Mausam, (1992), **43**, 3, 333-346

Weather

MONSOON SEASON (JUNE-SEPTEMBER 1991)*

1. Introduction

The summer monsoon rainfall 1 June to 30 September 1991 over the country was 91.2% of the seasonal. This is the fourth year in succession when monsoon was within in the normal range. 27 (about 80%) meteorological sub-divisions out of 35 received either normal or excess rainfall. No meteorological sub-division reported 'scanty' rainfall during the monsoon season. The seasonal rainfall departures, stationwise and meteorological sub-divisionwise are given in Figs. 1 and 2.

2. Features of the monsoon

2.1. *Advance of southwest monsoon*

Southwest monsoon, set in over Kerala on 2 June. It advanced northward covering the Peninsula, northeast and central India, south Gujarat, East Uttar Pradesh, the Hills of West Uttar Pradesh and Himachal Pradesh by 15 June. The monsoon did not advance further for about 3 weeks. It further advanced from 11 July covering north Gujarat, Rajasthan and northwest India. It covered the entire country by 19 July. The isochrones of advance of southwest monsoon are shown in Fig. 3.

2.2. *Weekly performance*

Weekly rainfall percentage departures (from normal) for the 18 weeks (30 May-2 Oct 91) for all the meteorological sub-divisions are given in Fig. 5. Monsoon rainfall was either in excess or normal during 8 to 13 weeks in 19 meteorological sub-divisions. 5 to 7 weeks in 12 meteorological sub-divisions and 2 to 4 weeks in 4 meteorological sub-divisions. It was scanty during 8 to 11 weeks in 6 sub-divisions, namely, East Uttar Pradesh and Hills of West Uttar Pradesh, Jammu & Kashmir, East Rajasthan, Saurashtra & Kutch and Marathwada.

2.3. *Monthly performance*

After a quick advance of monsoon till 15 June there was a halt for about 3 weeks. During June, the monsoon was either active or vigorous on 12 to 13 days over Sub-Himalayan West Bengal & Sikkim and on 2 to 8 days over Gangetic West Bengal, Bihar, East Uttar Pradesh, Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. Monsoon rainfall in June was in excess in 27 meteorological sub-divisions, deficient in 6 meteorological sub-divisions and scanty in 2 meteorological sub-divisions.

During July the monsoon was active to vigorous on 4 to 10 days over West Bengal & Sikkim, Madhya Pradesh, Gujarat region, Maharashtra, Andhra Pradesh, coastal and North Interior Karnataka and Kerala and on 1 to 3 days over Assam & Meghalaya, East Uttar Pradesh, Haryana, Punjab, East Rajasthan, Saurashtra & Kutch and South Interior Karnataka.

Rainfall in July was in excess or normal in 24 meteorological sub-divisions, deficient in 8 meteorological sub-divisions and scanty in 3 meteorological sub-divisions.

During August the monsoon was active or vigorous on 4 to 9 days over West Bengal & Sikkim, Orissa, Bihar Plains, East Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, East Rajasthan, Madhya Pradesh, Coastal Andhra Pradesh, Rayalaseema, North Interior Karnataka and Kerala and on 1 to 3 days over Arunachal Pradesh, Assam & Meghalaya, Bihar Plateau, Plains of Uttar Pradesh, Madhya Maharashtra, Tamil Nadu and South Interior Karnataka.

Rainfall in August was in excess or normal in 23 meteorological sub-divisions, deficient in 11 meteorological sub-divisions and scanty in 1 meteorological sub-division.

During September, the monsoon was active to vigorous on 6 to 11 days over Assam & Meghalaya, West Bengal & Sikkim, Himachal Pradesh and Coastal Andhra Pradesh and on 1 to 4 days over Nagaland, Manipur, Mizoram & Tripura, Orissa, Bihar, Plains of Uttar Pradesh, Haryana, Punjab, East Rajasthan, East Madhya Pradesh, Madhya Maharashtra, Marathwada, Telangana, Rayalaseema and Interior Karnataka.

Rainfall in September was in excess or normal in 13 meteorological sub-divisions, deficient in 12 meteorological sub-divisions and scanty in 10 meteorological sub-divisions.

2.4. *Seasonal performance*

The rainfall during the monsoon season (June to September) of 1991 for the country as a whole was 91.2% of the long period, average value. Of the 35 meteorological sub-divisions, seasonal rainfall was in excess in 1, normal

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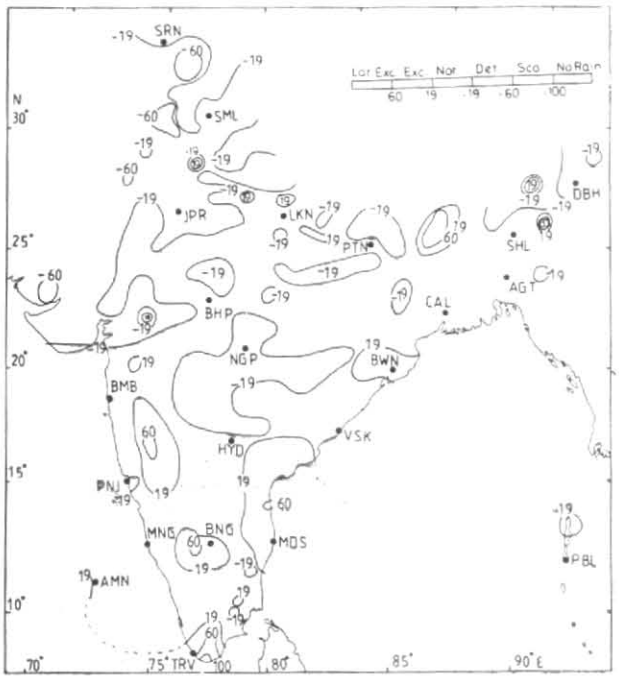

Fig. 1. Rainfall departure as percentage of normal for June-September 1991

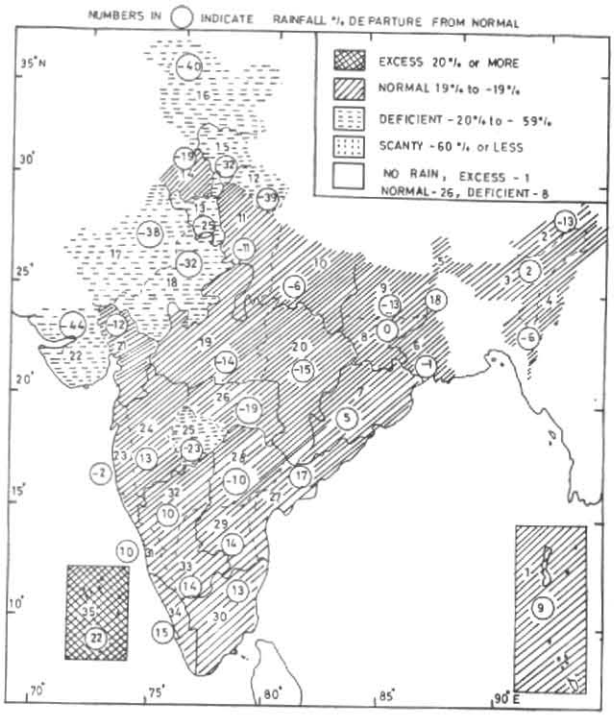

Fig. 2. Seasonal rainfall departure from normal for 1 June to 30 September 1991

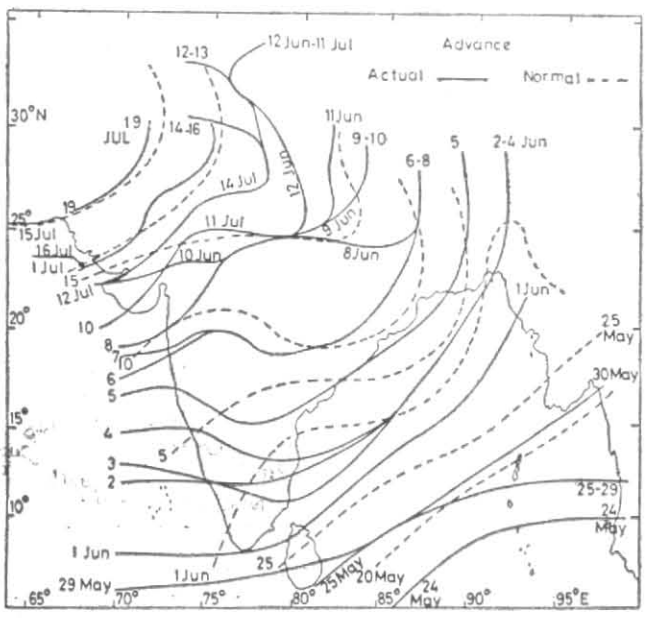

Fig. 3. Advance of southwest monsoon 1991

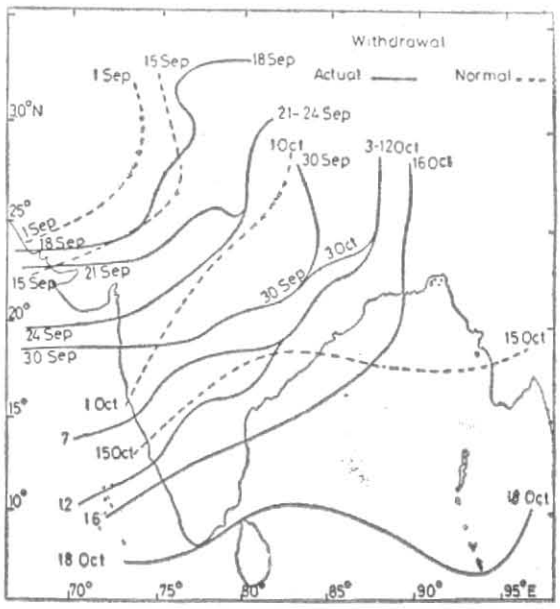

Fig. 4. Withdrawal of southwest monsoon 1991

TABLE 1

Sub-divisional means of rainfall (mm) for each month & season as a whole June-September 1991

Sub-divisions	June			July			August			September			Season		
	Act.	Norm.	%	Act.	Norm.	%	Act.	Norm.	%	Act.	Norm.	%	Act.	Norm.	%
(1) Bay Islands	167	470	—64	545	275	98	526	360	46	444	434	2	1683	1539	9
(2) Arunachal Pradesh	378	572	—34	665	678	—2	355	436	—19	437	273	60	1581	1823	—13
(3) Assam & Meghalaya	549	558	—2	388	540	—28	391	414	—6	419	326	28	1687	1651	2
(4) Naga., Mani. & Mizo.	366	388	—6	274	331	—17	171	288	—41	335	231	45	1166	1236	—6
(5) S.H.W.B. & Sikkim	635	535	19	551	609	—9	466	503	—7	777	411	89	2429	2058	18
(6) Gangetic West Bengal	248	254	—2	334	310	8	257	308	—17	271	246	10	1110	1118	—1
(7) Orissa	145	220	—34	453	360	26	450	354	27	191	249	—23	1138	1183	5
(8) Bihar Plateau	210	192	9	257	335	—23	330	331	0	280	220	27	1077	1078	0
(9) Bihar Plains	141	171	—18	179	306	—41	330	312	6	232	227	2	882	1015	—13
(10) East Uttar Pradesh	86	105	—19	127	303	—58	347	319	9	164	193	—15	835	888	—6
(11) Plains of West U.P.	57	80	—29	119	256	—54	336	294	14	78	167	—54	689	775	—11
(12) Hills of West U.P.	103	169	—39	155	451	—66	401	519	—23	157	278	—44	730	1196	—39
(13) Haryana, Chandigarh & Delhi	76	53	42	56	175	—68	208	175	19	48	111	—56	388	514	—25
(14) Punjab	75	43	76	108	190	—43	169	169	0	51	99	—49	403	501	—19
(15) Himachal Pradesh	79	94	—16	156	365	—57	304	343	—11	126	169	—25	664	971	—32
(16) Jammu & Kashmir	51	56	—9	120	139	—14	118	124	—5	50	84	—41	324	544	—40
(17) West Rajasthan	27	52	—15	66	95	—30	63	106	—40	24	56	—57	181	289	—38
(18) East Rajasthan	24	62	—62	198	238	—17	179	229	—22	38	115	—67	440	644	—32
(19) West Madhya Pradesh	98	115	—14	360	329	9	313	287	9	23	187	—88	795	919	—14
(20) East Madhya Pradesh	135	166	—19	375	407	—8	473	400	18	17	207	—92	1000	1180	—15
(21) Gujarat Region	86	137	—37	558	421	32	224	294	—24	53	180	—70	920	1041	—12
(22) Saurashtra, Kutch & Diu	62	122	—49	232	242	—4	57	127	—55	10	83	—88	323	573	—44
(23) Konkan & Goa	758	683	—11	1374	1141	20	581	684	—15	93	355	—74	2805	2862	—2
(24) Madhya Maharashtra	304	144	111	330	277	19	144	180	—20	71	154	—54	849	755	13
(25) Marathwada	236	144	64	230	205	12	39	182	—79	39	178	—78	543	709	—23
(26) Vidarbha	185	167	11	346	335	3	249	277	—10	18	201	—91	797	980	—19
(27) Coastal A.P.	217	112	95	156	170	—8	133	160	—17	245	171	43	715	613	17
(28) Telangana	191	136	40	227	238	—4	149	213	—30	140	194	—28	707	781	—10
(29) Rayalaseema	178	61	193	73	86	—15	86	99	—13	98	134	—27	435	380	14
(30) Tamil Nadu	145	54	166	55	77	—29	71	100	—29	117	104	12	388	341	13
(31) Coastal Karnataka	976	871	12	1445	1173	23	870	674	29	67	307	—78	3357	3040	10
(32) N.I. Karnataka	239	98	143	158	149	6	97	120	—19	80	151	—47	574	521	10
(33) S.I. Karnataka	277	149	86	270	281	—4	178	189	—6	144	141	2	870	761	14
(34) Kerala	1084	691	57	837	760	10	471	434	8	50	247	—80	2443	2133	15
(35) Lakshadweep	603	307	97	241	280	—14	259	222	17	46	161	—72	1149	940	22

Act. — Actual, Norm.— Normal.

in 26 and deficient in 8 sub-divisions. The seasonal rainfall was not scanty over any meteorological sub-divisions. Areawise about 75% of the Indian land mass received excess or normal rainfall. However, in the normal category the rainfall departure was negative (between —1% and—19%) over 12 meteorological sub-divisions. In the deficient category rainfall departures were between—38% and—44% in Hills of West Uttar Pradesh, West Rajasthan, Jammu & Kashmir and Saurashtra & Kutch and were between —25% and —32% in Haryana, Himachal Pradesh and East Rajasthan. Rainfall figures for the month and season as a whole are given in Table 1. The seasonal rainfall departures analysed on the basis of individual stations are shown in Fig. 1.

2.5. *Withdrawal of southwest monsoon*

Southwest monsoon withdrew from northwest India on 18 September. By 30 September it withdrew from Uttar Pradesh, Madhya Pradesh, Gujarat and north Maharashtra. Southwest monsoon gradually withdrew from the entire country by 18 October. The isochrones of withdrawal of the southwest monsoon from the country are shown in Fig. 4.

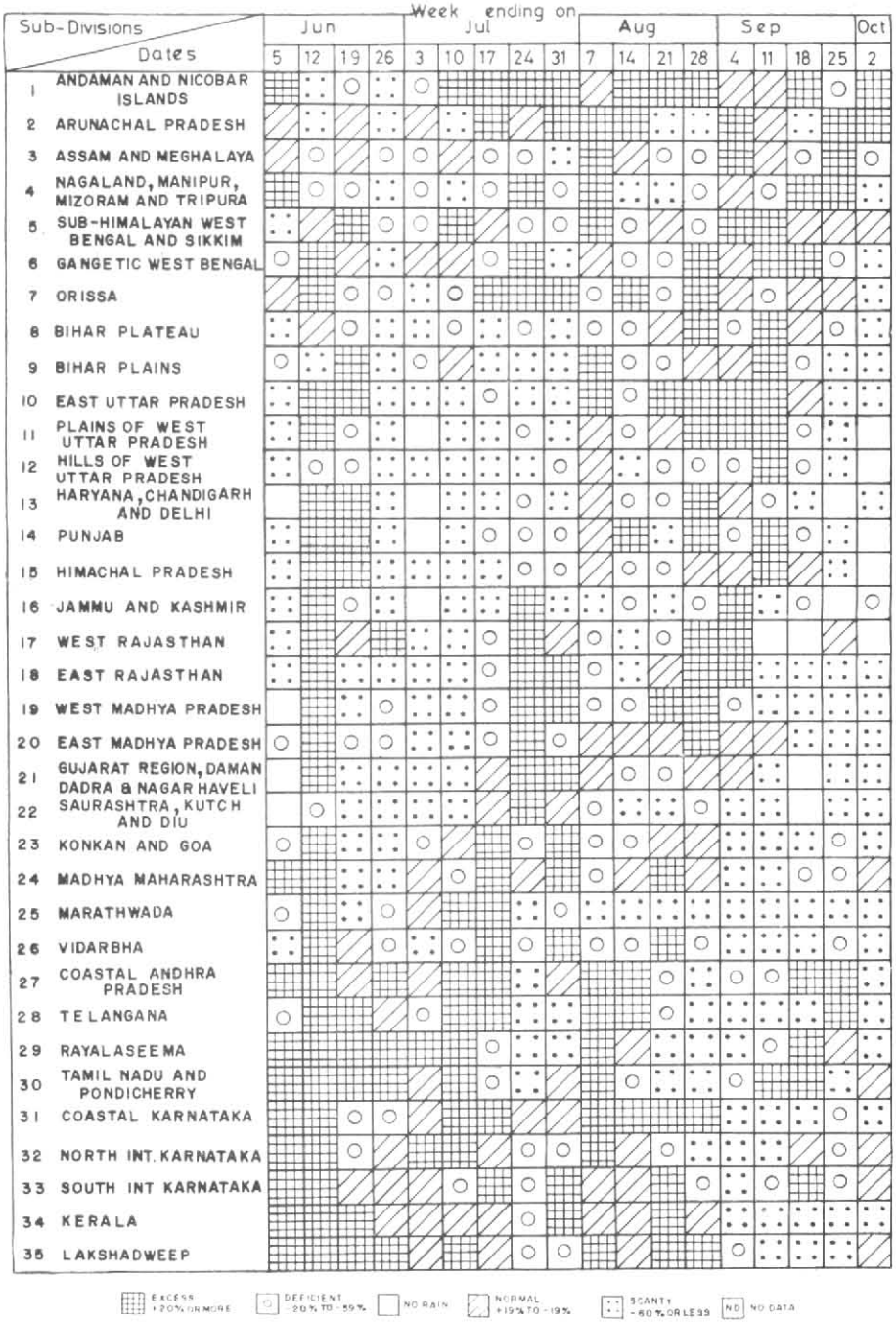

Fig. 5. Progress of the monsoon week by week (1 June-30 September 1991)

3. Chief synoptic features during monsoon

The monthwise distribution of synoptic disturbances which affected the Indian monsoon region are given below :

Systems	*Jun*	*Jul*	*Aug*	*Sep*	*Total*
(*i*) Depression/Deep depression/C.S.	1	1	1	1	4
(*ii*) Low pressure area/well marked low pressure area	1	2	5	2	10
(*iii*) Cyclonic circulation	5	4	6	4	19
(*iv*) Western disturbance	3	1	Nil	4	8
(*v*) Induced circulation	Nil	1	Nil	Nil	1
Total	10	9	12	11	42

Note–(*i*) Though the depression developed on 31 May it became cyclonic storm on 1 June and weakened over northeastern states on 2 June ushering in monsoon there.

(*ii*) Two of these 4 cyclonic circulations actually developed on 27 June and included for the month. They continued during July. The No. 4 includes those two of June. Actual development during July was No. 2.

(*iii*) Those two low pressure areas actually developed during the last week of August, which are included for that month and carried over to September. Actual development of low pressure area during September was Nil.

Actual — Low pressure area/well marked low pressure area — 8, cyclonic circulation — 17.

3.1. *Depression/Deep depression/Cyclonic storm*

The first important low pressure system of the season developed over Bay on 31 May. It intensified into a cyclonic storm on 1 June. Moving in a northnorthwesterly to northnortheasterly direction and crossing Bangladesh coast the system dissipated over Tripura and neighbourhood. The system ushered in the southwest monsoon over the northeastern States. The July deep depression and the September depression initially appeared as upper air disturbances, while the August depression formed out of the remnant of the Pacific typhoon '*Fred*'.

No depressions developed over the Arabian Sea during monsoon 1991. In July and August depressions moved far inland into northwest Uttar Pradesh up to west of Long. 80° E.

Fig. 6 shows the track of storms/depressions for the season.

The deep depression of July brought good monsoon rainfall over Orissa, Maharashtra, Rajasthan and Gujarat while the depression of August increased monsoon rainfall over northern plains of India. The September depression gave rainfall only to Andhra Pradesh and Orissa.

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

During the season, 8 low pressure areas /well marked low pressure areas formed in the monsoon trough (LPA —4, WMLPA —4). Out of these one developed during the month of June, two during July and five during August. No low pressure area formed during September. However, the well marked low pressure area, which developed on 27 August and the low pressure area, which developed on 31 August continued till 3 September. These two low pressure areas in September increased monsoon rainfall over the plains of north India.

All these low pressure areas, except the one between 16 and 22 August initially appeared as upper air circulations.

3.3. *Cyclonic circulation (CYCIR)*

Out of a total of 17 cyclonic circulations, 7 developed over the Bay of Bengal, 1 over the Arabian Sea and 9 over the land areas. The cyclonic circulation which developed over northwest and adjoining west central Bay on 27 June continued for a long period before dissipating on 15 July over north Madhya Pradesh and adjoining south Uttar Pradesh.

3.4. *Western disturbances (WD)*

In all 8 western disturbances affected northwest India as upper air system. Of these three were in June, one in July and four in September. There was no western disturbance activity during August.

3.5 *Mid-latitude troughs*

During the season, 14 mid-latitude troughs moved across northwest India and Tibetan Plateau. The westerly trough between 10 and 19 June extended to south Peninsula on a couple of days and the westerly trough during 18-24 September extended to Gujarat and Madhya Pradesh. The remaining troughs affected northwest India only. Monthwise details of these troughs are given below :

Jun — Total 3, between (*i*) 5 and 8, (*ii*) 10 and 19, and (*iii*) 25 and 29.

Jul — Total 4, between (*i*) 1 and 5, (*ii*) 3 and 6, (*iii*) 19 and 23 and (*iv*) 22 and 26.

Aug — Total 5, between (*i*) 1 and 6, (*ii*) 8 and 13, (*iii*) 15 and 18, (*iv*) 20 and 26 and (*v*) 28 and 31.

Sep — Total 2, between (*i*) 5 and 9 and (*ii*) 18 and 24.

3.6. *Westerly jet*

Sub-tropical westerly jet was seen over Delhi between 200 and 150 hPa levels up to 12 June. It was again seen over north India (along 36° N, 80° E) during the 1st week of September at 250/200 hPa levels and persisted there up to mid-September.

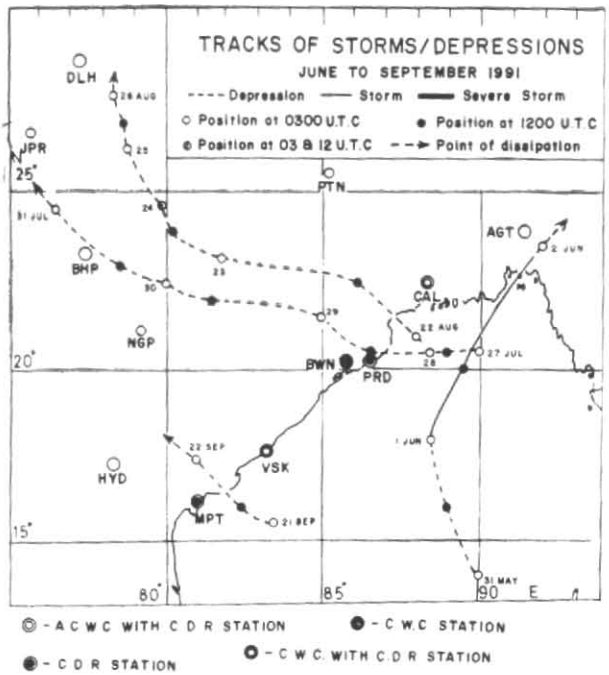

Fig. 6. Tracks of storm / depressions (June to September 1991)

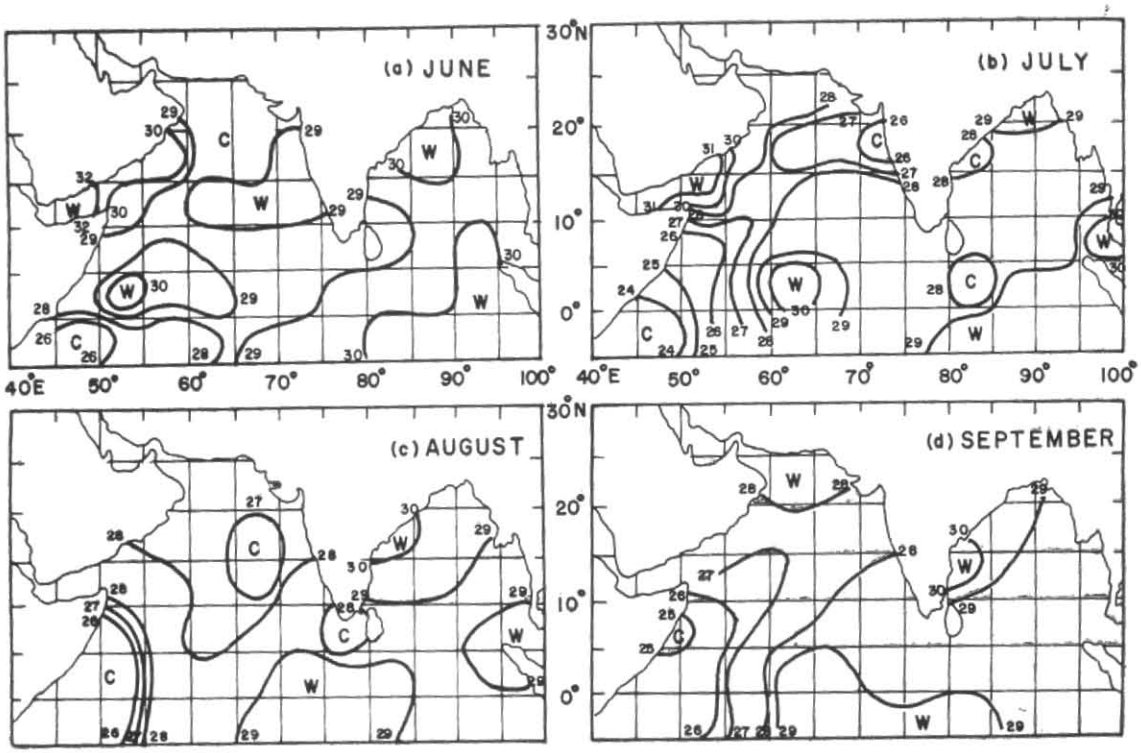

Fig. 7. Mean monthly sea surface temperature (SST in °C) of Indian seas during monsoon 1991

4. Semi-permanent system during monsoon

4.1. *Heat low*

Heat low was observed near its normal position (28°N, 68°E) during July and in the first fortnight of August 1991. During the second half of August, it moved slightly north of its normal position (32°N, 68°E). Its intensity was normal with central pressure value of 996 hPa.

4.2. *Axis of monsoon trough*

Monsoon trough extending up to 0.9 km a.s.l. normally runs from Ganganagar to north Bay through Allahabad in July.

During this year the monsoon trough at 0.9 km a.s.l. became well established by the middle of July and was about 4 to 6 degree south of its normal position. It was active in August and was around its normal position till 15 September. It was mainly confined to northeast India running from East Uttar Pradesh to Nagaland, Manipur, Mizoram & Tripura during the first fortnight of September. Thereafter, it lay mainly over Peninsular India and adjoining central Bay of Bengal.

4.3. *Cross-equatorial flow*

The southern hemispheric equatorial trough (SHET) n south Indian Ocean was located roughly along 3°S in June, August and the first fortnight of September 1991. In July 1991 SHET was located roughly along 1°S. In the last week of September 1991 it shifted roughly to 6°S. However, the cross-equatorial flow was maintained which caused moderate to strong monsoon current throughout the monsoon season in the Arabian Sea.

4.4. *Sea surface temperature (SST) over Arabian Sea and Bay of Bengal (Fig. 7)*

During the monsoon season of 1991, the cold pool of SST off and along Somalia coast became well established during July and extended northwards to Arabia coast during August only. Normally warm pool over east central Arabian Sea was replaced by cold pool (about 0.5°C to 1.5°C below normal value) during July 1991. The cold pool expanded over almost the entire central Arabian Sea during August and merged with the Somalian cold pool during September.

The Comorin cold pool was noticeable during August only.

Northwest and adjoining west central Bay of Bengal and southeast Bay and adjoining south Andaman Sea were warmer by about 0.5 °C to 1.0°C during June. During July a cold pool developed over west central Bay off Andhra coast. The Bay of Bengal sea surface temperatures were higher (about 0.5°C to 1.0°C) during August. During this month a warm pool developed along and off Andhra coast replacing the cold pool there.

During September the values of SSTs were normal over the Arabian Sea and the Bay of Bengal. However, the warm pool, observed off Andhra coast during August was seen off south Andhra, north Tamil Nadu coast during September.

4.5. *Tibetan anti-cyclone*

Tibetan anti-cyclone/high got established by mid-July. It shifted southeastwards over northeast India and neighbourhood in the beginning of August and lay there up to mid-August. Moving to its normal position around 20 August, it remained prominent till 29th. Its position in the middle tropospheric levels was mainly to the south of its normal position during September.

Tibetan anti-cyclone was intense during the 2nd fortnight of July and between 20 and 30 August.

4.6. *Tropical easterly jet (TEJ)*

TEJ was observed with maximum speed of 75 kt in June, 90 kt in July, 95 to 100 kt in August. Wind speeds decreased to about 65 to 70 kt in September. TEJ was observed between 100 hPa and 150 hPa levels in June, July and September and around 150 hPa in August.

During June, Jet core lay mainly between Thiruvananthapuram and Madras latitudes, but on a couple of days it was seen at Nagpur latitude. During July it lay mainly around Lat. 17.0°N. The highest wind speed of 135 kt was recorded at Goa at 120 hPa level on 4 July. The Jet core was around Lat. 14°N during August. In this month the highest wind speed of 145 kt was observed at Goa at 125 hPa level on 2 August. The Jet lay around Thiruvananthapuram—Minicoy latitudes during September.

5. Other features

5.1. *Stratospheric features (10 hPa)*

The following main features of circulation have been noticed :

Balasore

The region around 10 hPa is dominated mainly by easterly flow during the monsoon season. Strong easterly winds of about 60 kt were noticed in the middle of June decreasing (to 50 kt) in the first week of July. It picked up again in the middle of July when the speeds were about 70 kt continued till mid. August. The winds were about 40-50 kt during the rest of the season.

Thumba

At Thumba winds were mainly easterlies throughout the monsoon season at 10 hPa level. The speed was around 80 kt in the middle of June and about 110 knots in the middle of July. The winds were about 65-70 kt during the rest of the season.

The temperature over Thumba at about 10 hPa was found to be approximately —40°C during the monsoon period except in the middle of July when it was about —50°C.

5.2. *Aridity conditions during SW monsoon season 1991*

Moderate to severe arid conditions prevailed in June over Gangetic West Bengal, Orissa Bihar Plains, East Uttar Pradesh, West Uttar Pradesh, Punjab, Haryana, Himachal Pradesh, East Rajasthan, Gujarat Region,

TABLE 2

Details of weather systems during June 1991

S. No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
	(A) *Low pressure area/ Depression etc*					
1	Well marked low pressure area	4th-11th eve.	Southwest Bay off Tamil Nadu coast	Northwesterly to Northerly	Central parts of Madhya Pradesh. The associated cyclonic circulation became unimportant there on 31th	First located over southwest Bay as a cyclonic circulation in lower and middle tropospheric levels on 3rd
	(B) *Cyclonic circulation*					
1	Lower levels (*i.e.* upto 0.9 km a.s.l.)	7th-9th	Gujarat region and adjoining west Madhya Pradesh	Northwesterly	West Rajasthan	
2	Lower and middle tropospheric levels	20th-22nd	Northwest and adjoining west central Bay	Quasi-stationary	Coastal Orissa and neighbourhood	
3	Middle and upper tropospheric levels	24th-27th	West central Bay off Andhra coast		*In situ*	
4	*Lower and middle tropospheric levels	27th-30th	Northwest and adjoining west central Bay off south Orissa—North Andhra coast	Northerly		*Lay on 30th over northwest Bay off Orissa coast
5	**Lower and middle tropospheric levels	27th30th	East central Arabian Sea off south Maharashtra—North Karnataka coasts	Quasi-stationary		**Lay over the same area on 30th
	(C) *Western disturbance*					
1	Upper air system	9th-12th eve.	North Pakistan	Easterly	Moved away across Jammu and Kashmir & neighbourhood	
2	Upper air system	19th-21st	Punjab and adjoining North Pakistan	Easterly	Do.	
3	Upper air system	21st-23rd	Central parts of Pakistan	Easterly	Do.	
	(D) *Trough in westerlies*					
1	Middle and upper tropospheric levels	23rd-28th	Axis at 9.5 km a.s.l. along Long. 65°E, north of Lat. 25°N	Quasi-stationary	*In situ*	

Saurashtra & Kutch, West Madhya Pradesh and Vidarbha and Marathwada.

Moderate to severe arid conditions prevailed in July over Jammu & Kashmir, Punjab, Haryana, West Rajasthan, East Rajasthan, Gujarat Region, Saurashtra & Kutch, East Uttar Pradesh, Bihar Plains, Telangana, Rayalaseema and Tamil Nadu & Pondicherry.

Moderate to severe arid conditions prevailed in August over Haryana, West Rajasthan, East Rajasthan, Saurashtra & Kutch, Madhya Maharashtra, North interior Karnataka, Telangana, Rayalaseema and Tamil Nadu & Pondicherry.

Moderate to severe arid conditions prevailed in September over Jammu and Kashmir, Haryana, west Rajasthan, east Rajasthan, Gujarat region, Saurashtra & Kutch, West Madhya Pradesh, east Madhya Pradesh, Madhya Maharashtra, Marathwada, Vidarbha, Konkan & Goa, Telangana, Rayalaseema, North Interior Karnataka, South Interior Karnataka, Kerala and Tamil Nadu & Pondicherry.

Remaining parts of the country experienced non-arid to mild arid conditions during the southwest monsoon period 1991.

6. Extra Indian systems

6.1. *Systems in south China sea/west Pacific Ocean*

From June to September 1991, 13 typhoons, 3 tropical storms and 4 depressions formed in the western north Pacific Ocean and south China Sea. Out of these,

5 typhoons and 2 storms formed in the western north Pacific Ocean and moved west/northwestwards, crossed the coast and weakened over south central China. 6 typhoons and 1 storm initially moved northwest/northwards, then recurved northeastwards and became extra tropical system.

One typhoon formed in south China Sea, crossed south China coast and weakened over south central China.

Only one typhoon — '*Fred*' formed over western north Pacific Ocean on 10 August 1991 moved westwards, crossed the Vietnam coast and weakened over Thailand on 18 August 1991. Remnant of this system emerged as a well marked low pressure area in the east central Bay on 20 August 1991.

6.2. *Systems in southern hemisphere*

(a) From Jun to Sep 1991, 2 tropical storms and one depression formed in the south Indian Ocean. One tropical storm formed on 11 June 1991 centred near 11.2°S, 68.7°E. It moved westwards and weakened into a depression on 12 June 1991, it moved southwestwards and was centred near 12.0°S, 67.0°E at 1200 UTC on 13 June 1991. It weakened rapidly thereafter. Second tropical storm formed at 1200 UTC on 10 Sep 1991 centred near 9.0°S, 78.5°E. It moved slowly southwestwards and weakened into a low pressure area at 00 UTC on 13 September 1991.

One depression formed on 7 Sep 1991 centred near 5.0°S, 78.0°E and weakened over the same area on the next day.

(b) During the period June to September 1991, 21 troughs in upper tropospheric westerlies move across south Indian Ocean between 40°E and 100°E. Most of these troughs were seen poleward of 25°S.

(c) The intensity of Mascarene High (M.H.) was normal to above normal on 65% occasions during the season. It was located east of its normal position by 5°-10° on 50% occasions.

7. Characteristic features of the southwest monsoon 1991

(*i*) During June to September only 3 depressions formed in the Bay of Bengal as against a normal of 6 to 7 depressions.

(*ii*) Most of the depressions and low pressure areas appeared initially as upper air disturbances.

(*iii*) No depression formed during the month of June.

(*iv*) Onset of monsoon over Kerala was not associated with 'onset' vortex.

(*v*) The onset of monsoon over Peninsula, central and northeast India, was in association with low pressure area off the Tamil Nadu coast (4-11 June).

(*vi*) There was a hiatus in the advance of the monsoon for over 3 weeks from 16 June to 10 July. Such a prolonged hiatus in the advance of the monsoon current was not observed in the last 4 decades.

(*vii*) Tibetan anti-cyclone/high was located mostly to the south of its normal position.

(*viii*) The cumulative rainfall from 1 June to 31 July was either deficient or scanty in all the meteorological sub-divisions in the plains of north India. During this period monsoon was erratic over Bihar, Uttar Pradesh, Delhi, Haryana and adjoining Rajasthan.

(*ix*) The drought prone area of Saurashtra & Kutch had excess or normal rainfall for a period of 3 weeks only.

(*x*) Hills of West Uttar Pradesh experienced excess or normal rainfall for a period of 2 weeks only.

(*xi*) East Rajasthan, Saurashtra & Kutch and Marathwada received scanty rainfall for 10 to 11 weeks period.

(*xii*) Rain shadow areas like Rayalaseema and Tamil Nadu received excess and normal rainfall respectively.

8. Damages due to floods etc during the season

During the season heavy rains/floods affected Assam, Bihar, Kerala, Maharashtra, Orissa, West Bengal and Uttar Pradesh. Nearly 23.5 million people were affected in the above areas of the country damaging crops and property worth Rs. 2,888 millions. 673 human lives and 41,03,777 heads of cattle were lost as a result of the floods and heavy rains.

9. Significant monthly features

9.1. *June*

The southwest monsoon set in over Kerala by 2 June without any onset vortex. Further advance of southwest monsoon was in association with a well marked low pressure area (4-11 June) over the southwest Bay and its movement into the country. By 15 June, the southwest monsoon had advanced into south Gujarat. Peninsula, central and northeast India, Bihar and Uttar Pradesh. Thereafter, the monsoon did not advance further till 11 July 1991.

9.1.1. *Features heralding the advance of monsoon during June-July*

Though monsoon set in over Kerala without any onset vortex its further advance from 2 June to 15 June was in association with a low pressure area as mentioned above. It was followed by a prolonged lull till 11 July. Monsoon further advanced on 12 July in association with a low pressure area (14-19 July) which formed over northwest Bay moved inland and dissipated over east Rajasthan and neighbourhood.

9.1.2. *Synoptic features*

Synoptic features during June are given in Table 2.

9.1.3. *Monthly rainfall and monsoon activity*

Principal amounts of daily rainfall (in cm) are given in Table 6.

9.1.4. *Temperature*

Day temperatures were abnormally high in the Plains of Uttar Pradesh, Rajasthan and Madhya Pradesh from the last week of June and early July, as the southwest monsoon did not advance over northwest India and was weak over Madhya Pradesh and east Uttar Pradesh. Agra recorded a maximum 45°C (dep +9°C) on 6 July. Jhansi also recorded 45°C on 8 July.

TABLE 3

Details of weather systems during July 1991

S. No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
	(A) *Low pressure area/ Depression etc*					
1	Well marked low pressure area	14th-19th eve.	Northwest Bay and neighbourhood	Westnorthwesterly to westerly	Northwest Madhya Pradesh. However, the associated cyclonic circulation in lower tropospheric levels dissipated over North Gujarat region and adjoining east Rajasthan on 25th	Initially seen as a cyclonic circulation between 1.5 km and 7.6 km a. s. l. over the same area on 14 morning
2	Low pressure area	21st-27th	North Bay	Westnorthwesterly	Northwest Madhya Pradesh and adjoining south Uttar Pradesh	Initially seen as a cyclonic circulation up to 7.6 km a.s.l. over the same area on 20th
3	Deep depression	27th-31st eve.	Northwest Bay	Westerly to westnorthwesterly	East Rajasthan and neighbourhood. The remnant became less marked over northwest Rajasthan on 2nd August	First appeared as a cyclonic circulation up to 5.8 km a.s.l. over north and adjoining central Bay on 25th
	(B) *Cyclonic circulation*					
1(a)	*Lower and middle tropospheric levels	1st-5th	East central Arabian Sea off south Maharashtra-north Karnataka coasts	Northerly	East central Arabian Sea off north Maharashtra coast	*The system developed on 27th June (S. No 5**)
1(b)	Do.**	1st-15th	Northwest Bay and neighbourhood	Quasi-stationary upto 5th thereafter westerly to northerly	North Madhya Pradesh and adjoining South Uttar Pradesh	**The system developed on 27th June (S. No. 4*)
1(c)	Do.	10th-20th	Konkan and neighbourhood	Northerly	North Konkan and adjoining Gujarat	
2	Do.	27th-30th	North Gujarat and neighbourhood	Stationary	*In situ*	
	(C) *Western disturbance*					
1	Upper air system	5th-7th	North Pakistan and neighbourhood	Easterly	Moved away across Jammu & Kashmir	
	(D) *Induced cyclonic circulation*					
1	Lower levels (*i.e.* upto 0.9 km a.s.l.)	5th-7th	North Pakistan	Easterly	Punjab and adjoining Himachal Pradesh	

9.1.5. *Disastrous weather events and damages during June*

The *Brahmaputra* and its tributaries were flooded during first, second and third week affecting 6 districts of Assam. Floods claimed 43 human and 62 heads of cattle.

Bombay (Santacruz) reported 35.1 cm of rainfall on 9, 30.9 cm on 10 and Bombay (Colaba) reported 39.7 cm on 9 and 47.8 cm on 10. The rainfall recorded at Colaba on 10 and at Santacruz on 9 are all time highest rainfall in 24 hours during the month of June. Torrential rains claimed 74 lives in Bombay and its suburbs. 14 persons were reported to have died when a boat capsized in a river due to strong winds in Nagpur district.

9.2. *July*

9.2.1. *Synoptic features*

Details of the synoptic features are given in Table 3.

9.2.2. *Monthly rainfall and monsoon activity*

Principal amounts of daily rainfall (in cm) are given in Table 6.

9.2.3. *Disastrous weather events and damages*

The *Brahmaputra* in Assam, the *Indravati* in Madhya Pradesh, the *Wainganga* and the *Wardha* in Maharashtra, the *Valnsadhara* in Orissa, the *Mahananda* and the *Kosi* in Bihar were in spate during the month. Communication links were totally disrupted in some parts of Assam.

TABLE 4

Details of weather systems during August 1991

S No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Low Pressure area/Depression etc*						
1	Low pressure area	4th-8th eve.	East Uttar Pradesh	Stationary	*In situ*	First observed over the region as a cyclonic circulation up to 5.8 km. a.s.l. on 3rd evening
2	Well marked low pressure area	9th-16th	Northwest Bay and neighbourhood	Westnorthwesterly	Bihar Plateau and adjoining parts of east Madhya Pradesh	Initially observed over the region as a cyclonic circulation up to 5.8 km a.s.l. on 8th
3	Low pressure area	16th-22nd	Do.	Westnorthwesterly	Northeast Rajasthan	Associated cyclonic circulation became less marked over the same region on 24th
4	Depression	22nd-26th	Northwest Bay	Westnorthwesterly to Northerly	Plains of Uttar Pradesh. The remnant became less marked over the region on 28th]	Remnants of Pacific Typhoon 'FRED' emerged in east central Bay as a well marked low pressure area on 20th, which developed into the present depression
5	Well marked low pressure areas	27 Aug-3 Sep	Northwest Bay and adjoining land area	Westnorthwesterly	North Rajasthan & adjoining Haryana	Initially appeared as an Upper air disturbance between 3.1 and 7.6 km a.s.l. over northwest Bay on 25th evening
6	Low pressure area	31 Aug-2 Sep eve.	Northwest Bay	Westnorthwesterly	Bihar Plateau and neighbourhood	Initially observed as Cyclonic circulation up to 3.1 km a.s.l. over North Bay on 30th August
(B) *Cyclonic circulation*						
1	Middle tropospheric levels	3rd-6th	North coastal Andhra Pradesh and adjoining southeast Madhya Pradesh	Stationary	*In situ*	
2	Lower and middle tropospheric levels	2nd-5th	North Konkan and neighbourhood	Northerly	Saurashtra and neighbourhood	
3	Lower and middle troposperic levels	6th-8th	Northwest Bay and adjoining land areas	Quasi-stationary	Coastal Orissa and neighbourhood	
4	Lower and middle tropospheric levels	13th-22nd	Gujarat and neighbourhood	Stationary	*In situ*	
5	Lower and middle tropospheric levels	18th-20th	Northwest Bay	Do.	*In situ*	
6	Lower tropospheric levels	28th-29th	North Rajasthan & neighbourhood	Do.	*In situ*	

TABLE 5

Details of weather systems during September 1991

S No.	Weather system	Period	Place of first location	Direction of movement	Place of dissipation	Remarks
(A) *Low pressure area/Depression etc*						
1 (a)	Low pressure area*	1st-3rd	Lay on 1st over north Rajasthan and adjoining Haryana	Westnorthwesterly	North Rajasthan and adjoining Haryana	*Continuation of August system under S. No. 5.
(b)	Low pressure area**	1st-2nd eve.	Lay on 1st over northwest Bay and adjoining north coastal Orissa and Gangetic West Bengal	Westnorthwesterly	Bihar Plateau and neighbourhood	**Continuation of August system under S. No. 6.
2	Depression	21st-22nd eve.	West central Bay	Northwesterly	Telangana and neighbourhood the remnant became less marked over south-east Madhya Pradesh and neighbourhood on 25th	Initially observed as a cyclonic circulation in the lower and middle tropo spheric levels over west central off Bay Andhra coast on 12th
(B) *Cyclonic circulation*						
1	Lower and middle tropospheric levels	5th-13th	Central parts of Bihar	Easterly	Sub-Himalayan West Bengal & Sikkim and neighbourhood	
2	Lower tropospheric levels	6th-7th	Punjab and neighbourhood	Easterly	Himachal Pradesh and neighbourhood	
3	Lower and middle tropospheric levels	11th-13th	Northwest Bay and neighbourhood	Stationary	*In situ*	
4	Lower and middle tropospheric levels*	26th-30th	West central and adjoining southwest Bay off south Andhra-North Tamil Nadu coast	Stationary	—	*Persisted in the same region on 30th
(C) *Western disturbance*						
1	Cyclonic circulation in the lower tropcspheric levels	14th-19th	Northwest Rajasthan and adjoining Pakistan	Eastnortheasterly	Moved away across Jammu & Kashmir and adjoining Himachal Pradesh	
2	Cyclonic circulation in the lower and middle tropospheric levels	21st-25th	Punjab and adjoining Haryana and northwest Uttar Pradesh	Quasi-stationary	Became less marked over west Uttar Pradesh	
3	Upper Air System	26th-27th	North Pakistan and adjoining Punjab	Easterly	Moved away across Jammu & Kashmir and neighbourhood	
4	Upper Air System	27 Sep-3Oct	North Pakistan and neighbourhood	Eastnortheasterly	Moved away across extreme northern parts of Kashmir	

TABLE 6

Date	June	July	August	September
1	—	Kannur 28, Kundapur 19, Jhalung 17, Padrauna 17	Cherrapunji 26, Agumbe 25, Kasrkala 19, Salbari 18	Car Nicobar 15, Malpura 14, Ragul 11, Sarotary 11
2	Minicoy 28, Tnuckalay 25, Cnerrapunji , 14, Kanya-kumari 10	Hasimara 17, Jalpaiguri 16, Kudal 16, Bnagamandala 13	Silchar AP 26, Sevoke 18, Shirali 17, Kishnanganj 15	Chargharia 15, Chauldhaghat 11, Durgapur 11, Itanagar 10
3	Ponnani 30, Cochi AP 24, Karaikal 16, Alapuza 13	Jalpaiguri 31, Jagatballapur 18, Calcutta AP 14, Kudule 11	Chanpatia 23, Hasimara 13, Banrgaon 13, Hyderabad AP 10	Arambagh 29, Alipurdwar 12, Bahraich 10, Shillong 10
4	Quiliandy 37, Kozikode 25, Denkanikotti 19, Aaskal 18	Thakurganj 22, Cherrapunji 21, Bardwan 20, Panagara 11	Champavati 23, Buxar 20, Khajurano 16, Mirzapur 16	Salbari 14, Sevoke 11, Galgalia 10, Basti 9
5	Kundapur 22, Kasargode 19, Amragnat 16, Cochi AP 14	Cherrapunji 26, Khanapur 14, Deogarn 13, Kandanar 11	Cherrapunji 18, Kangra 17, Lucknow AP 14, Kamalapuram 13	Pantnagar 17, Roorkee 17, Joginder nagar 15, Tiruchirappalli AP 15
6	Arasalu 23, Aryankvu 16, Badvel 16, Nellore 16	Malda 23, Cherrapunji 20, Rajapur 20, Ratnagiri 18	Hosket 15, Rampurhat 14, Kanpur 13, Durgapur 12	Maharajganj 13, Bangerpet 10, Mangalore AP 10, Tirumangalam 10
7	Mannar 21, Karkala 18, Murbad 18, Digha 16	Silchar 49, Dinhata 17, Panambur 15, Bnagamandala 14	North Lakhimpur 17, Baghdogra 15, Balasore 12, Chaparmukh 11	Katihar 20, Shahganj 20, Dharampur 13, Varanasi 13
8	Bhivpuri 29, Alibag 21, Hosnangabad 20, Peermade 20	Panambur 22, Kasargode 17, Koyana 17, Kollam 16	Gadoarwa 17, North Lakhimpur 17, Umrer 15, Cnaparmukh 13	Mohitnagar 28, Katihar 4, Kalimpong 22, Car Nicobar 21
9	Dnaravi 46, Bombay 40, Silchar 22, Bnagamandala 20	Karwar 34, Kankawali 23, Harnai 19, Honavar 18	Khandala 18, Madhabarida 10, Bnarmour 10, Snajahanpur 10	Baghdogra 30, Malda 18, Sabour 17, Gazipur 15
10	Bombay 48, Harnai 29, Siddapur 23, Hosanagara 19	Koderu 22, Alipurdwar 19, Jalpaiguri 12, Menaoooonagar 11	Puri 18, Nauashafar 15, Kasauli 14, Phulbani 13	Mekhliganj 30, Kalimpong 24, Salbari 24, Katihar 22
11	Bhagamandala 19, Digha 19, Poonampetn 17, Deoria 16	Roorkee 19, Saukaloa 18, Pasighat 17, Calcutta 13	Ambadola 12, Maheshwar 10, Kishanganj 9, Manmatnnagar 9	Jalpaiguri 17, Nagrota 11, Bhakra 9, Nangal 7
12	Cherrapunji 24, Samudrapur 16, Rampuirhat 13, Thanesar 12	Kannur 24, Gadchiroli 22, Kalyan 19, Bhagamandala 15	Rajkishornagar 33, Tensa 19, Begaoli 12, Phulbani 11	Shrinivaspura 10, Adirampattinam 9, Domnani 9, Krishnagar 9
13	Kodungallur 21, Balarampur 19, Cherrapunji 17, Jalpaiguri 15	Alibag 25, Lonavala 22, Alipurdwar 18, Bombay 17	Khairamal 33, Phulbani 24, Sambalpur 18, Chaparmukh 17	Hubli 21, Magadi 13, Kaisarganj 12, Bangalore 7
14	Cherrapunji 17, Domohani 17, Balarampur 16, Baghdogra 13	Pasighat 18, Madangad 16, Deogarh 15, Alibag 13	Aluva 14, Shirgaon 14, Mahabaleshwar 13, Gaganbavada 11	TN Pura 20, Khirpai 19, Joginder nagar 15, Tiruchirapalli AP 12
15	Baghdogra 14, Cherrapunji 14, Malda 13, Kangra 10	Tamini 31, Bhira 29, Alibag 14, Ambadola 13	Dharamsala 29, Mathanguri 17, Koyana 15, Agumbe 14	Idukki 20, Uluberia 18, Joginder nagar 10, Chendipada 9
16	Cherrapunji 26, Chincoli 12, Calcutta AP 11, Dharamtul 9	Ambadola 25, Cherrapunji 25, Koyana 20, Damanagar 16	Cherrapunji 42, Gadchiroli 29, Sevoke 23, Wardna 20	Islampur 27, Mekhilganj 20, Talcner 12, Jalpaiguri 11
17	Cooch Behar 24, Jawhar 16, Cherrapunji 14, Dibrugarn AP 9	Mindol 31, Tezpur 22, Sakoli 19, Bhira 15	Bankura 17, Agumbe 15, Karkala 15, Koyna 15	Car Nicobar 10, Turuvekera 8, Gokak 7, Suri 7
18	Cherrapunji 19, Cooch Behar 14, Agumbe 13, Vaikam 12	Dibrugarh AP 25, Vapi 23, Cherrapunji 18, Radhanagari 13	Bhagamandala 19, Cnabra 19, Etan 19, Raibareilly 15	Mekhilganj 10, Bellary 8, Jeur 8, Bokajan 7
19	Alapuza 14, Baghdogra 11, Eraniel 9, Mangaon 9	Dharampur 17, Tamini 16, Mount Abu 11, Banda 9	Damoh 16, Sevoke 10, Jamankhira 9, Kalasa 9	Bobbilli 21, Car Nicobar 9, Potangi 7, Sukma 7
20	Mohitnagar 14, Kuhi 9, Bhadrachalam 7, Gaganbavda 7	Lolitpur 30, Rajasma 23, Ajaigarh 19, Daitry 15	Sailana 18, Rattam 17, Koyna 12, K. Patan 12	Tuni 9, Hasimara 8, Calcutta 7, Gopalpur 7
21	Cherrapunji 14, Mahabaleshwar 10, Agumbe 8, Dungarwadi 8	Teikol 26, Bhagamandala 19, Jabalpur 17, Sagar Island 13	Mandalgarh 14, Daitary 13, Koyna 12, Mahabaleshwar 12	Baptla 11, Gharmura 8, Kalingapatnam 7, Malsiras 7
22	Cherrapunji 27, Ratnagiri 19, Haldibari 14, Agumbe 10	Tensa 29, Guna 18, Bankura 16, Dharampur 13	Akhuapada 15, Bankura 15, Bantwal 13, Mangalore AP 12	Eluru 23, Nandigama 17, Kankavali 15, Vijayawada AP 14
23	Polavaram 11, Dibrugarh AP 9, Zahseerabad 9, Dhamtari 8	Barwaha 15, Koyana 14, Radhanagari 11, Toradi Sagar 11	Katghora 28, Desuri 16, Agumbe 15, Amgaon 15	Bhongir 22, Kankavli 13, Gangtok 12, Nalgonda 12
24	Sevoke 18, Karimganj 15, Hindol 11, Ankapalli 9	Car Nicobar 24, Khajuraho 13, Banswada 12, long Island 11	Bareilly 22, Jabalpur 22, Tamini 17, Ratlam 16	Chauldhaghat 15, Daltonganj 14, Gondia 12, Kasargode 10

TABLE 6—*contd.*

Date	June	July	August	September
25	Peermade 10, Cherrapunji 9, Bhatkal 7, Cochi AP 7	Hut Bay 18, Shahapur 18, Jaora 16, Nadiad 16	Orcha 17, Badi 14, Koyna 14, Gaganbavda 13	Koderu 17, Jhalung 14, Madras 10, Chauldhaghat 9
26	Connur 22, Kumta 17, Mangalore AP 11, Tiruvala 9	Kishanganj 20, Munnar 19, Radhanagari 17, Kadam 15	Sohagpur 16, Panbari 13, Kondul 12, Cooch Behar 11	Cherrapunji 19, Rosera 14, Sevoke 9, Shillong 7
27	Mananthavady 19, Panambur 16, Sandheads 16, Gharmura 12	Gaganbavada 32, Mahabaleshwar 25, Bhagamandala 25, Vadakancherry 22	Bankura 16, Chandbali 13, Gurgaon 13, Basua 8	Pattambi 9, Pasighat 8
28	Hubli 20, Vikarabad 15, Purnea 11, Agumbe 10	Agumbe 48, Mahabaleshwar 39, Poladpur 38, Puri 32	Daltonganj 18, Pathankot 15, Nancowry 13, Bansur 11	Port Blair 8, Shivpuri 7, Dharmapuri 7
29	Koyna 21, Pandavapura 20, Hubli 17, Harnai 12	Kataghora 37, Munnar 32, Puri 22, Agumbe 15	Sitapur 24, Bareilly 16, Lohinipada 14, Kahu 11	Sevoke 14, Champasarai 12
30	Hasimara 19, Baghdogra AP AP 12, Afzalpur 12, Sandheads 12	Betul 36, Narkhed 36, Hoshangabad 34, Nagpur 18 AP	Ragaul 22, Ajaigarh 11, Ujjain 11, Khajuraho 10	Sathankulam 8, Lakkavalli 7
31	—	Banswara 27, Cherrapunji 25, Thikri 25, Gandhinagar 18	Etah 16, Fatehgarh 7, Manmathnagar 7, Kursela 7	

NOTE — Rainfall amounts are in cm

25 persons lost their lives due to flash flood in west Siang districts of Arunachal Pradesh. 500 people of Mowad village in Nagpur district were washed away in a flash flood in *Wardha* river. 32 labours working in the upper Indravati Project were washed away by the surging flood waters that entered the tunnel at Koraput in Orissa on 20 July. 120 human lives were lost in floods over different parts of the country. Nearly 35 million people and 4,000 villages were affected while 1,111 heads of cattle were lost due to floods in Assam.

9.3. *August*

9.3.1. *Synoptic features*

Details of the synoptic features during August are given in Table 4.

9.3.2. *Monthly rainfall and monsoon activity*

Principal amounts of daily rainfall (in cm) are given in Table 6.

9.3.3. *Disastrous weather events and damages*

Assam experienced the third spell of floods during the month. The *Brahmaputra* and its tributaries, *viz., Sankosh, Manas, Buri-Dihing, Dikhaw, Dhansri, Jiabharali* and *Beki* were above danger mark. The *Kosi* river in Bihar, the *Baitarni* and the *Mahanadi* in Orissa, the *Ghaghra* in Uttar Pradesh, the *Ganga* in Bihar, West Bengal and Uttar Pradesh and the *Narmada* in Madhya Pradesh and Gujarat were in spate during the month.

22 people were reported missing in a boat accident in Puri district due to floods in the rivers *Bhargavi* and *Dharna*. Over 1.2 million people in about 2,000 villages were marooned due to floods in the Cuttack district of Orissa. The floods in Orissa affected 7.57 million people and damaged 84,786 houses and took a toll of 37 human lives and 4 lakh cattle heads. 49 people lost their lives due to flood in Uttar Pradesh.

9.4. *September*

9.4.1. *Synoptic features*

Details of synoptic features for the month of September are given in Table 5.

9.4.2. *Withdrawal of southwest monsoon*

Details are given under 2.5.

9.4.3. *Monthly rainfall and monsoon activity*

Principal amounts of daily rainfall (in cm) are given in Table 6.

9.4.4. *Disastrous weather events and damages*

Major rivers in Assam, Bihar, Uttar Pradesh, West Bengal were in spate till the third week of September. In Alwar district of Rajasthan 9 persons lost their lives due to incessant heavy rains. 60 persons died and 36.2 lakhs people were affected due to floods in sixty six blocks of West Bengal. 160 persons lost their lives and nearly 3,600 were affected due to Gastro enteritis in the state (West Bengal). Sikkim remained disconnected with other parts of the country for 9 days due to continuous rain and resulting land slide and around Sikkim State resulting land slide.