Mausam, (1991), 42, 3, 309-328

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Weather

SUMMER MONSOON SEASON (JUNE - SEPTEMBER 1990)*

1. Introduction

For the third year in succession, the summer monsoon rainfall, 1 June to 30 September, 1990 over the country was above normal. The 1990 monsoon rainfall ranks the third best during the last decade, when the total rainfall for the country as whole is considered; the other two years are 1983 and 1988. The total monsoon rainfall (1 June to 30 September) over the country in 1990 was 106% of the seasonal normal. 32 meteorological sub-divisions out of 35 (about 91%) received either normal or excess rainfall. Areawise, nearly 99% of the Indian land mass received either normal or excess rainfall. Most of the drought prone areas received normal to excess rainfall. There were no major floods over the country during this season.

For describing rainfall distribution for the week and period the following norms have been used.

Classification	*Percentage departure of rainfall from the normal*
(*i*) Excess	+20 or more
(*ii*) Normal	+19 to —19
(*iii*) Deficient	—20 to —59
(*iv*) Scanty	—60 or less
(*v*) Dry	—100

2. Chief features of the season

2.1. *Advance of southwest monsoon*

Southwest monsoon, 1990 set in over Kerala and extreme southern parts of Tamil Nadu on 19 May and further advanced into the rest of Tamil Nadu, coastal and south interior Karnataka and adjoining parts of north interior Karnataka, south Konkan and Goa and southwestern parts of Rayalaseema by 21 May. It further advanced into north Konkan, south Madhya Maharashtra, more areas of north interior Karnataka and rest of Rayalaseema on 31 May. By 4 June the Bay of Bengal branch of the monsoon current advanced over northeastern states and Sub-Himalayan West Bengal & Sikkim. By 6 June it further advanced into most parts of north Madhya Maharashtra, Marathwada, Vidarbha, rest of Andhra Pradesh, southeast Madhya Pradesh and south Orissa. Further it covered rest of Orissa, Gangetic West Bengal, Bihar, east Uttar Pradesh, whole of Madhya Pradesh and south Gujarat. In the last phase, between 27 June and 1 July, it further advanced over west Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, Rajasthan and north Gujarat. Datewise advance of the southwest monsoon is shown in Fig. 1.

In 1990, the southwest monsoon set in over Kerala, coastal and south interior Karnataka, north Konkan and western parts of west Rajasthan early by 10 to 14 days. It advanced 4 to 7 days earlier than normal over north interior Karnataka, Andhra Pradesh, rest of Maharashtra and the remaining areas of west Rajasthan. It advanced around normal dates over Assam and adjacent states, Sub-Himalayan West Bengal and Sikkim, Uttar Pradesh, Himachal Pradesh and Jammu & Kashmir. Its advance to north Gujarat region and Saurashtra & Kutch was delayed by 12 to 15 days and to Madhya Pradesh, east Rajasthan and south Gujarat region by 4 to 5 days.

2.2. *Weekly performance of the monsoon*

During the 18 weeks period (31 May 1990 to 3 October 1990) of the season, excess or normal rainfall was recorded in 22 sub-divisions during 9 weeks or more and in the remaining 13 sub-divisions during less than 9 weeks. Of these 22 sub-divisions, 13 sub-divisions were in the north India and 9 were in the Peninsular India. In the second category, the hills of west Uttar Pradesh received excess or normal rainfall for 4 weeks followed by Kerala for 5 weeks.

Monsoon activity was normal or above normal in 18 meteorological sub-divisions for 11 weeks and in 16 meteorological sub-divisions for 7 weeks period. The peak monsoon activity was observed during the weeks, 28/6 to 3/7 and 9/8 to 15/8, when 24 meteorological sub-divisions experienced normal or excess rainfall. The activity over the country was lowest during the weeks, 26/7 to 1/8 and 13/9 to 19/9 when rainfall was normal or excess in 12 sub-divisions only and was deficient or scanty in 23 sub-divisions.

Sub-division-wise weekly rainfall departures are given in Fig. 3 and week by week cumulative rainfall position from 1 June 1990 to 30 September 1990 for the country as a whole is given in Fig. 6.

*Compiled by : S/Shri G. R. Gupta, D. S. Desai and N. C. Biswas, Office of the Dy. Director General of Meteorology (WF), Pune.

TABLE 1

Sub-divisional means of rainfall (mm) for each month and season as a whole June to September 1990

(Based on DWS data)

S. No.	Sub-divisions	Jun		Jul		Aug		Sep		Season Jun to Sep		
		Act.	%Dep.	Act.	%Dep.	Act.	%Dep.	Act.	%Dep.	Act.	Normal	%Dep.
1	A. & N. Island	255	—46	196	—46	238	—34	330	—19	1019	1598	—36
2	Arunachal Pradesh	771	37	721	20	358	10	656	16	2507	2052	22
3	Assam & Meghalaya	519	4	514	—5	311	—25	501	50	1845	1791	3
4	Nag., Mani., Mizo. & Tri.	339	—11	388	19	329	3	238	3	1294	1254	3
5	S.H.W.B. & Sikkim	567	6	501	—18	635	27	456	11	2160	2062	5
6	Gangetic W. B.	227	—11	431	39	262	—14	280	13	1200	1118	7
7	Orissa	221	1	255	—30	344	—3	258	4	1078	1185	—9
8	Bihar plateau	247	28	551	64	254	—22	267	21	1319	1075	23
9	Bihar plains	167	—2	498	59	210	—33	196	—12	1071	1021	5
10	East U. P.	97	—6	474	51	188	—32	162	—15	959	890	7
11	Plains of west U.P.	38	—45	345	31	199	—21	244	44	849	782	8
12	Hills of west U.P.	92	—40	439	10	351	—4	189	—3	1131	1104	2
13	Har., Chandi. & Delhi	26	—51	245	24	141	—19	219	98	632	536	18
14	Punjab	18	—57	274	46	189	12	215	115	695	498	40
15	H. P.	100	6	355	—4	342	0	245	46	1042	972	7
16	J. & K.	13	—79	141	29	164	2	103	38	421	406	4
17	West Rajasthan	29	7	213	106	194	67	50	—1	486	298	63
18	East Rajasthan	75	33	196	—19	204	—19	219	43	693	705	—2
19	West M. P.	185	59	293	—12	360	20	307	63	1145	936	22
20	East M. P.	303	80	356	—12	296	—21	338	48	1294	1177	10
21	Gujarat Reg. Daman, Dadra & Nagar Hav.	84	—33	253	—35	593	121	244	44	1173	953	23
22	Saur. Kutch & Diu	98	19	35	—83	277	112	88	—3	498	502	—1
23	Konkan & Goa	778	14	734	—35	1069	57	373	5	2953	2852	4
24	Madhya Maharashtra	150	—1	233	—18	337	78	103	—37	823	789	4
25	Marathwada	223	54	117	—43	372	102	107	—41	819	715	15
26	Vidarbha	301	81	321	—4	506	83	126	—38	1254	983	27
27	Coastal A. P.	96	—14	118	—31	182	12	159	—8	554	616	—10
28	Telangana	199	43	187	—22	385	84	110	—43	881	780	13
29	Rayalaseema	52	—16	61	—31	81	—18	141	5	335	384	—13
30	Tamil Nadu & Pondi.	30	—43	41	—43	78	—20	126	22	275	327	—16
31	Coastal Karnataka	933	7	996	—15	1027	50	269	—12	3226	3037	6
32	N. I. Karnataka	156	59	95	—36	186	53	72	—52	507	520	—3
33	S. I. Karnataka	168	17	200	—29	266	42	82	—42	732	755	—3
34	Kerala	512	—26	630	—17	361	—17	104	—58	1607	2131	—25
35	Lakshadweep	166	—46	336	20	124	—35	99	—39	725	941	—23

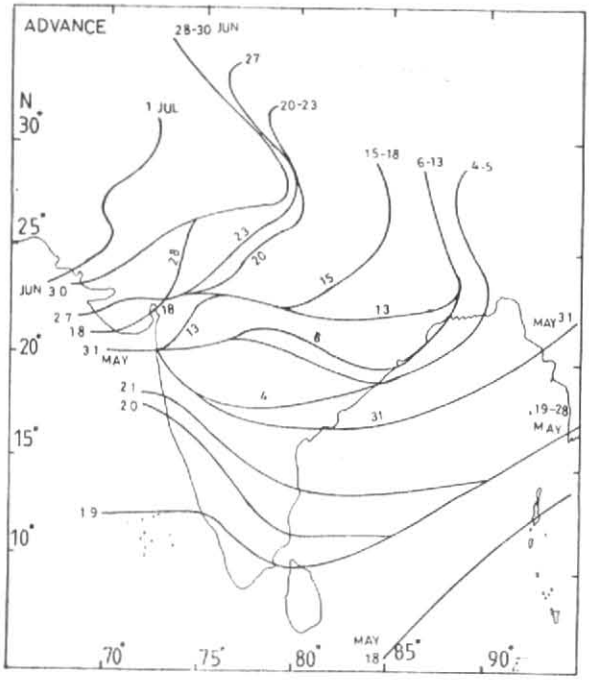

Fig. 1. Actual dates of onset of southwest monsoon 1990 over India

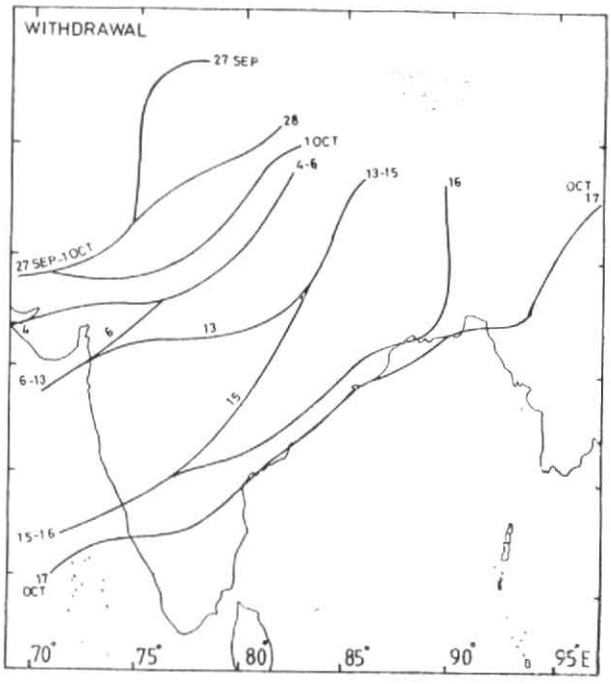

Fig. 2. Actual dates of withdrawal of southwest monsoon 1990 over India

2.3. *Monthly performance of the monsoon*

By the middle of June southwest monsoon advanced over the most parts of the Peninsular India and in northeast India. It advanced over northwest India at the end of June. The rainfall activity during June was normal in the country outside west Uttar Pradesh, Haryana, Punjab and Jammu & Kashmir. These sub-divisions received 40 to 60 per cent of the normal rainfall. The rainfall over Jammu & Kashmir was even less. During July monsoon activity was normal to above normal over north India, while in general it was below normal over the Peninsular India and Gujarat. Saurashtra & Kutch received scanty rainfall during this month resulting in very large deficiency of cumulative rainfall for June and July in the region (dep. —53%). In the Peninsular India, though Madhya Maharashtra, Vidarbha, coastal Karnataka and Kerala had normal rainfall, but the departures were on the negative side. Consequent to good rainfall over west Uttar Pradesh, Haryana, Punjab and Jammu & Kashmir during this month, the deficiency of June rainfall was made up and the cumulative rainfall for June and July became normal in these sub-divisions. During August, monsoon activity was normal over most parts of the country, except Assam & Meghalaya, Bihar and Plains of Uttar Pradesh in north India, east Madhya Pradesh in the central India and Tamil Nadu in Peninsular India where the rainfall for the month was deficient. However, except Bihar the deficiency was marginal (dep. between—20 and — 25%) in other sub-divisions while in Bihar it was —32 to 33 per cent. In short, August rainfall was well distributed in space and time. At the end of August, the cumulative rainfall was deficient only in three meteorological sub-divisions. Of these three sub-divisions the departure of the seasonal rainfall was marignal in Rayalaseema (—22%) and Kerala (—20%) but was considerable in Tamil Nadu (—33%). In September the monsoon activity was good over north and central India and so in Tamil Nadu. The cumulative rainfall in Tamil Nadu became excess in September for the first time in the season. Monthly rainfall figures for the 35 sub-divisions is given in Table 1.

2.4. *Seasonal performance of the monsoon*

The seasonal rainfall during the monsoon period (June to September) of 1990 in term of average quantity for the country as a whole ranks the third best during the last ten years. Of the 35 meteorological sub-divisions of the country, seasonal rainfall was excess in 7 sub-divisions, normal in 25 sub-divisions and deficient in 3 sub-divisions. There was no sub-division in the scanty category. Of the three deficient sub-divisions 2 were the island sub-divisions, *i.e.,* Andaman & Nicobar Islands in the Bay of Bengal and Lakshadweep in the Arabian Sea. The third deficient sub-division was Kerala. Even in Kerala and Lakshadweep, the rainfall deficiency was marginal. Seasonal rainfall was excess in Arunachal Pradesh, Bihar Plateau, Punjab, west Rajasthan, west Madhya Pradesh, Gujarat region and Vidarbha and was normal in Assam & Meghalaya, Nagaland, Manipur, Mizoram and Tripura, West Bengal and Sikkim, Orissa, Bihar Plains, Uttar Pradesh, Haryana, Himachal Pradesh, Jammu & Kashmir, east Rajasthan, east Madhya Pradesh, Saurashtra & Kutch, Konkan & Goa, Madhya Maharashtra, Marathwada, Andhra Pradesh, Tamil Nadu and Karnataka. Rainfall figures for the month and the season as a whole are given in Table 1. The seasonal rainfall departures analysed on the basis of individual stations rainfall are shown in Fig. 5. Maps showing monthly and seasonal rainfall are given in Figs. 8 to 12.

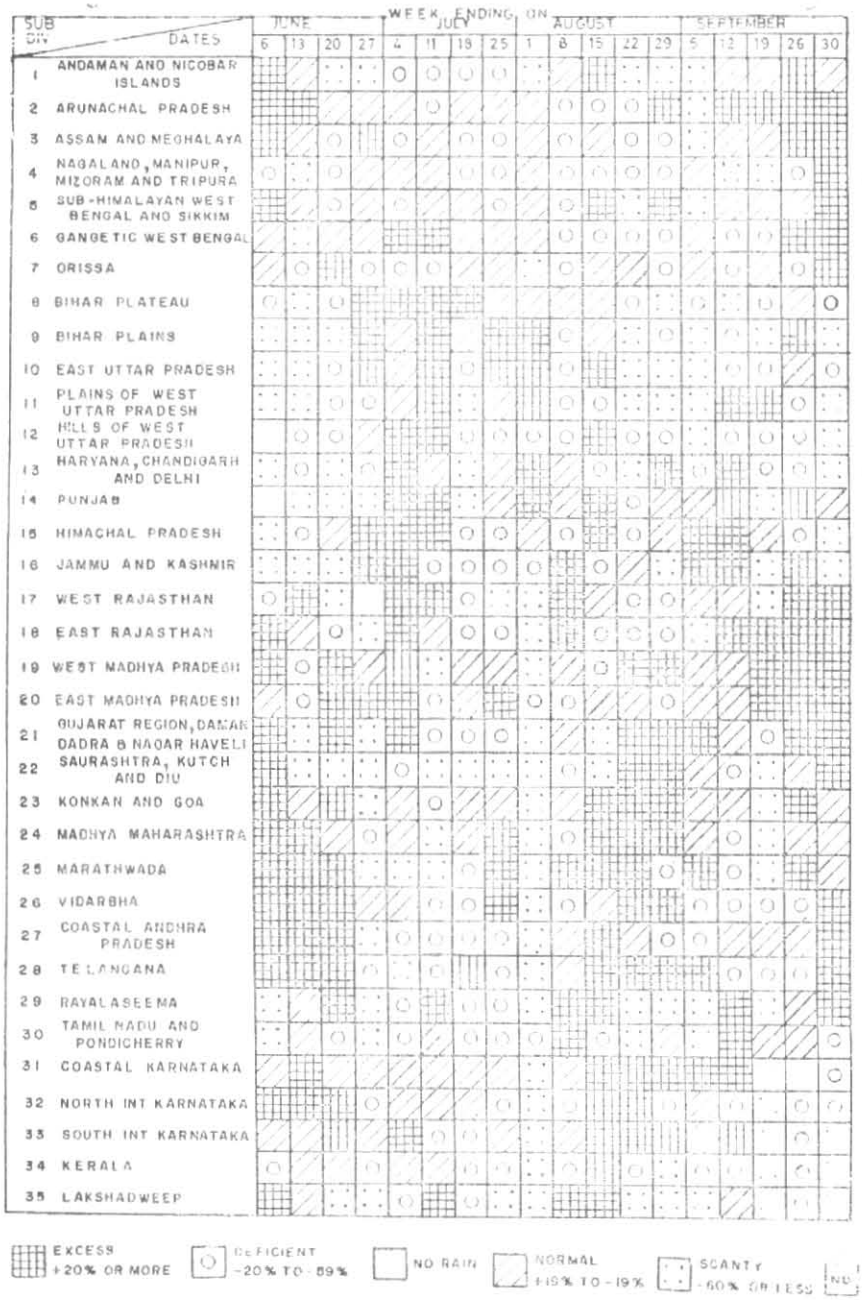

Fig. 3. Performance of week by week southwest monsoon season (Jun-Sep 1990) rainfall over 35 meteorological sub-divisions of India

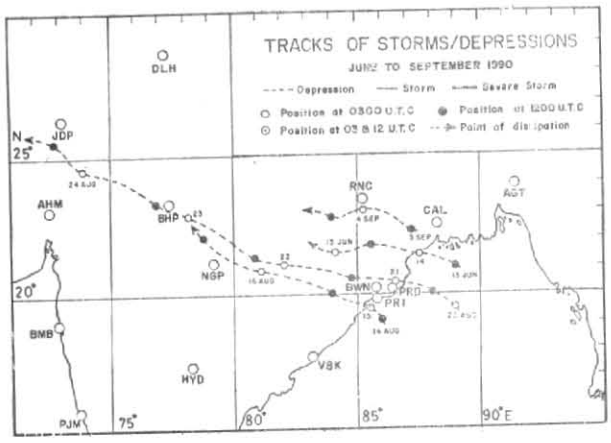

Fig. 4. Tracks of depression/cyclonic storms formed during southwest monsoon season (Jun-Sep 1990) over Bay of Bengal

2.5. *Storms and Depressions*

Normally 7 to 8 cyclonic disturbances (depressions or storms) develop during the monsoon season. During the monsoon season of 1990, however, only 4 such systems developed in the region. Of these 4 systems, 3 developed over northwest Bay and one over the land. In June a deep depression developed over the northwest Bay. During July, no depression formed in the region. In August, one deep depression and one depression developed over the Bay. Both the systems moved upto the west of Long. 80°E across central India. The deep depression in August moved westward upto west Rajasthan. The September system was a land depression formed under the influence of the remnant of the Pacific typhoon 'Becky'. The tracks of these depressions/ deep depressions are shown in Fig. 4.

2.6. *Axis of the monsoon trough (at 0.9 km a.s.l.) and Break — monsoon condition*

Normally the axis of the monsoon trough at 0.9 km passes through Delhi, Allahabad and Asansol. During monsoon 1990 this trough was established to the east of Long. 80°E during the third week of June, and over northwest India by the end of June. During July the trough was generally weak and ill defined except during the periods of low pressure areas when it was well defined with its position to the south of its normal position. In August axis of the monsoon trough at this level was well defined but lay south of its normal position. During the month of September it was well delineated on most of the days.

During the monsoon season of 1990 typical "Break monsoon" conditions were almost absent. However, on a few occasions the eastern or the western end of the monsoon trough moved close to the foot-hills of Himalayas. But such situations were also very short lived.

2.7. *Trough in mid latitudes westerlies*

During June, two middle and upper tropospheric troughs, (one between 3rd and 10th and other between 11th and 13th) moved across the plains of north India to the north of Lat. 25°N. The third and fourth troughs observed only in the middle tropospheric levels moved across northwest India between 14th and 17th and northeast India between 22 and 25 June respectively.

During July four such troughs affected north India. The first one moved across the Gangetic plains between 10th & 11th. The other three troughs moved across the north India, north of 30°N latitude between (*i*) 14th and 18th, (*ii*) 21st and 24th and (*iii*) 28th and 30th affecting extreme north India.

During August, the first trough moved across northeast India between 11th and 13th. The other two troughs, between 14th and 17th and 22nd and 28th moved across extreme north India to the north of Lat. 30°N.

Four mid-latitude troughs moved across Jammu & Kashmir and neighbourhood during September. The first trough, in the middle tropospheric levels moved between 2nd and 5th. The other three troughs in the middle and upper tropospheric levels moved between (*i*) 7th and 13th, (*ii*) 24th and 28th and (*iii*) 28th and 30th.

These troughs mainly affected extreme north India. However, Gangetic plains were affected twice once during June and the second time during July.

2.8. *Sea surface temperature (SST) of north Indian Ocean*

During June, southeast Arabian Sea and the eastern parts of east central Arabian Sea was warmer by about 1°C (normal 28°C to 29°C). The west central Bay of Bengal was also warmer by more than 1°C (normal 29°C) in June.

During July, Arabian Sea, Bay of Bengal and adjoining Indian Ocean appeared to be warmer by about 1°C than normal. The normal SST's off Somalia coast during the month is 26°C. However, it was around 27°C during July 1990.

During August, a tongue of cold pool extended southwards to equator, which is an uncommon feature.

During September, a tongue of the cold pool over southwest Bay extended into the central Bay upto Lat. 15°N which is rather uncommon. Mean monthly SSTs over the north Indian ocean for the months of June to September, 1990 have been shown in Fig. 7.

2.9. *Withdrawal of southwest monsoon*

The withdrawal of southwest monsoon commenced by the end of September. It withdrew from Jammu & Kashmir, west Rajasthan and parts of Punjab on 27

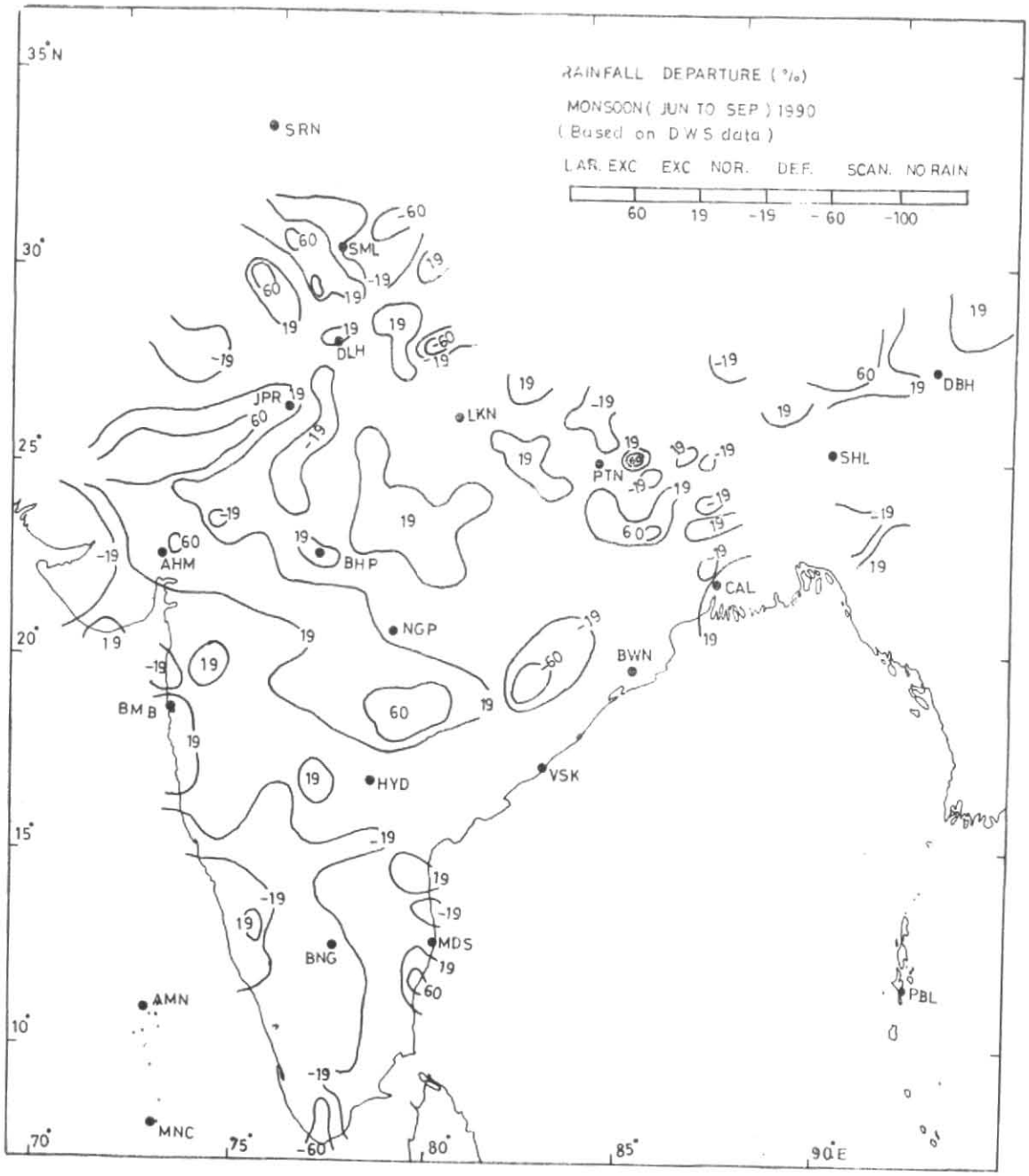

Fig. 5. Percentage rainfall departure for the period 1 June to 30 September 1990 based on Disaster weather station data

September. It further withdrew from Himachal Pradesh, northwest Uttar Pradesh, Haryana and rest Punjab on 28 September. During the first week of October it withdrew from rest of west Uttar Pradesh, east Rajasthan, Gujarat, northwest Madhya Pradesh and western parts of east Uttar Pradesh. It further withdrew from rest of east Uttar Pradesh, southwest Madhya Pradesh and extreme northern parts of east Madhya Pradesh on 13 October. The southwest monsoon withdrew from the country outside Kerala and Tamil Nadu on 17 October. Datewise withdrawal of the southwest monsoon from the country has been shown in Fig. 2.

2.10. *Characteristic features of the season*

(*i*) Most of the depressions/well marked low pressure areas were initially observed as upper air circulations.

(*ii*) Against a normal of 7 to 8 depressions in the Bay of Bengal, only 4 depressions formed during this monsoon season.

(*iii*) No monsoon depression formed during the month of July, also no depression developed over the Arabian Sea during the season.

TABLE 2

Details of the systems which caused advance of SW monsoon during June 1990

S. No.	System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Depression/Low pressure area*						
1	Deep depression	13-15	Northwest Bay	NW/WNW'ly	East M.P. & adjoining Bihar plateau and Orissa. The remnant became less marked over northeast Madhya Pradesh on 18th	Initially observed as a cyclonic circulation between 2.1 & 4.5 km a.s.l. over west central Bay on 7th
2	Well marked low pressure area	21-30	Bihar Plateau & neighbourhood	Initially easterly upto north Bay and then west-northwesterly	South Uttar Pradesh & adjoining north Madhya Pradesh. Associated cyclonic circulation up to middle tropospheric levels became less marked there in the evening of 30th	Initially observed as a cyclonic circulation in the lower & middle tropospheric levels over Bihar Plateau & neighbourhood on 20th
(B) *Cyclonic circulation*						
1	Lower & middle tropospheric levels	4-7	Northwest & adjoining west central Bay off south Orissa-north Andhra coast	Westerly	Telangana & neighbourhood	
2	Do .	26-30	Gulf of Cambay and adjoining land areas	Stationary	*In situ*	

(*iv*) Onset of monsoon over Kerala took place as early as on 19 May. During the onset phase no onset vortex was observed.

(*v*) Cross equatorial flow in the lower tropospheric levels off Somalia coast was observed from the month of May as indicated by cloud motion vectors (CMVs).

(*vi*) One depression (20-24 August) moved to as far west as west Rajasthan. The remnant of the other depression in August and a few low pressure areas also moved westwards up to west Rajasthan.

(*vii*) There was regular movement of mid latitude troughs in westerlies across extreme north India and Tibetan plateau resulting in the shifting of the Tibetan anticyclone to southern latitudes.

(*viii*) There was no typical 'break monsoon' situation during the season.

(*ix*) Most of the drought prone areas received normal rainfall during the season.

(*x*) Duration of the monsoon period over northwest India was more than the normal.

(*xi*) Monsoon 1990 was the third good monsoon in succession (*i.e.* 1988 to 1990) during the last 10 years.

(*xii*) No severe floods occurred in the flood prone areas of the country.

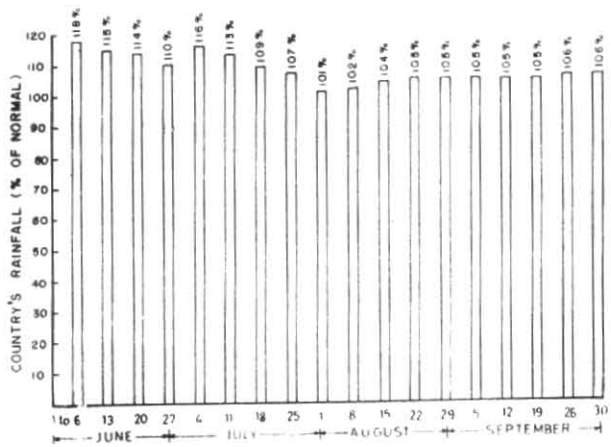

Fig. 6. Week by week cumulative rainfall position from 1 June 1990 for the country as a whole

2.11. *Damages due to floods etc during the season*

As per the reports of the Central Water Commission, floods and heavy rainfalls during the season took a toll of 882 human lives and perished about 1,22, 498 cattle heads in the Indian sub-continent. The estimated cost of the damaged crops, houses and public property was about Rs. 412.5 millions. Of which the estimated cost of the damaged crops was about Rs. 281 millions. Details of the calamities for each month of season had been

TABLE 3

Details of weather systems during June 1990

S. No.	Weather System	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Depression/Low pressure area*						
1	Deep depression	13-15	Northwest Bay	NW/WNW'ly	East Madhya Pradesh & adjoining Bihar Plateau and Orissa. The remnant became less marked over northeast Madhya Pradesh on 18th	Initially observed as a cyclonic circulation between 2.1 & 4.5 km a.s.l. over west central Bay on 7th
2	Well marked low pressure area	21-30	Bihar Plateau and neighbourhood	Initially easterly upto north Bay and then west-northwesterly	South Uttar Pradesh & adjoining north Madhya Pradesh. Associated cyclonic circulation upto middle tropospheric levels became less marked there in the evening of 30th	Initially observed as a cyclonic circulation in the lower & middle tropospheric levels over Bihar Plateau & neighbourhood on 20th
(B) *Cyclonic circulation*						
1	Lower & middle tropospheric levels	2-3	East central & adjoining northeast Arabian Sea	Stationary	*In situ*	
2	Do.	4-7	Northwest & adjoining west central Bay off south Orissa-north Andhra coast	Westerly	Telangana & neighbourhood	
3	Do.	6-8	Gulf of Cambay & neighbourhood	Stationary	*In situ*	
4	Do.	26-30	Gulf of Cambay & adjoining land areas	Do.	Do.	
(C) *Western Disturbance*						
1	Upper air system	2-6	East Afghanistan	Easterly	Moved away across Jammu & Kashmir and neighbourhood	
2	Do.	11-12	Jammu & Kashmir & adjoining North Pakistan	Do.	Do.	
3	Do.	21-24	Do.	Do.	Do.	
(D) *Induced cyclonic circulation*						
1	Lower levels	12-14	West Rajasthan	Do.	Central parts of Rajasthan	

given separately. Floods during the season affected 17 districts in Assam, 4 districts in West Bengal, 24 districts in Bihar, 51 districts in Uttar Pradesh, 6 in Rajasthan and 2 each in Gujarat and Andhra Pradesh.

3. System in Southern Hemisphere (SH) during the Indian summer monsoon period

The clouds associated with the Southern Hemisphere Equatorial Trough (SHET) were observed over the north Indian ocean between latitude 5°S and equator, east of Long. 80°E on most of the days. However, the cloud coverage was rather less during the month of July. One tropical storm developed in southwest Indian Ocean during the month of September (22-25) centred near 7.9°S/68.5°E, and weakened near 10.0°S/57.9°E. On a few occasion the SHET clouds were observed to cross the equator.

The sub-tropical anticyclone over south Indian Ocean was very intense (1032 hPa) during the second half of June. The available observation suggested that the sub-tropical ridge in the Southern hemisphere was mostly 3 to 4 degree south of its normal position (Lat. 25° to 30°S) during the entire monsoon period.

About 10 deep troughs in middle and upper tropospheric westerlies moved between 40°E and 80°E during June to September 1990. These troughs penetrated equatorwards upto Lat. 20°S. It was also observed that the cross equatorial flow from the southern hemisphere to the Arabian Sea enhanced in the wake of these troughs.

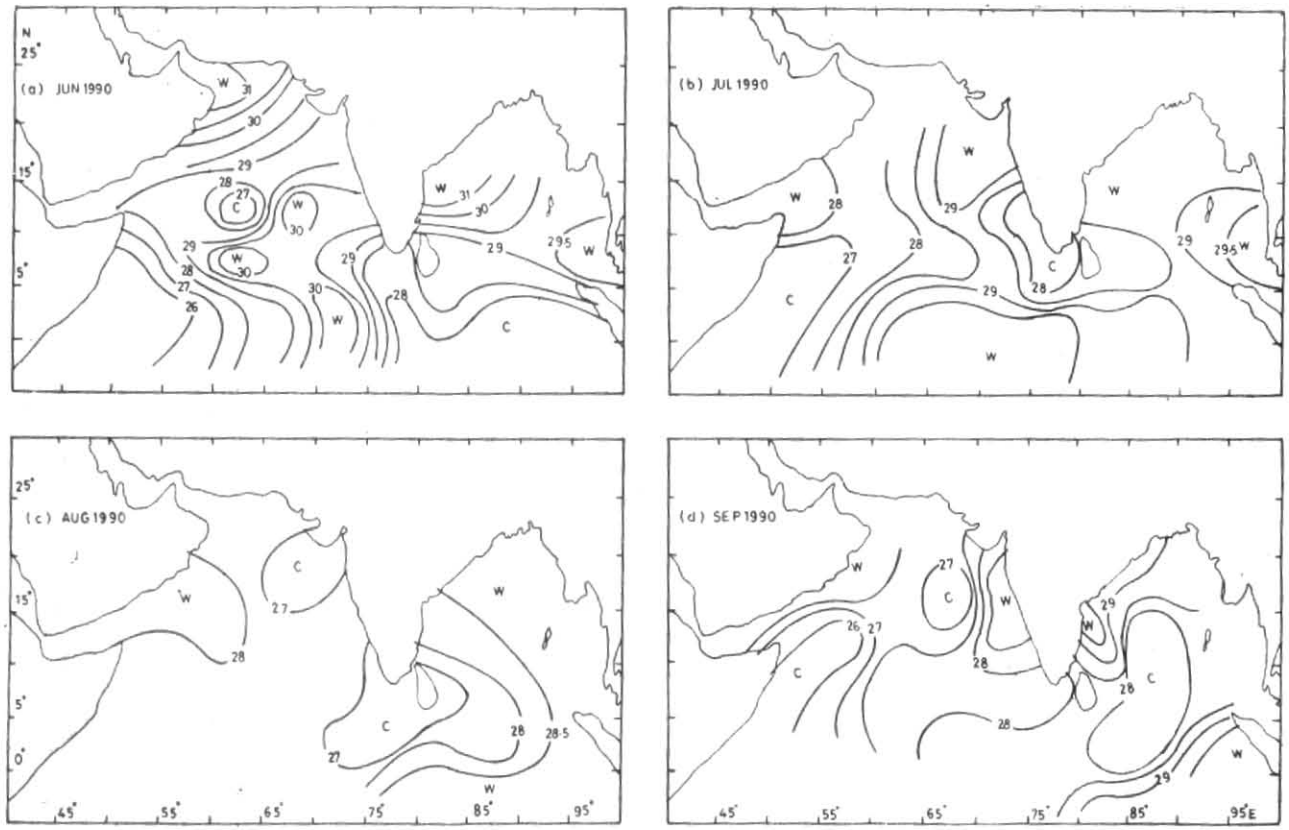

Fig. 7. Mean monthly sea surface temperature (°C) distribution over the Indian seas during monsoon season 1990

4. Significant monthly features

4.1. *June*

The southwest monsoon set in over Kerala on 19 May (about 10 days early) without any onset vortex. By middle of June, monsoon further advanced into Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra, east Madhya Pradesh and northeast India. By the end of June, the monsoon further advanced into west Madhya Pradesh, Uttar Pradesh, east Rajasthan, Himachal Pradesh and Jammu & Kashmir.

4.1.1. *Features heralding the advance of southwest monsoon during June*

One deep depression in the northwest Bay, one well marked low pressure area and two upper air circulations during the month were the chief synoptic features that caused the advance of the southwest monsoon over the country in June. Details of these systems are given in Table 2.

4.1.2. *Synoptic features of the month*

Details of all the synoptic features of the month are given in Table 3.

4.1.3. *Monsoon activity during the month*

Monsoon was active to vigorous on 5 to 9 days in Arunachal Pradesh, Assam and Meghalaya, Orissa, Bihar, Konkan and Goa, Marathwada, Vidarbha, Telangana and coastal Karnataka; on 2 to 4 days in Nagaland, Manipur, Mizoram & Tripura, east Uttar Pradesh, coastal Andhra Pradesh, Rayalaseema, north interior Karnataka and Kerala and one day each in Himachal Pradesh and Gujarat. There was no active monsoon spell of rain in south interior Karnataka, east Madhya Pradesh, east Rajasthan, west Uttar Pradesh and Jammu & Kashmir. However, rainfall occurred at many places in west Madhya Pradesh on 7 days and in east Madhya Pradesh on 16 days. With heavy falls at one or two places on 2 days in west Madhya Pradesh and 4 days in east Madhya Pradesh during the month. Rainfall also occurred at many places on 8 days in hills of west Uttar Pradesh and 3 days in Himachal Pradesh. Rainfall mainly occurred at one or two places in west Uttar Pradesh, Haryana, Punjab & west Rajasthan during the month.

4.1.4. *Month's rainfall*

During the month, rainfall was excess in 9, normal in 16, deficient in 9 and scanty in one meteorological sub-divisions. It was excess in Arunachal Pradesh, Bihar Plateau, east Rajasthan, Madhya Pradesh, Marathwada, Vidarbha, Telangana and north interior Karnataka; normal in Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Orissa, Bihar Plains, east Uttar Pradesh, Himachal Pradesh, West Rajasthan, Saurashtra and Kutch, Konkan and Goa, Madhya Maharashtra, coastal Andhra Pradesh, Rayalaseema and coastal and south interior Karnataka and was deficient over the other meteorological sub-divisions outside Jammu & Kashmir where the rainfall was scanty. Fig. 8 gives the rainfall distribution over India for June.

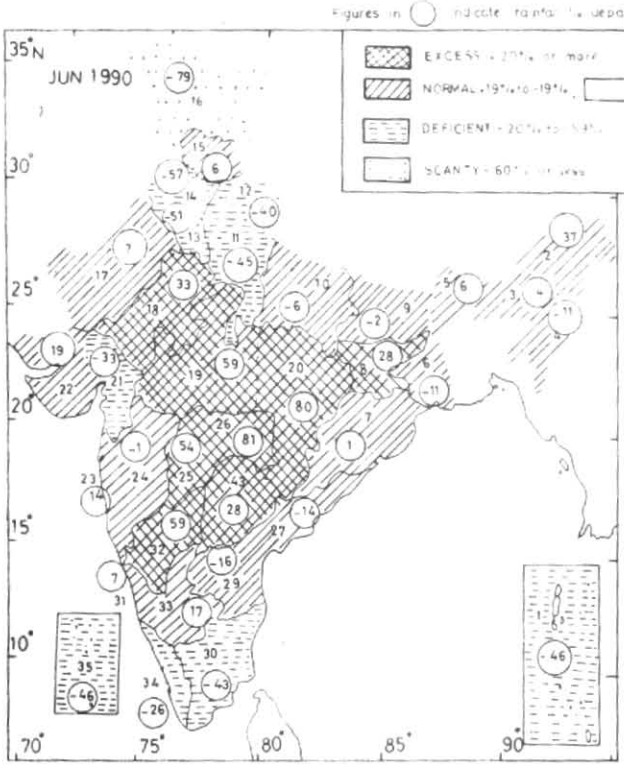

Fig. 8. Percentage departure of rainfall from normal for the month of June 1990

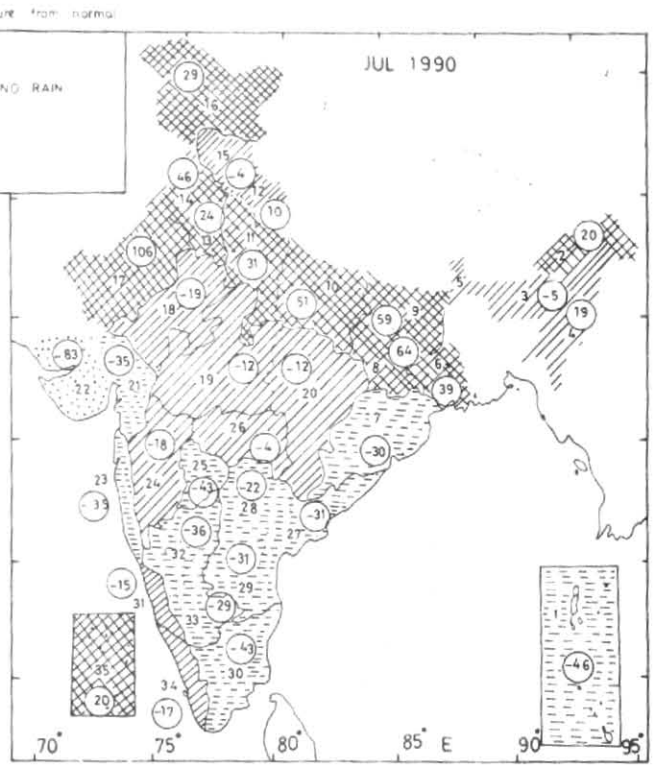

Fig. 9. Percentage departure of rainfall from normal for the month of July 1990

(Figures outside the circles indicate serial number of met. sub-divisions)

The significant amounts (cm) of rainfall during the month of June are given below :

1st : Karimganj 17, Manvi 15, Ponneri 10, V.V. Nagar 9, Amini Divi 9, Chopda 7.

2nd : Kailashahar 9, Subroom 8.

3rd : Cherrapunji 50, Madhabarida & Tezu 9 each, Gopalpur & Jamshedpur 7 each.

4th : Bhatkal 10, Panambur 9, Shirali 8, Mangalore AP 7.

5th : Cherrapunji 21, Akola AP 13, Bobbili 11, Shanigram 10, Mahabubnagar 8, Bombay AP, Gondia & Port Blair 7 each.

6th : Chauldhaghat 12, Nidadavole 9, Sandheads 8, Aijawl & Passighat 7 each.

7th : Cherrapunji 24, Passighat 19, Peermade & Tezu 9 each, Chauldhaghat 7.

8th : Cherrapunji 41, Karimganj 22, Passighat 19, Rupsi 17, Chauldhaghat & Harnai 12 each, Gangtok & Panjim 9 each, Bombay 8, Akola & Cooch Behar 7 each.

9th : Karimganj 38, Ahmednagar & Ambad 13 each, Solapur 11, Temini 10, Kailashahar & Silchar 9 each, Berhampore & Parbhani 8 each, Aurangabad AP & Rajura 7 each.

10th : Gulbarga & Kasargode 11 each, Sirpur 10, Umarkhad 8, Baghdogra AP 7.

11th : Shirali 20, Karwar 16, Devgarh 15, Agumbe 14, Banswada 11, Honavar 10, Pune 7.

12th : Kundapur 19, Honavar & Ratnagiri 13 each, Mangalore AP 11, Malda & Port Blair 10 each, Shirali 9, Kasargode 8, Kakinada & Lonavala 7 each.

13th : Kumta 34, Berhampur 21, Kasargode 16, Hosdurg & Shirali 12 each, Cochi AP 9, Harnai, Parbhani & Solapur 8 each, Mangalore AP & Yeotmal 7 each.

14th : Sandheads 49, Balasore & Shirali 12 each, Kasargode & Sultanpur 11 each, Madikeri 10, Mulki 9, Shimla 7.

15th : Kigga 21, Peermade 18, Igatpuri 17, Agumbe & Keonjhargarh 16 each, Madikeri 11, Car Nicobar 9, Dibrugarh AP & Sangarh 8 each.

16th : Bombay 42, Alibag 20, Perur 14, Devgarh 12, Agumbe 9, Kumta, Kozikode & Manvi 8 each, Gaya AP, Gondia & Ratnagiri 7 each.

17th : Khanapur 23, Lonavala 20, Karwar 19, Devgarh 17, Bombay 15, Panjim 14, Utnoor 12, Ratnagiri & Sevok 11 each, Nagpur AP 10, Wardha 9, Nanded, Nizamabad & Vengurla 7 each.

18th : Utnoor 18, Rajapur 15, Champasarai 14, Asifabad & Chandrapur 13 each, Yeotmal 11, Passighat 10, Koderu 9, Nagpur AP & Sirsi 8 each, Chauldhaghat & Ratnagiri 7 each.

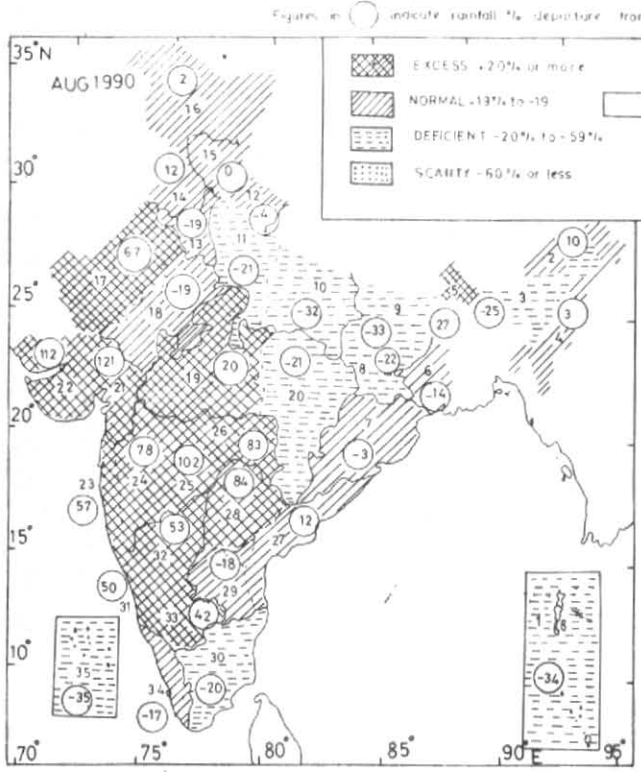

Fig. 10. Percentage departure of rainfall from normal for the month of August 1990

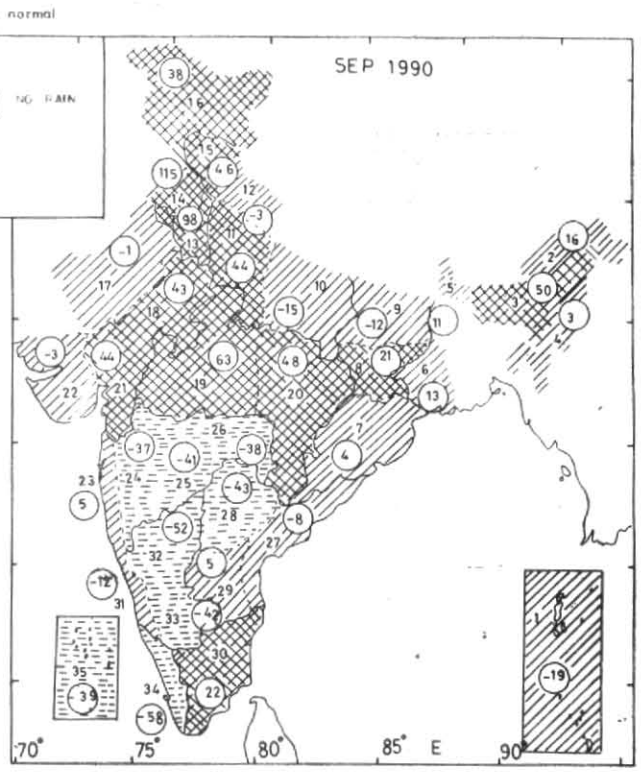

Fig. 11. Percentage departure of rainfall from normal for the month of September 1990

(Figures outside the circles indicate serial number of met. sub-divisions)

19th : Ambone 15, Champasarai 12, Tezu 9, Bareli 8, Ujjain 7.

20th : Peermade 13, Amraghat 11, Ambikapur 9, Narsapur 8, Parli 7.

21st : Sevok 13, Gadchiroli, Kishanganj & Mathanguri 12 each, Patna AP 11, Champasarai & Dhanbad 9 each, Akola, Baghdogra AP, Gangtok & Jabalpur 8 each, Kohima, Kottayam & Utnoor 7 each.

22nd : Chauldhaghat 20, Mathabhanga 16, Basti 15, Dibrugarh AP 14, Cooch Behar & Damoh 11 each, Tezu 10, Bansgaon, Hosdurg & Jashpurnagar 9 each, Dehra Dun, Mangalore AP & Sagar 8 each, Jogindernagar 7.

23rd : Chaparmukh 22, Manarajganj 15, Patna AP 11, Gangtok & Tezu 8 each, Daltonganj & Dibrugarh AP 7 each.

24th : Sandheads 17, Daltonganj 14, Chaparmukh 10, Dhanbad 9, Balasore, Bansgaon, Honavar & Pendra 7 each.

25th : Mohanpur 15, Jogindernagar & Midnapore 13 each, Chowri & Poladpur 11 each, Dalhousie 10, Raipur 8, Jabalpur & Kundapur 7 each.

26th : Bombay 12, Agumbe 10, Bantwal 9, Ratnagiri & Valsad 8 each, Alibag 7.

27th : Bhagamandala 30, Chiplun 17, Bombay AP & Sandheads 12 each, Agumbe, Chaibasa & Munnar 11 each, Alibagh 10, Balasore 9, Diu & Keshod 8 each, Jamshedpur AP 7.

28th : Bhagamandala 12, Bombay AP 11, Hosanagara 10, Jabalpur, Peermade, Harnai, Jagdalpur, Pindwara & Satna 8 each, Dudhi & Hazaribagh 7 each.

29th : Pali 26, Ambone 22 & Sagar 12 each, Haldwani 11, Agra & Bombay 9 each, Jagdalpur & Passighat 8 each, Ajmer, Honavar & Igatpur 7 each.

30th : Harij 40, Agumbe 16, Rajgarh 15, Bhagamandala 13, Dharamsala 11, Dahanu 10, Chittorgarh 9, Gohar, Honavar, Kasargoda & Kota AP 8 each, Ajmer & Guna 7 each.

4.1.5. *Temperature*

Day temperatures were appreciably above normal in Uttar Pradesh between 5 th and 10th where Jhansi, Agra and Allahabad AP recorded maximum temperature of 45°C on many days. However, month's highest day temperature was 47° C, recorded at Ganganagar on 17 June.

4.1.6. *Disastrous weather events and damages during June*

Upper Assam experienced first floods during the first week when *Brahmaputra* and its tributaries crossed danger levels. The floods in the *Brahmaputra* valley continued during the second week of the month. The

TABLE 4

Details of weather systems during July 1990

S. No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Depression/Low pressure area*						
1	Low pressure area	3-7	Southwest Uttar Pradesh & adjoining northwest Madhya Pradesh	WNW'ly	Northwest Rajasthan & neighbourhood	Associated cyclonic circulation of the low pressure area extended into lower tropospheric levels
2	Low pressure area	14-17 eve	Gangetic West Bengal & adjoining northwest Bay	WNW'ly	Northwest Madhya Pradesh & neighbourhood	Initially observed as a cyclonic circulation in the lower & middle tropospheric levels over northwest Bay adjoining Gangetic West Bengal & Bangladesh on 10th
3	Low pressure area	23-25	Northwest & adjoining west central Bay off Orissa, north Andhra coast	WNW'ly	Central parts of Madhya Pradesh	Initially observed as a cyclonic circulation in the middle tropospheric levels over north Bay & neighbourhood on 22nd
(B) *Cyclonic circulation*						
1	Lower & middle tropospheric levels	1-5	Gangetic West Bengal & neighbourhood	Quasi stationary	Gangetic West Bengal & adjoining Bihar plateau	
2	Lower tropospheric levels	6-10	Bangladesh	NE'ly	Assam & Meghalaya	
3	Middle tropospheric levels	6-7	Orissa & adjoining Gangetic West Bengal & northwest Bay	Stationary	*In situ*	
4	Middle tropospheric levels	16-23	West central Bay off north Andhra coast	NW'ly	Central Bihar & adjoining east Uttar Pradesh	
5	Lower & middle tropospheric levels	18-20	Gujarat	Stationary	*In situ*	
6	Lower & middle tropospheric levels	25-26	West Madhya Pradesh & adjoining east Rajasthan	Do.	*In situ*	
7	Lower tropospheric levels	27-30	North Pakistan & neighbourhood	Do.	*In situ*	
(C) *Western disturbance*						
1	Upper air system	10-12	North Pakistan & neighbourhood	Easterly	Moved away across Jammu & Kashmir and neighbourhood	
(D) *Induced cyclonic circulation*						
1	Lower levels	10-12 eve	West Rajasthan	NE'ly	Northwest Rajasthan & neighbourhood	

second wave of floods in the river *Brahmaputra* and its tributaries were experienced in the state during the fourth week of June. Also *Gandak* and *Kamala Balan* rivers in Bihar were in spate during this week. Landslides and heavy rain during the first week, cut off Barak valley of Assam from the rest of the country. Floods in Assam rivers inundated vast areas of human habitation and submerged paddy fields. It affected 800 villages in the state of which at least 17 villages were under water.

Bombay (Colaba) recorded 421.2 mm of rainfall on 16 June. This was the highest ever recorded rainfall in 24 hours during the month of June in the last 104 years. The last highest 24-hour rainfall was 408.9 mm recorded on 18 June 1886. The torrential rains disrupted air, rain and road transport and power supply in Bombay. There was heavy flooding in several localities and water loggings in the low lying areas. The flood water was as much as 3 ft. deep in King's Circle. As per reports nearly 45 lakh commuters travelling by the central and western railways were stranded due to complete breakdown on both these lines. The torrential heavy rain claimed 22 lives in Bombay and 7 in Thane district. Telephone services were disrupted in the city for a day or two. The June depression also caused floods in Balasore district of Orissa and cut off atleast 29 villages for sometime in the district.

4.2. *July*

4.2.1. *Synoptic features of the month*

No monsoon depression formed in the Bay of Bengal during this month. However 3 low pressure areas and 7 upper air cyclonic circulation developed in the monsoon trough. Details of the synoptic features are given in Table 4.

4.2.2. *Monsoon activity during the month*

Monsoon rainfall occurred in Gangetic West Bengal, Bihar and east Uttar Pradesh, where monsoon was active to vigorous on 13 to 19 days during the month. It was also active to vigorous on 5 to 9 days in Arunachal Pradesh, Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Orissa, Haryana, Punjab, Himachal Pradesh, Madhya Pradesh, Konkan and Goa, Madhya Maharashtra, Vidarbha, coastal Andhra Pradesh, Telangana and Kerala and on 2 to 4 days in Nagaland, Manipur, Mizoram & Tripura, west Uttar Pradesh, Rajasthan, Gujarat region, Marathwada and Rayalaseema. Monsoon rainfall was weak over Jammu & Kashmir, Saurashtra and Kutch and Karnataka, during the month. Rainfall occurred almost at all the places or at many places throughout the month in coastal Karnataka on 12 to 15 days in Andaman and Nicobar Islands and Lakshadweep and on 2 to 4 days in Jammu and Kashmir and interior Karnataka. Rainfall occurred at one or two places only on 13 days in Saurashtra and Kutch resulting in very large deficiency of rainfall in the sub-division during the month.

4.2.3. *Month's rainfall*

The rainfall during the month was excess in 11, normal in 12, deficient in 11 and scanty in one met. sub-divisions.

It was excess in Arunachal Pradesh, Gangetic West Bengal, Bihar, plains of Uttar Pradesh, Haryana, Punjab, Jammu & Kashmir, west Rajasthan and Lakshadweep; normal in Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, Hills of west Uttar Pradesh, Himachal Pradesh, east Rajasthan, Madhya Pradesh, Madhya Maharashtra, Vidarbha, coastal Karnataka and Kerala; and was deficient in the remaining meteorological subdivisions except Saurashtra & Kutch where it was scanty. Fig. 9 gives the rainfall distribution over India for July.

The significant amounts (cm) of rainfall during the month of July are given below :

1st : Ambala AP 17, Amritsar AP 15, Ambone, Harinkhola, Lansdowne & Yellapur 13 each, Hosangara & Panna 12 each, Agartala AP & Sirsi 11 each, Hasimara & Lonavala 9 each, Calcutta AP & Ujjain 8 each, New Delhi & Pratapgarh 7 each.

2nd : Bhatinda 41, Bhagamandala 21, Sirsa 18, Uluberia 15, Panna & Sringeri 14 each, Pendra & Sadulpura 11 each, Farilka 9, Baijnath, Bharatpur, Sagar & Tadong 8 each, Amraghat, Calcutta AP & Yellapur 7 each.

3rd : Sakri 30, Sagar 26, Ambone 18, Jodhpur 17, Khanapur 15, Guna 14, Cochi AP 13, Agumbe & Lonavala 12 each, Shivpuri 11, Dhanbad & Punalur 10 each, Belgaum, Jhalwar & Yellapur 9 each, Kottayam & Purulia 8 each, Ajmer, Krishnagar & Ranchi AP 7 each.

4th : Ambone 28, Jodhpur 16, Deesa & Sirohi 13 each, Gazipur 12, Bhagamandala & Lonavala 10 each, Harnai, Jaipur AP & Nahan 8 each, Ranaghat 7.

5th : Mount Abu 52, Jallore 27, Jodhpur AP 22, Gazipur 21, Barmer 19, Agumbe & Morena 14 each, Kishanganj & Panagarh 12 each, Jalpaiguri, Buxar & Udupi 10 each, Gangtok 9, Bahraich, Katwa & Rajkot AP 8 each, Cochi AP, Durgapur & Mathanguri 7 each.

6th : Mount Abu 40, Jallore 16, Jodhpur AP 14, Kishanganj & Peermade 11 each, Calcutta & Dharamsala 10 each, Lansdowne 9, Chauldhaghat & Honavar 8 each, Agatti, Banswara, Minicoy & Passighat 7 each.

7th : Sagar Island 17, Contai & Rajghat 15 each, Bahraich & Baijnath 13 each, Amini Divi 12, Dharamsala, Kishanganj & Sevoke 8 each, Jodhpur AP & Uluberia 7 each.

8th : Baijnath 18, Sevoke 16, Bhagamandala & Dehra Dun 13 each, Honavar & Kasargode 12 each, Ambala & Jogindernagar 10 each, Ambikapur, Bhatkal & Guwahati AP 9 each, Agumbe 8, Mangalore AP & Shimla 7 each.

9th : Hardwar 23, Tibri 20, Kishanganj 18, Bahraich & Mandi 14 each, Pantnagar 12, Jogindernagar 11, Karimganj 10, Bhira & Varanasi AP 8 each, Dehra Dun, Dibrugarh AP & Panjim 7 each.

10th : Narsiangarh 22, Muradabad 18, Mandi 17, Malda 15, Jogindernagar 13, Supaul 11, Dehra Dun, Guwahati AP, Lonavala & Mukteswar 9 each, Shimla 8, Cochi AP, Krishnagar, Sagar Islands & Una 7 each.

11th : Padrauna 35, Bhatkal 17, Shirali 14, Ludhiana & Passighat 10 each, Bhagamandala, north Lakhimpur & Rampurhat 9 each, Nahan 7.

12th : Kishanganj 15, Calcutta, Honavar & Sevoke 12 each, Agumbe & Shirgaon 10 each, Karwar & Shirali 9 each, Bhubaneswar AP & Lonavala 8 each, Kohima & Muzaffarpur 7 each.

13th : Ambone 20, Bagodar & Sirgaon 15 each, Chauldhaghat 14, Haldwani & Tezu 12 each, Igatpuri 10, Ambikapur, Bolangir & north Lakhimpur 9 each, Burdwan, Kumta & Ranchi AP 7 each.

14th : Telkoi 16, Kankavli 15, Champua 12, Goalpara 9, Jamshedpur & Lonavala 8 each, Muzzaffarpur & Sambalpur 7 each.

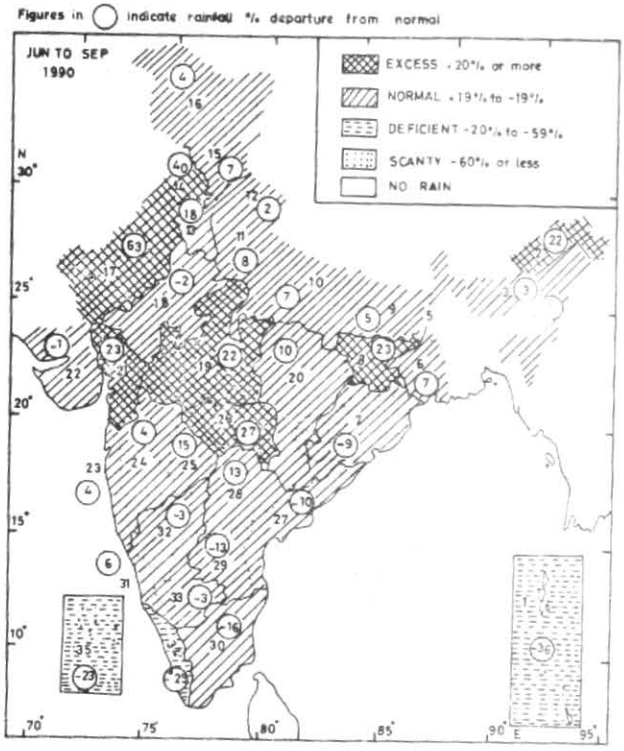

Fig. 12. Percentage departure of rainfall from normal for June to September 1990 (Figures outside the circles indicate serial number of met. sub-divisions)

15th : Jogindernagar 20, Poladpur 14, Sundernagar 13, Palkot 12, Baijnath & Kundapur 11 each, Damoh, Ratnagiri & Umrer 10 each, Jamshedpur AP 9, Mangalore AP & Sriniketan 8 each, Jashpurnagar 7.

16th : Seoni 16, Kankavli 14, Balaghat 13, Ratnagiri 10, Agumbe & Perur 9 each, Naharkatia 8, Passighat, Tezu & Yellapur 7 each.

17th : Bhira 29, Sirgaon 25, Lonavala 17, Bhopal 14, Aliporadur 11, Passighat & Sehore 10 each, Jogindernagar 9, Bombay, Car Nicobar & Tezu 8 each, Raisen & Yellapur 7 each.

18th : Bhira 22, Haldibari 21, Agumbe 20, Taibpur 16, Karkala 14, Sevoke 12, Sirsi 11, Passighat 9, Kangra 8, Jalpaiguri, Parbhani & Sringeri 7 each.

19th : Champasarai 25, Agumbe 22, Sevoke 21, Karkala 18, Baghdogra 12, Fazilka & Raibareilly 10 each, Lucknow AP & Majbat 7 each.

20th : Talguppa 34, Bhira 18, Paint 13, Calcutta 12, Ranchi AP 11, Agumbe, Gwalior & Hazaribagh 9 each, Gondia 8, Dalhousie, Hathua & Walia 7 each.

21st : Dungarwadi 46, Bhira 43, Lonavala 21, Ramanujganj 14, Calcutta & Gaya AP 12 each, Honavar & Mandla 11 each, Daltonganj 10, Kasauli & Wardha 9 each, Diamond Harbour 8, Dholpur 7.

22nd : Bhira 23, Passighat 15, Shirali 14, Gadchiroli 10, Behri & Kundapur 9 each, Kasargode, North Lakhimpur & Patan 8 each, Kalka & Sidhi 7 each.

23rd : Gadchiroli 19, Bhira 17, Agumbe 16, Yeotmal 11, Talcher 9, Quilandy & Sringeri 8 each, Jabalpur 7.

24th : Ambone 30, Bhira & Chandrapur 21 each, Lonavala 17, Khargaon & Yeotmal 14 each, Akola & Mathanguri 10 each, Agumbe & Karkala 9 each, Dibrugarh AP, Thakurmunda & Ujjain 8 each, Latur & Madikeri 7 each.

25th : Ambone 19, Lonavala 18, Bhira 17, Kangra & Wardha 15 each, Khargaon 13, Akola 11, Agumbe 10, Bantwal & Ratlam 9 each, Idar & Nadiad 7 each.

26th : Sagwara 22, Sagar 13, Ahmedabad & Dibrugarh AP 12 each, Passighat 10, Majbat 9, Chittorgarh 8, Sevoke 7.

27th : Sevoke 20, Jagadhari 16, Karimganj 13, Kangra & Varanasi AP 11 each, Hazaribagh & Kanpur 9 each, Dehra Dun & Silchar 8 each, Dhanbad 7.

28th : Baruipur 22, Ambala & Kangra 17 each, Jagadhari 16, Buxar & Kasauli 15 each, Patna AP 13, North Lakhimpur 11, Calcutta, Dibrugarh AP, Malda & Ropar 10 each, Una 8, Agra, Chandigarh AP & Patiala 7 each.

29th : Raibareilly 18, Lucknow AP 13, Patna AP 11, Aliporeduar, Jagadhari, Kohima & Mathanguri 9 each, Kasauli, Ropar & Sultanpur 8 each.

30th : Dhanbad 13, Asansol, Chapra, Dehra Dun, & Sabour 8 each, Chattarpur, Huzurabad & Raya 7 each.

31st : Allahabad AP 11, Dhanbad, Kalka, Panagarh, Sriniketan & Varanasi 7 each.

4.2.4. *Disastrous weather events and damages during July*

During this month several states in north India experienced floods.

As per the Central Water Commission (CWC) reports and press reports Assam and north Bihar were under the grip of floods throughout the month due to spate in the river *Brahmaputra* and its tributaries and in rivers *Punpun, Kamala Balan and Koshi*. Uttar Pradesh experienced the first wave of flood of this season in the second week of July when rivers *Ganga, Gandak* and *Ghaghra* were in spate. River *Ghagra* continued to be in spate throughout this month. During the first week of July heavy rain cut off Itanagar, the capital city of Arunachal Pradesh from the rest of the country. During this week heavy rains in Rajasthan caused severe floods in the state affecting Jodhpur, Jaipur, Barmer, Jallore, Sirohi and Churu districts and in the river *Banas* in Gujarat, which caused havoc in Banas Kantha districts of the

TABLE 5

Details of weather systems during August 1990

S. No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Low pressure area/Depression*						
1	Low pressure area	5-10	South Rajasthan	Westerly	Merged with the seasonal low over south Pakistan	Initially appeared as a cyclonic circulation between 1.5 & 4.5 km a.s.l. over Gangetic West Bengal and neighbourhood on 30th July
2	Low pressure area	7-10	West central Bay off south Orissa, north Andhra coast	Quasi-stationary	Off north Andhra coast. However, associated cyclonic circulation up to mid tropospheric levels became unimportant over Marathwada & neighbourhood on 12th	Initially observed as a cyclonic circulation in the lower & middle tropospheric levels over central Bay on 4th Aug
3	Depression	15-17	Northwest and adjoining west central Bay off south Orissa north Andhra Pradesh	WNW'ly	West Madhya Pradesh. The remnant dissipated over south Rajasthan & adjoining north Gujarat on 19th	First appeared as a cyclonic circulation extending up to mid tropospheric levels over west central & adjoining northwest Bay on 12th Aug
4	Depression	20-25	Northwest Bay	WNW/W'ly	South Pakistan. The remnant merged with the seasonal low on 26th Aug	Initially observed as a cyclonic circulation upto mid tropospheric levels over north Bay on 18th Aug
5	Low pressure area	27 Aug-1 Sep	Northwest Bay & neighbourhood	WNW'ly	Northwest Madhya Pradesh & neighbourhood. Associated cyclonic circulation extending up to 5.8 km a.s.l. became less marked over northwest Madhya Pradesh & neighbourhood on 2nd Sep	Associated cyclonic circulation extended up to mid tropospheric levels
(B) *Cyclonic circulation*						
1	Lower tropospheric levels	9-11	Northwest Madhya Pradesh and neighbourhood	NW'ly	Northwest Rajasthan and neighbourhood	
2	Lower levels	15-19 eve	Punjab and adjoining Haryana	Stationary	*In situ*	
3	Lower & middle tropospheric levels	21-22	South Gujarat & adjoining north Maharashtra	Do.	Do.	
4	Lower levels	22-23	Northwest Rajasthan & adjoining Haryana & Punjab	Do.	Do.	
5	Lower tropospheric levels	27 Aug-1 Sep	Central Pakistan	NE'ly	Jammu & Kashmir	Seen as a trough over Pakistan on 29th

state. In Rajasthan 66 villages were inundated and in Gujarat 54 low lying villages were seriously affected. It disrupted rail and road lines in Rajasthan. 20 Irrigation dams anicuts in Rajasthan were breached at various places. Incessant rain during the first fortnight caused floods in *Kelaghat, Kapaleswari, Chandia* and *Rupnarayan* rivers in Midnapore districts of West Bengal, which submerged about 1000 villages and affected about 3 lakh population. The floods during this month claimed 215 lives in Uttar Pradesh, 137 in Rajasthan and 18 each in Assam and West Bengal. In Rajasthan about 1,16,368 cattle heads were also perished in the floods.

4.3. *August*

4.3.1. *Synoptic features of the month*

Two depressions and three low pressure areas formed during this month. Besides these systems five upper air cyclonic circulations developed in the monsoon trough. Details of the synoptic features are given in Table 5.

4.3.2. *Monsoon activity during the month*

Monsoon was active to vigorous on 15 to 19 days in Konkan & Goa, and Madhya Maharashtra and on

10 to 14 days in Orissa, west Madhya Pradesh, Marathwada, Vidarbha and Telangana. It was also active to vigorous on 4 to 7 days in Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, east Uttar Pradesh, Punjab, Himachal Pradesh, east Rajasthan, east Madhya Pradesh, Gujarat region, coastal Andhra Pradesh, Rayalaseema and Kerala, on 2 to 3 days in Bihar, west Uttar Pradesh, west Rajasthan ,Saurashtra & Kutch and interior Karnataka and on one day each in Gangetic West Bengal and Haryana. There was no active monsoon day in Jammu & Kashmir during the month. Rainfall occurred almost at all the places or at many places on 12 to 18 days in Andaman & Nicobar Islands, Gangetic West Bengal, Bihar Plateau, hills of west Uttar Pradesh, east Madhya Pradesh, Konkan & Goa, coastal Karnataka and Kerala, on 5 to 11 days in Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal & Sikkim, Himachal Pradesh, west Madhya Pradesh, Gujarat region and Kerala and so on 1 to 4 days over the rest of the country.

4.3.3. *Month's rainfall*

During this month rainfall was excess over 13, normal over 13 and deficient over 9 meteorological sub-divisions. It was excess in Sub-Himalayan West Bengal & Sikkim, west Rajasthan, west Madhya Pradesh, Gujarat, Maharashtra, Telangana and Karnataka; normal in Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura, Gangetic West Bengal, Orissa, hills of west Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu & Kashimr, east Rajasthan, coastal Andhra Pradesh, Rayalaseema and Kerala and was deficient over the rest of the country. Fig. 10 gives the rainfall distribution over India for August.

The significant amounts (cm) of rainfall during the month of August are given below :

1st : Satna 11, Agumbe 10, Rangiya & Rewa 8 each, Dehra Dun, Idikki & Uluberia 7 each.

2nd : Sandheads 24, Barhi 21, Jamsolaghat 20, Sunam 17, Bankura & Kasargode 16 each, Nahan 15, Sidhi 10, Agumbe & Jammu 9 each, Jamshedpur AP & Una 8 each, Bhira, Belthangady, Guna, Ranchi AP & Sambalpur 7 each.

3rd : Bhira 16, Baijnath, Belthangady, Digha & Karwar 9 each, Dumka 8, Shirgaon & Udupi 7 each.

4th : Roorkee 17, Jaora 13, Khandala 12, Varanasi 10, Pondicherry 9, Nagpur, Nahan & Sagar 8 each, Car Nicobar, Ganganagar, Guna & Lansdowne 7 each.

5th : Dungarpur 23, Chittorgarh 22, Bhira 14, Nurpur 12, Rupsi 10, Ganganbavda, Kota AP & Rawat Bhata 8 each, Lonavala & Ratnagiri 7 each.

6th : Jallore 22, Barmer & Mount Abu 18 each, Kasargode & Sundernagar 12 each, Amraghat 10, Hosadurg & Karwar 8 each, Aurangabad AP, Cooch Behar, Dehra Dun & Jammu 7 each.

7th : Barmer 25, Angul 20, Khanapur 16, Allahabad AP 13, Paddapalli & Prathipadu 11 each, Latur & Panna 10 each, Jammu, Murtizapur, Pondicherry & Silchar 8 each, Jagdalpur & Taibpur 7 each.

8th : Amraghat 24, Paratwada 17, Nahan 15, Amravati 12, Varanasi AP 11, Dhar 10, Kundapur & Prathipadu 9 each, Aijawl 8, Akola & Kundaghat 7 each.

9th : Orchha 17, Kangra 15, Debgarh 14, Bhira, Ratlam & Udupi 12 each, Baghdogra AP & Harnai 10 each, Elwah 9, Champasarai 8, Honavar, Jogindernagar & Ratnagiri 7 each.

10th : Matizuri 22, Rampur 17, Beed 16, Harnai 13, Devgrah 10, Jalpaiguri 9, Dalhousie 8, Aijwal, Aurangabad AP, Kasargode, Machilipatnam & Silchar 7 each.

11th : Padrauna 35, Sevak 21, Munnar 19, Mathanguri 18, Taibpur 16, Agumbe 15, Cooch Behar 12, Shirali 11, Solapur 10, Bombay AP 9, Honavar & Kasargode 7 each.

12th : Khandala 24, Poladpur 21, Agumbe 16, Batala & Dharamsala 13 each, Champasarai 12, Dhanbad, Harnai & Purulia 11 each, Shivpuri 10, Okhimath 9 ,Jagdalpur, Karwar & Port Blair 8 each, Goalpara, Mangalore AP & Ratnagiri 7 each.

13th : Bhira 31, Lonavala 21, Yellareddy 20, Solan 18, Harnai & Sevak 16 each, Hardwar & Malerkotla 15 each, Kanpur 14, Bombay 13, Haldwani & Jogindernagar 12 each, Satna 11, Karwar & Tekkali 10 each, Dalhousie, Igatpuri, Mahabubabad 8 each, Mangalore AP, Nizamabad, Ranchi AP & Visakhapatnam AP 7 each.

14th : Khandala 24, Agumbe 21, Munnar & Raya 16 each, Kasauli 15, Devgarh 14, Bhatkal 12, Amritsar AP, Honavar, Kangra & Shivpuri 9 each, Dahanu & Mangalore AP 8 each, Bombay AP & Madikeri 7 each.

15th : Khandala 31, Agumbe 28, Bombay 26, Munnar 17, Latur & Sringeri 14 each, Madikeri 11, Perur & Polavaram 10 each, Tezu & Dibrugarh AP 7 each.

16th : Bhira 37, Lonavala 30, Bhadravati 23, Perur 18, Munnar 15, Agumbe 14, Harnai & Wardha 13 each, Udgir 10, Bombay, Jorhat & Nagpur 9 each, Osmanabad & Sagbara 7 each.

17th : Koyna 42, Mosali 38, Gaganbavda 32, Bhagamandala 30, Ratnagiri 28, Agumbe 25, Valsad 24, Buldhana 22, Nediad 20, Harnai 19, Sringeri 15, Baroda 14, Satna 11, Rajkot 8, Bombay, Nahan & Tezpur 7 each.

18th : Veraval 30, Bhavnagar AP 20, Lonavala 16, Gandhinagar, Shajapur & Surat 13 each, Agumbe 10, Sringeri 8, Sukma 7.

19th : Bhira 19, Lonavala 17, Shajapur 13, Igatpuri 12, Veraval 11, Mansa 9, Pathankot 7.

20th : Igatpuri 33, Aheri 16, Jogindernagar 13, Peddapalli 11, Sironcha 10, Ratlam 9, Agumbe 8, Kaithal & Neemuch 7 each.

21st : Puri 17, Mansa 12, Billoli & Nizamabad 11 each, Aheri & Agumbe 10 each, Bhavnagar AP 9, Sringeri 8, Nanded & Phulbani 7 each.

22nd : Bhira & Bramhapuri 19 each, Lonavala 17, Jogindernagar 13, Durg 11, Bolangir & Dalhousie 10 each, Jagdalpur 9, Agumbe 7.

23rd : Khandwa 25, Chandrapur 21, Wardha 19, Dhar 17, Agumbe 16, Bhira 15, Bhopal 11, Sringeri 10, Mansa 7.

24th : Gandhinagar 33, Idar 27, Dohad 23, Bhira & Dhar 19 each, Passighat 13, Khargaon 11, Agumbe, Dibrugarh AP & Indore 10 each, Igatpuri 9, Paint 7.

25th : Mansa 19, Mathabhanga 18, Mehsana 17, Passighat 16, Bhuj AP 15, Kalaikunda 12, Ahmedabad & Cooch Behar 10 each, Igatpuri 9, Haldibari 7.

26th : Cooch Behar 29, Baghdogra AP 24, Rajapur 10, Baroda & Taibpur 7 each.

27th : Sanbarsa 15, Hamirpur 11, Rajapur 9, Nandigram 8, Nagapattinam 7.

28th : Angul & Nangal 10 each, Kangra, Salem, Sevak & Visakhapatnam AP 7 each.

29th : Chandrapur 15, Khanapur 14, Kaleswaram 12, Bhira & New Delhi 10 each, Nurpur & Nawashahar 8 each.

30th : Billoli & Navipet 20 each, Nizamabad & Seoni 18 each, Gangchiroli 17, Nanded 15, Agumbe & Parbhani 10 each, Phulbani 9, Nagpur AP & Sehore 7 each.

31st : Khanapur 25, Chikhaldara 12, Banswara 11, Idar 10, Shajapur & Wardha 8 each, Rajgad 7.

4.3.4. *Disastrous weather events and damages during August*

During August floods occurred in almost all the states of India.

The fourth wave of floods in the State commenced from 11 August due to spate in the rivers *Brahmaputra, Barak* and its tributaries, which continued up to the end of this month. North Bihar and Uttar Pradesh also experienced floods throughout the month. In north Bihar rivers *Ganga, Punpun, Kosi, Sona, Burhi Gandak, Mahananda* and *Ghaghra* were in spate while in Uttar Pradesh rivers *Ghaghra, Gandak* and *Ganga* were in spate. In west Bengal river *Ganga* was in spate at Farakka for sometime.

Heavy rains in the third week of the month caused floods in Buldhana, Jalgaon and Dhule districts in Maharashtra. As per press reports Amravati town was cut off as the connecting bridge on the river *Wardha* was submerged. Also Jalgaon, Aurangabad road traffic was suspended as the bridge on the river *Waghur* submerged.

In Andhra Pradesh river *Godavari* was in spate in the second half of the month. Floods in the state claimed 36 human lives and affected over 9.3 lakh people. Heavy rains and floods on 13th and 21st claimed 13 lives in north interior Karnataka. Rivers in Bidar, Raichur, Gulbarga and Belgaum districts were in spate. As per press reports torrential rain between 24th and 26th claimed 114 lives in Gujarat. River *Mahi* was in spate. The flood water washed away about 2 km reach of the National Highway. Damage to roads, private & public properties were around Rs. 2,000 millions in the state. Also heavy rain during the first week of the month took a toll of 23 lives in Rajasthan.

4.4. *September*

4.4.1. *Synoptic features of the month*

Besides, 6 upper air cyclonic circulations. 1 depression and 3 low pressure areas formed over Bay and Gangetic West Bengal during this month. Details of these systems are given in Table 6.

4.4.2. *Withdrawal of southwest monsoon*

The withdrawal phase of the southwest monsoon commenced towards the end of September. It withdrew from northwest India by 28 September except from Rajasthan. It withdrew from the country, except Kerala and Lakshadweep on 17th October.

4.4.3. *Monsoon activity during the month*

Spatial and temporal distribution of monsoon rain fall was good over northeast India, Himachal Pradesh, Madhya Pradesh and Konkan & Goa. Monsoon was active to vigorous on 9 to 13 days in Arunachal Pradesh, Assam & Meghalaya, Himachal Pradesh and west Madhya Pradesh, on 4 to 7 days in Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Orissa, Bihar, Plains of Uttar Pradesh, Haryana, Punjab, east Madhya Pradesh, Konkan & Goa, Madhya Maharashtra, Marathwada, Rayalaseema, and coastal

TABLE 6

Details of weather systems during September 1990

S. No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Low pressure area/Depression*						
1	Depression	3-5 Sep	Gangetic West Bengal and neighbourhood	Westerly	East Madhya Pradesh. The remnant, however, became less marked over northwest Rajasthan & adjoining Punjab & Pakistan on 10th evening	Remnant of Typhoon 'BECKY' emerged as a low pressure area across central Burma into northeast Bay on 1st
2	Well marked low pressure area	11-20 eve	Central & adjoining north Bay	WNW'ly	Plains of west Uttar Pradesh & adjoining north Madhya Pradesh. However, the associated cyclonic circulation became less marked there on 21st	Developed under the influence of an upper air cyclonic circulation which was over northwest Thailand and neighbourhood on 10th, emerged into central Bay on 11th
3	Low pressure area	18-22 eve	North Bay	Westerly	Northwest Bay & adjoining coastal Orissa & Gangetic West Bengal	
4	Low pressure area	30	West central & adjoining northwest Bay of south Orissa, north Andhra coasts	—	Persisted there on 30th evening	Cyclonic circulation in the lower & middle tropospheric levels which developed over Bay off north Tamil Nadu-south Andhra coasts on 27th, moved northwards. The low pressure area developed under the influence of this cyclonic circulation
(B) *Cyclonic circulation*						
1	Lower levels	9-11 eve	Central parts of Bihar and adjoining West Bengal	Quasi-stationary	Bihar plains and neighbourhood	
2	Lower tropospheric levels	13-16	North Pakistan and neighbourhood	Stationary	*In situ*	
3	Lower and middle tropospheric levels	14-17 eve	Northeast Arabian Sea off Gujarat coast	Quasi-stationary	Northeast Arabian Sea and adjoining Saurashtra & Kutch	
4	Lower tropospheric levels	21-27	Central Madhya Pradesh	Do.	North Maharashtra and adjoining Madhya Pradesh	
5	Lower and middle tropospheric levels	21-23	East central Arabian Sea off Gujarat coast	Stationary	*In situ*	
6	Lower and middle tropospheric levels	23	West central & adjoining northwest Bay off south Orissa-north Andhra coast	Do.	Do.	

Karnataka, on 3 days in Gujarat region, coastal Andhra Pradesh and Telangana and on one day each in east Rajasthan, Vidarbha and interior Karnataka. There was no active monsoon spell in east Uttar Pradesh, hills of west Uttar Pradesh, Jammu & Kashmir, west Rajasthan, Saurashtra & Kutch and in Kerala during the month. Rain or thundershowers occurred almost at all the places or at many places on 12 to 17 days in Andaman & Nicobar Islands, east Madhya Pradesh and Konkan & Goa, on 5 to 9 days in Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Bihar Plateau, hills of west Uttar Pradesh, west Madhya Pradesh, Gujarat region, coastal Karnataka, Kerala and Lakshadweep and on 1 to 2 days in east Uttar Pradesh, west Rajasthan and Saurashtra & Kutch. Rainfall occurred mainly at one or two places or at a few places almost throughout the month in east Rajasthan, Saurashtra & Kutch and interior Karnataka.

4.4.4. *Month's rainfall*

Rainfall during the month was excess over 12, normal over 15 and deficient over 8 meteorological sub-divisions.

It was excess in Assam & Meghalaya, Bihar Plateau, plains of west Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir east Rajasthan, Madhya Pradesh, Gujarat region and Tamil Nadu; normal in Andaman & Nicobar Islands, Arunachal Pradesh, Nagaland, Manipur, Mizoram and Tripura, West Bengal & Sikkim, Orissa, Bihar Plains, east Uttar Pradesh, hills of west Uttar Pradesh, west Rajasthan, Saurashtra & Kutch, Konkan & Goa, coastal Andhra Pradesh, Rayalaseema and coastal Karnataka and was deficient over the rest of the meteorological sub-divisions. Fig 11 gives the rainfall distribution over India for September.

The significant amounts (cm) of rainfall during the month of September are given below :

1st : Agumbe, Idar, Rajapur 10 each, Banswara 9, Mansa 7.

2nd : Kohima 13, Calcutta AP & Manas 10 each, Idar & Rajapur 8 each, Dhamtari & Kondul 7 each.

3rd : Rajghat & Sagar Islands 21 each, Jamshedpur 13, Bhograi 12, Dharamsala & Digha 11 each, Dhanbad, Pendra & Purulia 9 each, Bangana, & Ghatsila 8 each, Calcutta & Rajapur 7 each.

4th : Devgarh & Kangra 22 each, Hamirpur 16, Baripada 15, Kasauli & Panposh 11 each, Agumbe & Khowang 10 each, Mohanpur 9, Shirali 8, Honavar 7.

5th : Hamirpur 17, Rajapur 13, Faridabad 12, Bhira 11, Devgarh 9, Harnai & Lonavala 8 each, Joginder nagar & New Delhi 7 each.

6th : Rajapur 17, Ankola 13, Gangapur 11, Agumbe & Honavar 10 each, Datia & Ratnagiri 9 each, Jabalpur 8, Mangalore AP & Tallital 7 each.

7th : Samrala 21, Kasauli 19, Bayana & Shirali 11 each, Agumbe 10, Pusad & V. V. Nagar 9 each, Valsad 8, Banswara, Bhilwara & Bhandara 7 each.

8th : Halwara & Karwar 27 each, Rohtak 19, Amloh 16 & Hissar 14 each, Patiala 11, Cuddapah 10, Chittoor & Rajapur 9 each, Meerut & New Delhi AP 8 each, Bhatkal & Chauldhaghat 7 each.

9th : Panipat 28, Mathabhanga & Palayankottai 20 each, Nawashahar 15, Kokrajhar & Kolar Gold Field 13 each, Cooch Behar 12, Kangra 11, Chandigarh AP 10, Dhankanikottai 9, Halwara & Kasauli 8 each.

10th : Sevok 22, Baghdogra AP 13, Chaparmukh 12, Bhatinda & Jammu AP 9 each, Malarkotla 8, Chidambaram 7.

11th : Canning Town 10, Basua 9, Balasore, Jogindernagar & Karaikudi 7 each.

12th : Gudari 13, Kailashahar & Mayiladuthura 9 each, Raipur & Silchar 7 each.

13th : Balasore 15, Dharchula 11, Narsari 9, Allahabad AP, Dharampur & Durg 8 each, Kangra & Paradip 7 each.

14th : Bansgaon & Sambalpur 11 each, Naraingarh 9, Addanki, Kasauli & Mungeli 8 each, Kokrajhar & Rajgarh 7 each.

15th : Damoh 15, Pachmarhi 13, Hoshangabad 8, Nahan 7.

16th : Kuroli & Nandigama 12 each, Dinhata 11, Guna 10, Amraghat, Datia & Tezu 8 each, Tirupattur 7.

17th : Mathanguri 29, Datia 20, Gwalior & Tadong 18 each, Agra AP 17, Passighat 16, Dholpur 14, Calcutta AP & Sevok 9 each, Gangtok 8, Jalpaiguri 7.

18th : Dholpur 11, Morena 10, Baghdogra AP 9, Dumka & Gwalior 8 each, Agartala AP, Contai & Pondicherry 7 each.

19th : Kasauli 21, Damoh 15, Dharamsala 9, Mandla 8, Car Nicobar, Dalhousie, Etwah & Jabalpur 7 each.

20th : Dumari 11, Kakatpur 10, Burdhwan 9, Car Nicobar & Devgarh 8 each.

21st : Baruipore & Dudhi 11 each, Hindon AP 8, Car Nicobar 7.

22nd : Tuni 11, Baghdogra AP 10, Bhubaneswar AP & Meerut 8 each, Angul, Jabalpur & Punalur 7 each.

23rd : Chauldhaghat 17, Haldwani & Prathipadu 10 each, Chintalapudi 9.

24th : Mathabhanga 24, Jalpaiguri 15, Cooch Behar, Dahanu & Passighat 13 each, Tezu 12, Damoh & Taibpur 11 each, Tezpur 10, Adirampattinam & Thakurganj 9 each, Broach & Dibrugarh AP & Solapur 8 each.

25th : Bombay AP 15, Akbarpur & Balurghat 12 each, Panneri & Salem 11 each, Beed & Navsari 10 each, Dahanu & Parbhani 9 each, Kasauli & Tuljapur 8 each, Osmanabad & Surat 7 each.

26th : Alibag 15, Turtipur 12, Panagarh AP 11, Kottayam & Nawashahar 9 each, Bombay AP & Buxar 8 each, Ahmadnagar, Bhopal, Krishnagar, Passighat & Surat 7 each.

27th : Bilaspur 17, Sevok 11, Asansol, Goalpara, Shahapur & Wapi 8 each, Kokrajhar 7.

28th : Jalpaiguri 19, Mathabhanga 12, Ahwa & Passighat 10 each, Panneri 9, Chauldhaghat & Silchar 8 each, Indore & Tituttani 7 each.

29th : Sankalan 15, Nandurbar 14, Sevok 10, Bhadrachalam, Chauldhaghat, Passighat & & Port Blair 7 each.

30th : Purulia & Simulia 16 each, Tenali 13, Champua & Sonbarea 9 each, Patti 7.

4.4.5. *Disastrous weather events and damages during September*

Floods continued throughout the month in Assam, Bihar and Uttar Pardesh. High floods submerged vast areas of human habitations and standing crops in the valley. River *Ganga* was in floods at Farakka throughout the month. Heavy rains in the catchment area during the first half of the month caused floods in the rivers *Subarnarekha, Mahanadi* and *Borhabaland* in Orissa. As per reports, heavy rains from 15th to 19th in Gwalior & Chambal divisions caused floods in all the rivers flowing through the districts of Gwalior, Bhind, Morena Datia, Shivpuri and Guna. It submerged hundreds of settlements in these districts and claimed 8 human lives.