in June, July, August and September are given in paras 10.1.3., 10.2.1., 10.3.1. and 10.4.1.

9.1. *Significant spells of heavy rains*

During June, widespread rains with isolated heavy to very heavy falls occurred in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim during 6 to 23; in Konkan & Goa & Madhya Maharashtra, during 3rd week and in Gujarat state, coastal & south interior Karnataka and Kerala in last week.

In July, widespread rains with heavy to very heavy falls occurred over Gangetic West Bengal, Konkan & Goa, Madhya Maharashtra, coastal Karnataka and Kerala during first fortnight and over Sub- Himalayan West Bengal & Sikkim, Rajasthan, Madhya Pradesh, Gujarat region, Konkan & Goa, coastal & south interior Karnataka and Kerala during second fortnight.

TABLE 14

Monthly values of Southern Oscillation Index (SOI) and Sea Surface Temperature Anomaly (SSTA)

Month	Pacific SSTA (in °C)			SOI
	Nino 1+2 0-10°S 90°- 80°W	Nino 3 5°N-5°S 150°- 90°W	Nino 4 5°N- 5°S 160E°-150°W	
Jan 97	-0.6	-0.6	0.3	0.5
Feb 97	0.2	-0.3	0.3	1.6
Mar 97	1.0	0.2	0.4	1.1
Apr 97	1.3	0.4	1.0	-0.9
May 97	2.9	1.4	0.9	-1.8
June 97	3.9	2.1	0.9	-2.0
Jul 97	4.7	2.7	1.0	-1.0
Aug 97	4.2	3.1	0.9	-2.1
Sept 97	4.1	3.3	1.0	-1.6
Oct 97	4.1	3.5	1.0	-1.9
Nov 97	4.2	3.8	1.1	-1.4
Dec 97	4.5	3.9	1.1	-1.2

In August, widespread rains with heavy to very heavy falls occurred over Orissa, west Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Konkan & Goa, Madhya Maharashtra, coastal & south interior Karnataka and Kerala during first week; over west Bengal & Sikkim, Orissa, Punjab, Himachal Pradesh and east Madhya Pradesh during second and third week and over Orissa, Bihar, Haryana, Punjab, Himachal Pradesh, Madhya Pradesh and Kerala during last week.

During September, widespread rains with heavy to very heavy falls occurred on few days over West Bengal & Sikkim, Orissa, plains of Uttar Pradesh, Saurashtra & Kutch, Konkan & Goa, coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Kerala.

The statistics of spatial rainfall distribution in terms of active and vigorous monsoon and heavy and very heavy spells of rains for the monsoon 1997 as a whole is given in Table 13.

10. Significant monthly features

10.1. *June*

10.1.1. *Temperature*

Heat wave conditions prevailed on many days in coastal Andhra Pradesh and on few days in Telangana, Rayalaseema and in some parts of interior Orissa and of Tamil Nadu during first week of June.

Highest day temperature of 46°C was recorded at Machilipatnam on 1 June.

10.1.2. *Monthly rainfall*

Monthly rainfall is given in Fig. 5 and principal amounts of rainfall are given in Table 2.

10.1.3. *Disastrous weather events and damages during June*

It is reported that, in Gujarat State, 172 people lost their lives and damages to properties worth crores of rupees due to heavy rains and floods in the last week of the month. Land slides triggered by heavy rains took a toll of 50 human lives in Sikkim in the second week of the month. In addition, about 70 people lost their lives due to heavy rains and floods in various parts of the country during the month.

10.2. *July*

10.2.1. *Disastrous weather events during July*

According to media reports, 49 people in Kerala and 20 people in Assam and adjacent states died, many became homeless, 56 houses fully damaged and damages to properties worth crores of rupees due to heavy rains and floods. About 45 people died in various parts of the country due to heavy rains and flash floods during the month.

10.3. *August*

10.3.1. *Disastrous weather events and damages during August*

According to media reports, about 276 people lost their lives and properties worth crores of rupees damaged due to heavy rains and floods in various parts of the country including 140 deaths in Himachal Pradesh during second week and 33 in Marathwada during third week of the month.

10.4. *September*

10.4.1. *Disastrous weather events and damages during September*

According to press reports, 50 people in Andhra Pradesh and 2 people in Assam lost their lives due to flash

floods caused by heavy rains during third and fourth weeks of the month.

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