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Weather in India

POST-MONSOON SEASON (October - December 1997)*

1. Introduction

During the post-monsoon season 1997, one cyclonic storm (3-9 November) formed over the Bay of Bengal and one deep depression (11-13 November) formed over the Arabian Sea. The tracks of these systems are shown in Fig.1.

The southwest monsoon withdrew from the entire country on 8 October. The northeast monsoon set in over Tamil Nadu & Pondicherry, Kerala and adjoining parts of Andhra Pradesh and Karnataka states on 13 October. There was good rainfall activity over peninsular India during the season. Rainfall over all the eight meteorological sub-divisions of peninsular India was either excess or normal during the season. The seasonal rainfall for Tamil Nadu was 70% above normal and this surpassed the previous record of 66% above normal which was received in 1946. Northeast monsoon withdrew from the country on 31 December.

In addition to the seasonal northeast monsoon rainfall activity, most parts of India, particularly Maharashtra & Goa states, Madhya Pradesh, Uttar Pradesh, Bihar and western Himalayas received good amount of rainfall during first fortnight of December. This rainfall over other parts of India, out side Tamil Nadu, Kerala and adjoining parts of Karnataka and Andhra states was rather unusual.

During 11 to 17 December, cold wave conditions prevailed over northwest India. There was also widespread fog in the morning and persistence clouding during day time. Day temperatures were also below normal by 6° to 8°C during the above period.

2. Chief features

(*i*) Only one cyclonic storm over the Bay of Bengal and a deep depression over the Arabian Sea formed during the season.

(*ii*) Northeast monsoon rains commenced on 13 October over Tamil Nadu, Kerala and adjoining parts of Karnataka and Andhra states.

(*iii*) The seasonal rainfall during northeast monsoon was excess over the peninsular India. Most part of the country received usually high rainfall amounts during first fortnight of December.

(*iv*) During 2nd and 3rd week of December, cold wave conditions and widespread fog prevailed over northwest India, particularly in the morning. Persistent clouding was also observed during day time.

3. Seasonal rainfall (October-December)

Seasonal rainfall was excess in 22, normal in 5, deficient in 7 and scanty in 1 meteorological sub-divisions.

Rainfall was excess in Bihar Plateau, Uttar Pradesh, Haryana, Punjab, Himachal Pradesh, Jammu & Kashmir, Rajasthan, Madhya Pradesh, Madhya Maharashtra, Marathwada, Vidarbha, Telangana, Rayalaseema, Tamil Nadu, interior Karnataka, Kerala and Lakshadweep; normal in Orissa, Bihar Plains, Konkan & Goa, coastal Andhra Pradesh and coastal Karnataka; deficient in Andaman & Nicobar Islands, Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim and Gujarat Region and scanty in Saurashtra & Kutch. Seasonal rainfall departures are given Fig.2 and percentage departures in Table 1.

4. Monthly features

4.1. *October*

4.1.1. *Withdrawal of southwest monsoon*

Southwest monsoon withdrew from west Rajasthan on 18 September as against the normal date of 15 September. It further withdrew from rest of northwest India, Uttar Pradesh, west Madhya Pradesh, Gujarat State, Marathwada by 3 October as against the normal date of 1 October. It withdrew from entire country by 8 October, through the normal data is 15 October.

4.1.2. *Onset of northeast monsoon*

Northeast monsoon rains commenced over Tamil Nadu & Pondicherry, Kerala and adjoining parts of Andhra Pradesh and Karnataka by 13 October.

4.1.3. *Storms/depressions*

During the month of October no storm/depression formed over the Arabian Sea or the Bay of Bengal.

4.1.4. *Weather and associated synoptic features*

Table 2 gives details of the synoptic features for the month October 1997.

Northeast monsoon was vigorous on 1 to 2 days in coastal Andhra Pradesh and Rayalaseema and active on 3

*Compiled by: V. Thapliyal, D.S. Desai and V.Krishnan, Meterological Office, Pune, India

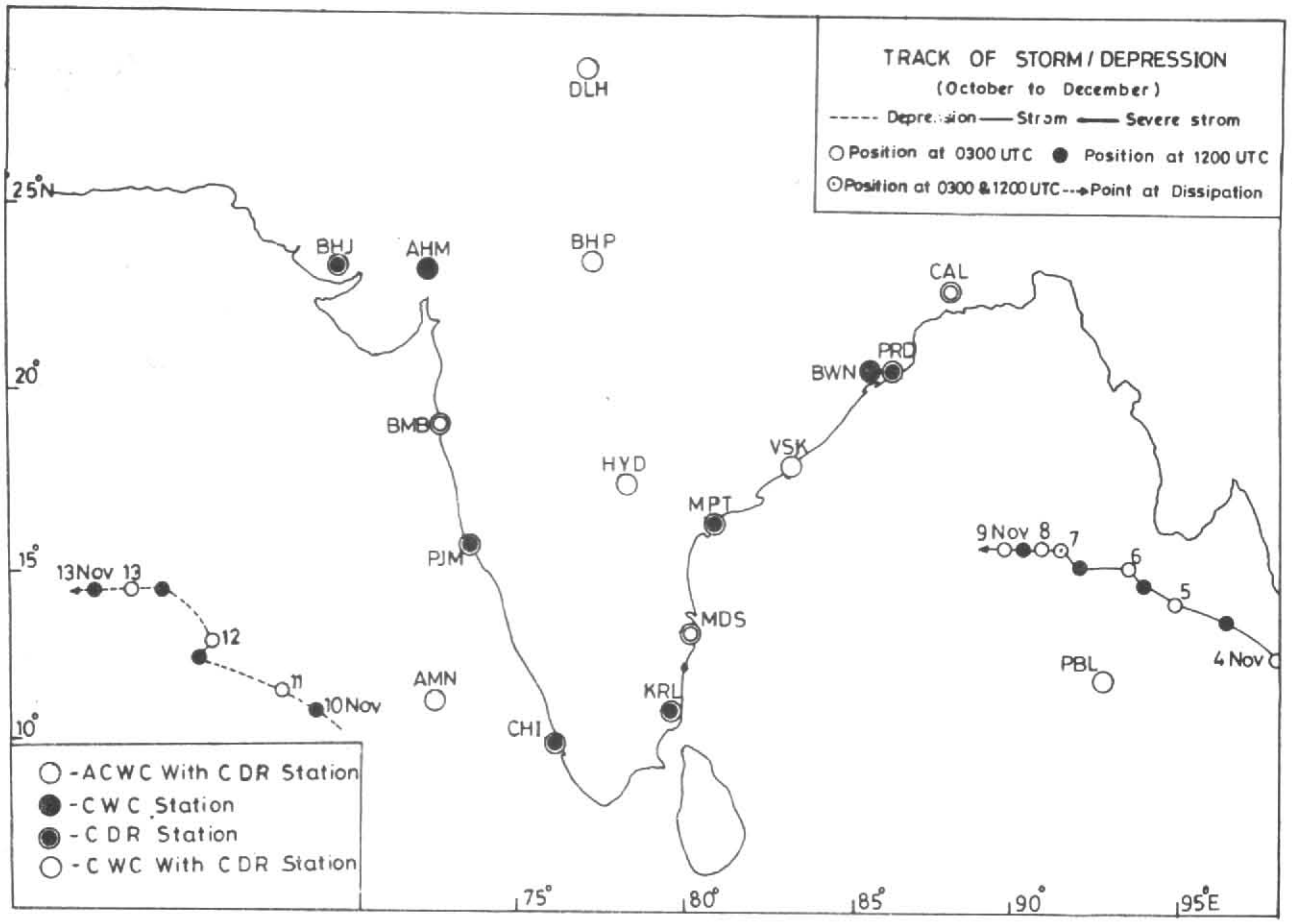

Fig.1. Tracks of storms/depressions during the period October to December 1997

days each in coastal Andhra Pradesh and Kerala. Very heavy rains occurred on 1 to 2 days in Orissa, Madhya Maharashtra, Tamil Nadu and south interior Karnataka. Rain or thundershowers have occurred either almost at all the places or at many places on 7 to 10 days in Marathwada and Kerala; on 4 to 6 days in Andaman & Nicobar Islands, Haryana, Himachal Pradesh, Jammu & Kashmir, Vidarbha, Tamil Nadu, coastal Karnataka and Lakshadweep and on 1 to 3 days in Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura, Gangetic West Bengal, east Uttar Pradesh, hills of west Uttar Pradesh, Punjab, Gujarat Region, Madhya Maharashtra, Telangana and south interior Karnataka.

4.1.5. *Monthly rainfall*

Monthly rainfall was excess in 11, normal in 8, deficient in 7 and scanty in 9 meteorological sub-divisions. Rainfall was excess in west Uttar Pradesh, Haryana, Punjab, Jammu & Kashmir, Rajasthan, west Madhya Pradesh, Marathwada, Vidarbha and Lakshadweep; normal in east Uttar Pradesh, Himachal Pradesh, east Madhya Pradesh, Madhya Maharashtra, Telangana, Tamil Nadu, south interior Karnataka and Kerala; deficient in Andaman & Nicobar Islands, Bihar Plateau, Gujarat Region, coastal Andhra Pradesh, Rayalaseema and coastal & north interior Karnataka and scanty in Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Orissa, Bihar Plains, Saurashtra & Kutch and Konkan & Goa. The significant amounts of rainfall (cm) during the month are given in Table 5.

4.1.6. *Temperature*

Day temperatures were appreciably to markedly above normal almost throughout the month over Konkan & Goa and coastal Karnataka. They were appreciably to markedly below normal by -5° to -9° C for many days in the month over the plains of west Uttar Pradesh, Haryana, Punjab, Kashmir and Rajasthan and were generally above normal or normal over the rest of the country except over interior Karnataka and Kerala where they were generally appreciably above normal for some days.

Highest maximum temperature of 37°C was recorded over some places in west Rajasthan, Gujarat Region and north Madhya Maharashtra during 10 to 13 October.

Night temperatures were either appreciably below or below normal on many days over Assam & Meghalaya,

The sample mean is $\bar{x} = 1.73422$ and so

$\hat{\theta} = 0.6379046$

After obtaining $\hat{\theta}$ we can compute the theoretical or expected frequencies and compare them with observed ones.The result of a goodness of fit test is as follows.

i	P_i	E_i	O_i
1	0.62796	189.01390	192
2	0.20028	60.28642	58
3	0.08518	25.63799	23
4	0.04075	12.26594	10
5	0.04583	13.79589	18

Chi-square calculated = 2.11

Chi-square tabulated = 9.49

Note that Cochran's model was applied to this data set in Section 2.2 and gave a Chi-square value of 24.21. In Section 4.2, the zero-truncated negative binomial distribution is fitted to the same data, with Brass estimates producing a Chi-square value of 0.56 and the maximum likelihood estimates giving a Chi-square value of 1.19. In comparison, the logarithmic series distribution gives a Chi-square value of 2.11. It then appears that the zero-truncated negative binomial distribution fits better than the logarithmic series distribution.

In this connection, it may be noted that the Chi-square value in case of the zero-truncated negative binomial distribution has 2 degrees of freedom, while that in case of the logarithmic series distribution is based on 3 degrees of freedom. This is so because the logarithmic series distribution has only one parameter, while the zero-truncated negative binomial distribution has two parameters, and that affects the degrees of freedom of the Chi-square test statistic.

We now summarise the results of fitting all the four distributions described above to rainfall data at the other four rainguage stations. In each case, O denotes the observed frequency, E_1 denotes the expected frequency according to the Cochran's model, E_2 denotes the expected frequency according to the zero-truncated Poisson distribution, E_3 denotes the expected frequency according to the zero-truncated negative binomial distribution (Brass estimator), E_4 denotes the expected frequency according to the zero-truncated negative binomial distribution (maximum likelihood estimator), and E_5 denotes the expected frequency according to the logarithmic series distribution.

6.1. *Buldhana*

	1	2	3	4	5	Sample value	Table value
O	289	114	62	25	29		
E_1	263.40	129.06	63.23	30.40	32.91	$\chi^2 = 5.69$	$\chi^2_3 = 7.81$
E_2	225.47	167.59	83.04	30.86	12.04	$\chi^2 = 65.37$	$\chi^2_3 = 7.81$
E_3	291.47	112.86	53.23	27.33	34.11	$\chi^2 = 2.44$	$\chi^2_3 = 5.99$
E_4	290.55	114.49	53.83	27.35	32.78	$\chi^2 = 1.89$	$\chi^2_3 = 5.99$
E_5	303.55	105.56	48.95	25.53	35.41	$\chi^2 = 6.02$	$\chi^2_3 = 7.81$

It may noted here that most of the distributions of fits satisfactorily, while their relative performances are more or less similar to what was observed for Osmanabad. Only, the maximum likelihood estimates have given a better fit than Brass estimates for the zero-truncated negative binomial distribution.

6.2. *Wardha*

	1	2	3	4	5	Sample value	Table value
O	387	136	65	31	46		
E_1	341.91	166.69	81,26	39.30	35.84	$\chi^2 = 19.48$	$\chi^2_3 = 7.81$
E_2	293.52	214.40	104.40	38.13	14.55	$\chi^2 = 142.62$	$\chi^2_3 = 7.81$
E_3	327.78	156.09	81.05	43.83	56.25	$\chi^2 = 22.09$	$\chi^2_3 = 5.99$
E_4	378.76	137.89	63.82	32.69	51.84	$\chi^2 = 0.97$	$\chi^2_3 = 5.99$
E_5	391.51	135.18	62.23	32.23	43.85	$\chi^2 = 0.33$	$\chi^2_3 = 7.81$

The results for Wardha are similar to those obtained for Osmanabad and Buldhana. Note that the zero-truncated Poisson distribution gives a very bad fit compared to the other three distributions.

6.3. *Gondia*

The zero truncated negative binomial and the logarithmic series distributions have provided with good fits, while the other two models have not provided with good fits, although the relative performances of the four models are very similar to the earlier results.

	1	2	3	4	5	6	7	Sample value	Table value
O	546	244	132	69	50	27	49		
E_1	514.67	273.47	146.26	77.97	57.75	22.15	24.73	$\chi^2 = 33.43$	$\chi^2_5 = 11.07$
E_2	358.40	315.67	229.97	112.81	44.26	14.47	5.42	$\chi^2 = 551.92$	$\chi^2_5 = 11.07$
E_3	543.12	274.15	131.74	75.37	44.88	27.43	20.32	$\chi^2 = 44.94$	$\chi^2_4 = 9.49$
E_4	544.78	245.36	130.69	74.98	44.88	27.60	48.71	$\chi^2 = 1.10$	$\chi^2_4 = 9.49$
E_5	584.37	225.23	115.75	66.92	41.27	26.51	56.95	$\chi^2 = 9.39$	$\chi^2_5 = 11.07$

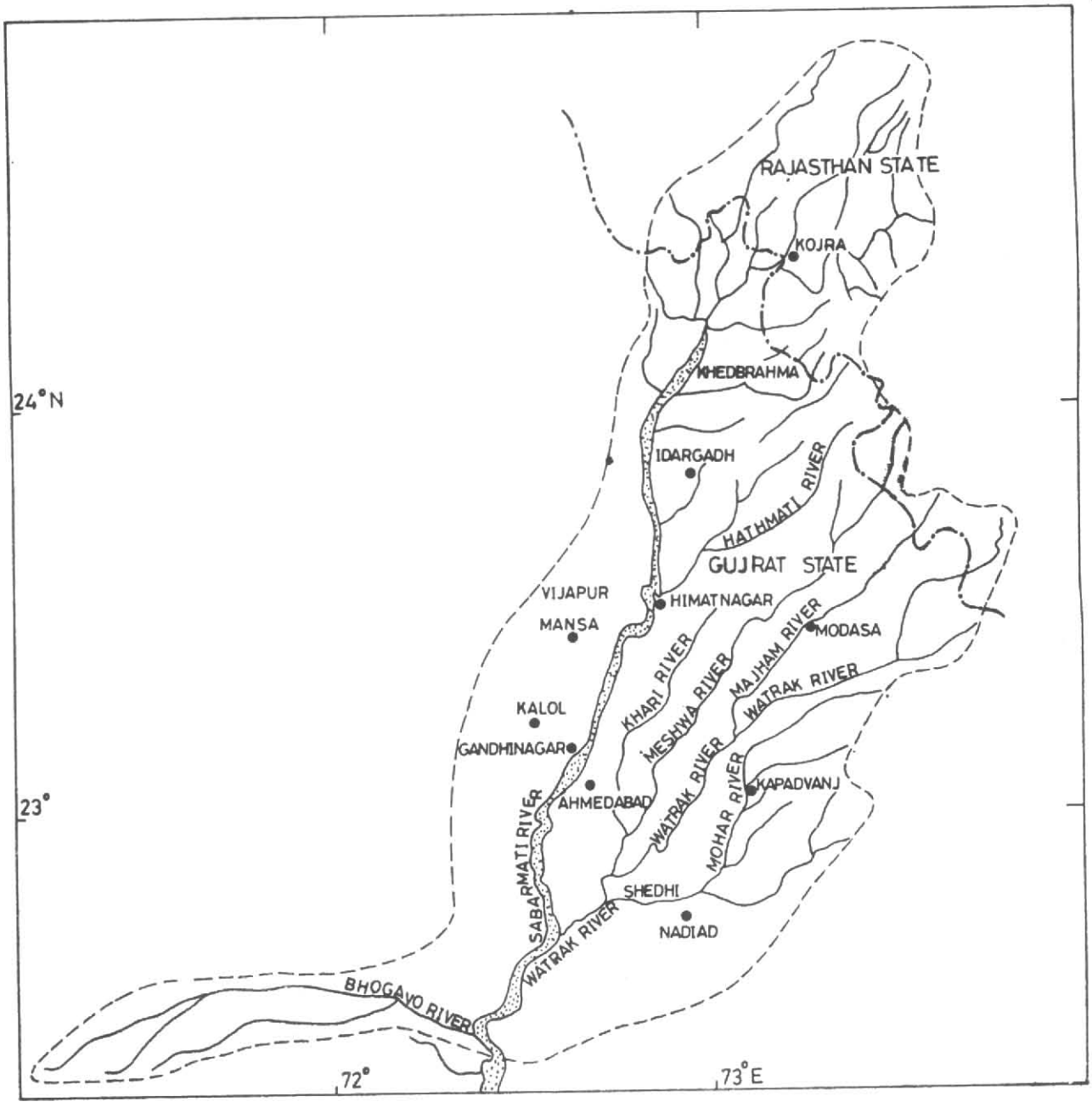

Fig. 1. Catching of river Sabarmati

0000 UTC upper air charts responsible for weighted average rainfall more than 11 mm have been collected data wise.

3. Results and discussion

It is found that out of total 307 occasions of rainfall more than 11 mm, for the given synoptic conditions (S1, S2, S3 and S4), maximum number of occasions of rainfall over the catchment are due to low / well marked low pressure (45 percent) and out of these, 60 percent of the occasions are due to low/well marked low pressure over west Madhya Pradesh and adjoining and 20 percent due to low/well marked low pressure over east Rajasthan (Table 1).

The second most important synoptic condition is the upper air cyclonic circulation, 31 percent of the occasions of rainfall are due to upper air cyclonic circulations (mostly at mid tropospheric level) and of these 57 percent are due to upper air cyclonic circulation over Gujarat region.

East west trough at mid tropospheric levels contributes 18 percent of the total cases and cyclones/deep depression/ depression contributes remaining 6.0 percent. From Table 1

(*iv*) *Crop growth duration* — The total crop duration D varied from 87 days at Parbhani to 120 days at Banswara. The seed yield Y varied from 5.51 q/ha at Parbhani to as high as 24.31 q/ha at Banswara. Correlation between yield Y and crop growth duration D, though not high, was neverthless significant and gave the following regression.

$$Y = 1.16\,D - 100.49 \qquad (R^2 = 39.7\%) \qquad (4)$$

3.3. *Evapotranspiration and the yield*

Soybean production is a complex integration of environmental factors and adequate water must be available for optimum growth. The water use, however, varies from location to location and phase to phase. The soybean crop in the tropics appears less sensitive to stress during flowering. Singh and Saxena (1969) have rightly pointed out that soybean can withstand short period of drought in India.

The seed yield was next correlated with ET during different phases as also during complete crop duration. Significant correlation (R^2 = 42.3%) could be obtained between yield and ET during vegetative phase only. Use of square and higher degree terms in ET did not improve the correlation coefficient substantially.

In order to improve the correlation, a multiple regression was next attempted using the following factors:

(a) ET during vegetative phase (X_2)

(b) Rainfall during vegetative phase (X_3)

(c) Rainfall during the entire growth period (X_4)

(d) Duration (days) of vegetative phase (X_5)

(e) Duration (days) of flowering (X_6)

The multiple regression obtained was

$$X_1 = -0.29X_2 + 0.91\,X_3 - 0.34\,X_4 + 96.4\,X_5 - 12.4\,X_6 - 2306.7 \qquad (5)$$

where X_1 is seed yield (kg/ha).

The multiple correlation in this case was found as R^2 = 75.7%, significant at 20% level.

Flowering being an important pheno-phase in the growth cycle of soybean, the duration of flowering was then split into those equal to or below 16 days and exceeding 16 days as in section 3.2(*ii*) retaining the factors (a) to (e) above. When the flowering duration was less than 16 days the multiple correlation coefficient was not high but improved conspicuously to R^2 = 94.1% for duration exceeding 16 days thus corroborating the observations made earlier that increase in flowering duration enhance the yield. The multiple regression obtained was

$$X_1 = -9.87\,X_2 + 3.48\,X_3 + 0.34\,X_4 + 174.35\,X_5 + 16.42\,X_6 - 6905.0$$

4. Conclusions

Following conclusions emerge from the present study:

(*i*) The vegetative phase rainfall bears a significant correlation with yield.

(*ii*) The duration (days) during vegetative phase is also significantly correlated with yield.

(*iii*) Above average number of days of flowering bear significant (at 5% level) correlation with soybean yield.

(*iv*) The soybean crop uses maximum amount of water, *i.e*, about 4.2 mm per day during vegetative phase when active growth takes place.

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on the same evening over the east-central Bay. Based on INSAT imagery, peak intensity was reported as T 2.5 from 061800 UTC to 080200 UTC on Devorak's scale. Since the system was far away from the Indian coast and dissipated over the sea area, it did not cause any adverse weather over the country. Northern parts of Andaman & Nicobar Islands received fairly widespread rainfall from 4 to 7 November.

(b) *Deep depression over Arabian Sea (11-13 November)* - A well- marked low pressure area formed over Kerala and adjoining parts of Tamil Nadu on 8. It moved westwards across Kerala and Lakshadweep area and lay over southeast Arabian Sea with its central region near Lat. 11.0° N/Long. 69.0° E on 10. It concentrated into a deep depression on 11 and lay centred at 110300 UTC within half a degree of Lat. 11.5° N/Long. 68.0°E. On 12, it lay as a deep depression centred at 120300 UTC near Lat. 13.0° N/Long. 66.0°E. The deep depression over east-central Arabian Sea weakened into a depression on 13 and lay centred at 130900 UTC near Lat. 14.5° N/Long. 62.5°E and further weakened into a low pressure area.

The system did not cause any adverse weather over the country as it was far away from the Indian coast and dissipated over the sea area.

4.2.2. *Weather and associated synoptic features*

Details of synoptic features for the month of November 1997 are given in Table 3.

Northeast monsoon was vigorous on 3 days in Kerala and on 1 day in coastal Andhra Pradesh. It was active on 6 to 7 days in coastal Andhra Pradesh and Kerala and on 1 day in Rayalaseema. Very heavy rainfall at one or two places occurred on 6 days in Tamil Nadu and on 1 to 3 days in Jammu & Kashmir and Kerala. Heavy rainfall also occurred at one or two places on 9 days in Tamil Nadu and on 4 to 6 days in Andaman & Nicobar Islands and Kerala and on 1 to 3 days in coastal Andhra Pradesh, south interior Karnataka and Lakshadweep. Rain or thundershowers occurred either almost at all the places or at many places on 18 days in Tamil Nadu, on 9 to 11 days in Andaman & Nicobar Islands and Marathwada on 4 to 7 days in Himachal Pradesh, Madhya Maharashtra, Kerala and Lakshadweep and on 1 to 3 days in Nagaland, Manipur, Mizoram & Tripura, hills of west Uttar Pradesh, Haryana, Punjab, Jammu & Kashmir, Madhya Pradesh, Konkan & Goa, Vidarbha, Rayalaseema and Karnataka.

4.2.3. *Monthly rainfall*

Rainfall was excess in 25 normal in 2, deficient in 4 and scanty in 4 meteorological sub-divisions. Rainfall was normal in Andaman & Nicobar Islands, coastal Andhra Pradesh deficient in Assam & Meghalaya, Sub-Himalayan West Bengal & Sikkim, Orissa and east Uttar Pradesh and scanty in Nagaland, Manipur, Mizoram & Tripura, plains of west Uttar Pradesh and Gujarat State. It was excess over the rest of the 25 meteorological sub-divisions.

4.2.4. *Temperature*

Night temperatures were below or appreciably below normal on 5 to 6 days in Assam & Meghalaya and Himachal Pradesh. They were appreciably to markedly above normal almost throughout the month over Nagaland, Manipur, Mizoram & Tripura, Orissa, Bihar Plains, plains of Uttar Pradesh, Haryana, Kashmir, Rajasthan, Madhya Pradesh, Gujarat Region, Maharashtra & Goa states, coastal Andhra Pradesh, Telangana and coastal & North interior Karnataka.

On many days from 22 to 30 November 6°C was the lowest minimum temperature over plains recorded at Amritsar and -3°C was the lowest minimum temperature recorded over hills at Kalpa on 11 & 27 November.

4.2.5. *Disastrous weather events and associated damages*

Due to heavy rains in Maharashtra, 4 children lost their lives on 27 November. In different parts of east Uttar Pradesh 36 people were killed and 50 injured following heavy thundershower activity on 30 November.

4.3. *December*

4.3.1. *Storms/depressions*

No storms/depressions formed over the Arabian Sea or the Bay of Bengal during the month.

4.3.2. *Weather and associated synoptic features*

Table 4 gives the details of the synoptic features for the month of December 1997.

Northeast monsoon was vigorous on 2 days each in coastal Andhra Pradesh, Rayalaseema and Kerala. Heavy to very heavy rains occurred on 12 days in Tamil Nadu and heavy rains also occurred on 1 to 2 days in Nagaland, Manipur, Mizoram & Tripura and Orissa. Rain or thundershowers occurred either almost at all the places or at many places on 12 days in Tamil Nadu; on 4 to 6 days in Haryana, Himachal Pradesh, east Madhya Pradesh, Marathwada and Vidarbha and on 1 to 3 days in Andaman & Nicobar Islands, Arunachal Pradesh, Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, West Bengal & Sikkim, Orissa, Bihar Plateau, Uttar Pradesh, Punjab, Jammu & Kashmir, east Rajasthan, west Madhya Pradesh, Konkan & Goa, Madhya Maharashtra, Telangana, Karnataka and Lakshadweep.

Snowfall occurred on 2 to 3 days in Himachal Pradesh and Jammu & Kashmir during the month.

TABLE 3

Details of weather systems during November 1997

S. No.	System	Duration	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(A) *Storms and depressions*						
(1)	Cyclonic Storm	3 - 9	North Andaman Sea	Initially northerly, then northnortheasterly, northnorthwesterly, northerly and finally northnortheasterly	North Bay	The TS LINDA emerged into north Andaman Sea on evening of 3 as a cyclonic storm. Moving in a northerly direction it weakened into a depression over east-central Bay on 9 and further weakened into a well-marked low pressure area over east-central Bay and neighbourhood on 10. It became less marked on 12 over the same area
(2)	Deep Depression	10 - 13	Southeast Arabian Sea and neighbourhood	Initially northwesterly and then westerly	West- central Arabian Sea	It was first observed as a cyclonic circulation on 30 October over southwest Bay off north Tamil Nadu coast. It lay as a low pressure area over southwest Bay off Sri Lanka coast on 5 November. It became well-marked on 8 and lay over Kerala and adjoining parts of Tamil Nadu. It concentrated into a depression probably deep near 11.5° N/68.0°E on 11 and as a deep depression on 12 near 13.0° N/66.0°E. It weakened into a depression on 13 afternoon over east-central Arabian Sea and further weakened into a low pressure area on 14 over west-central Arabian Sea
(B) *Low pressure areas*						
(1)	Low pressure area	16 - 18	Southwest Bay off Tamil Nadu-Sri Lanka coasts	Stationary	*In situ*	It was first observed as a trough of low pressure area over southwest Bay on 13. Associated cyclonic circulation extended upto mid tropospheric levels on 16 and tilted south westwards with height on 17. After the low pressure area became less-marked the associated cyclonic circulation apparently persists over north Tamil Nadu and neighbourhood. The cyclonic circulation lay over northern parts of Karnataka and adjoining Kerala and a trough from this system to south Maharashtra coast on 20 & 21. On 22, the cyclonic circulation lay over Lakshadweep-Maldives area and adjoining Kerala. It lay as a trough of low pressure area over the same area on 23 and 24. It became well-marked on 25 over Karnataka and adjoining Kerala and extends northwards to south Konkan & Goa along and off west coast
(C) *Induced cyclonic circulation*						
(1)	Lower tropospheric levels	9 - 12	West Rajasthan and neighbourhood	Northeasterly	Haryana and neighbourhood	

TABLE 3 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
(2)	Mid tropospheric levels	23 - 28	South Rajasthan and neighbourhood	Do	Punjab, Haryana, Himachal Pradesh and adjoining Jammu & Kashmir	With a trough aloft on 24
(D) *Other cyclonic circulations*						
(1)	Lower tropospheric levels	1 - 3	Southern parts of Lakshadweep and adjoining Maldives area	Quasi-Stationary	Lakshadweep and adjoining Kerala	
(2)	Mid tropospheric levels	7 - 9	Northwest Rajasthan and adjoining Punjab	Northeasterly	Haryana and adjoining parts of Uttar Pradesh	Moved away across hills of west Uttar Pradesh
(3)	Lower levels	10 - 11	Southwest Bay off Tamil Nadu coast	Stationary	In situ	
(4)	Lower tropospheric levels	12 - 14	Northwest Madhya Pradesh and neighbourhood	Do	Do	A trough from the system to Marathawada was observed on 12 and became less marked on 13
(5)	Mid tropospheric levels	15 - 16	North Haryana and neighbourhood	Northeasterly	Moved away northeastwards.	
(6)	Do	19 - 20	West-central Bay off south Andhra-north Tamil Nadu coasts	Stationary	*In situ*	
(7)	Lower levels	22 - 26	Gujarat State and neighbourhood	Northeasterly	South Gujarat State	
(E) *Troughs of low*						
(1)	Sea level chart	27 Nov - 11 Dec	Southwest Bay and adjoining westcentral Bay off Tamil Nadu-Sri Lanka coasts	Quasi-stationary	North Andhra Pradesh coast to south Tamil coast	
(F) *Troughs in easterlies*						
(1)	Lower levels	1 - 2	Gulf of Cambay to south Rajasthan	Stationary	*In situ*	
(2)	Do	3 - 4	Kerala coast to south Maharashtra coast	Do	Do	
(3)	Do	11 - 12	Haryana to south Madhya Maharashtra across east Rajasthan	Do	Do	
(G) *Other Troughs*						
(1)	Sea level chart	4 - 9	South Maharashtra coast to Kerala coast	Do	Do	
(2)	Do	18 - 21	Karnataka coast to Kerala coast	Do	Do	
(H) *Western disturbances*						
(1)	Upper air system	9 - 12	North Pakistan and neighbourhood	Northeasterly	Moved away northeasterly across Jammu and Kashmir	
(2)	Do	15 - 17	Do	Do	Do	
(3)	Do	19 - 21	North Pakistan and adjoining Jammu & Kashmir	Do	Do	
(4)	Do	21 - 25	North Pakistan and neighbourhood	Do	Do	
(5)	Do	22 - 26	South Pakistan and neighbourhood	Do	Do	
(6)	Do	27 - 28	Jammu & Kashmir and adjoining north Pakistan	Do	Do	
(7)	Do	30 Nov - 3 Dec	Do	Do	Do	

TABLE 4

Details of the weather systems during December 1997

S. No.	System	Duration	Place of first location	Direction of movement	Place of dissipation	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
(A) *Western disturbances*						
(1)	Upper air system	3 - 7	North Pakistan and adjoining Jammu & Kashmir	Northeasterly	Moved away northeastwards across Jammu & Kashmir	
(2)	Do	7 - 11	North Pakistan and adjoining Afghanistan	Do	Do	
(3)	Do	12 - 14	North Pakistan and neighbourhood	Do	Do	
(4)	Do	19 - 21	Do	Do	Do	
(5)	Do	22 - 25	Do	Do	Do	
(6)	Do	28 - 31	Do	Do	Do	
(B) *Induced cyclonic circulations*						
(1)	Lower tropospheric levels	7 - 11	West Rajasthan and neighbourhood	Easterly	Northern parts of east Uttar Pradesh	A trough from this system to Maharashtra coast in the lower levels was seen on 8, to Karnataka on 9 and to north coastal Andhra Pradesh on 10
(2)	Mid tropospheric levels	28 - 31	Punjab and adjoining parts of Pakistan	Northeasterly	Haryana and adjoining parts of Himachal Pradesh	Moved away across hills of west Uttar Pradesh
(C) *Other cyclonic circulations*						
(1)	Mid tropospheric levels	4 - 6	Punjab and adjoining areas of Haryana and Himachal Pradesh	Easterly	Haryana and adjoining areas of west Uttar Pradesh and Himachal Pradesh	
(2)	Lower tropospheric levels	10 - 11	Bihar Plateau and adjoining Sub-Himalayan West Bengal	Stationary	*In situ*	
(3)	Do	11 - 12	Gangetic West Bengal	Do	Do	
(4)	Do	13 - 15	East Rajasthan and adjoining parts of west Madhya Pradesh	Southeasterly	Southeast Uttar Pradesh and adjoining east Madhya Pradesh	A trough from this system to Telangana in the lower levels was observed on 14 and became less marked on 15. These two cyclonic circulations (Nos. 4 & 5) were embedded in mid and upper tropospheric westerlies whose axis at 9.5 kms a.s.l. passed from west Punjab to west Madhya Pradesh. The trough was seen from sub Himalayan West Bengal to northeast Bay on 14 and became less marked on 15
(5)	Mid tropospheric levels	13 - 15	Haryana and adjoining parts of Punjab	Northeasterly	Moved away across hills of west Uttar Pradesh	

TABLE 4 (*Contd.*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
(6)	Mid tropospheric levels	16 - 18	Northeast Rajasthan and neighbourhood	Easterly	Southwest Uttar Pradesh and neighbourhood	
(7)	Do	19 - 21	Punjab and adjoining parts of Haryana	Northeasterly	Hills of west Uttar Pradesh neighbourhood	
(8)	Lower tropospheric levels	22 - 23	South Gujarat Region and neighbourhood	Stationary	*In situ*	
(9)	Lower levels	24 - 25	East Vidarbha and neighbourhood	Do	Do	
(10)	Lower tropospheric levels	26 - 29	Nagaland, Manipur, Mizoram & Tripura	Do	Do	
(11)	Lower levels	27 - 31	Northwest Madhya Pradesh and neighbourhood	Southeasterly	Southwest Madhya Pradesh and adjoining Vidarbha	
(12)	Mid tropospheric levels	31 Dec-1 Jan	Eastern parts of northeast Bihar Plains	Stationary	*In situ*	
(D) *Troughs in westerlies*						
(1)	Mid and upper tropospheric levels	8 - 11	67°E, north of 15°N	Easterly	80°E, north of 17°N	Tilted westwards with height on 9, 10 and 11
(E) *Troughs in easterlies*						
(1)	Lower levels	13 - 14	Marathwada to south Tamil Nadu	Stationary	*In situ*	
(2)	Do	17 - 19	North interior Karnataka to south Tamil Nadu	Westerly	Coastal Karnataka to south Kerala	
(3)	Do	21 - 24	Do	Stationary	*In situ*	
(F) *East-west troughs*						
(1)	Do	15 - 16	Bihar Plains to north Assam	Do	Do	
(G) *Other troughs*						
(1)	Lower levels	11 - 12	Southeast Bay	Do	Do	
(2)	Sea level chart	12 - 18	Karnataka coast to Kerala coast	Do	Do	
(3)	Lower tropospheric levels	16 - 17	West Rajasthan to southwest Madhya Pradesh	Do	Do	
(4)	Sea level chart	24 Dec - 4 Jan	Karnataka coast to Kerala coast	Do	Do	

TABLE 5
Principal amounts of rainfall (cm)

Date	October	November	December
(1)	(2)	(3)	(4)
1.	Bangalore & Subramanyam 18 each, Dharamapuri 15, Sevoke 10, Devanahalli 9, Narasapur 6, Hyderabad & Gheropara 4 each, Kozhikode 3, Balasore, Dharamsala & Jaipur 2 each	Mysore 7, Vadakancherry 5, Hut Bay 4, Ranchi, Jagdalpur, K.Paramathy & Minicoy 3 each, Bhadgaon 2, Guna & Karwar 1 each	Purna 8, Gondia & Raigarh 6 each, Poladpur 5, Varanasi & Rampur Bushan 4 each, Dehra Dun & Hoshangabad 3 each, Car Nicobar, Chandigarh & Shirgaon 2 each, Bankura, Jamshedpur, Bareilly & Mahebubnagar 1 each
2.	Agartala 5, Calcutta 4, Sevoke, Kankavli, Chickmagalur 3 each, Mahendragarh, Jaisalmer, Gaganbavda, Ongole, Hyderabad & Chennai 2 each, Hut Bay & Dharamsala 1 each	Kondul 4, Nelore 3, Chennai 2, Sholapur, Medikeri & Punalur 1 each	Beed 3, Bankura, Jharsuguda & Patna 2 each, Nancowry, Bhagalpur, Tondi & Aryankavu 1 each
3.	Mysore 9, Guhla 7, Dehra Dun & Kahu 6 each, Salem 5, Raya & Amini Divi 3 each, Purulia & Karad 2 each, Ranchi, Ayodhya, Dabri, Churu, Jaipur, Jabalpur, Panjim & Medak 1 each	Vadakkancherry 7, Chennai 6, Nellore 4, Cuddapah 3, Ghodegaon 2, Medikeri 1	Amraoti 10, Tondi 5, Pune 4, Kondul 3, Aurangabad 2, Gopalpur 1
4.	Nedumangad 7, Bikaner & Virudhunagar 6 each, Shirol 4, Nakodar, Guhla, Jaipur & Bodeli 3 each, Port Blair, Bareilly, Mukteswar & Guna 1 each	Nagapattinam 9, Cochi 7, Nellore 6, Kondul 4, Arogyavaram 2	Vedaraniyam 12, Khandwa 5, Jabalpur 4 Kondul 3, Nagpur 2
5.	Nancowry & Bikaner 4 each, Hissar & Visakhapatnam 3 each, Ranchi, Mainpuri & Islampur 2 each, Amritsar, Shimla, Jaipur, Deesa, Gadag & Alapuzha 1 each	Kondul 6, Pamban & Kumarakon 5 each, Nellore 3, Hassan 2, Surat 1	Kondul & Thanjavur 8 each, Jabalpur 5, Nellore 3, Bhopal, Minicoy & Jalgaon 2 each, Haripad 1
6.	Ghamroor 6, Kanpur 5, Ambala, Dholpur, Kannod, Palayamkottai, Punalur & Minicoy 3 each, Kondul, Keonjhargarh, Agra, New Kandla & Kandhar 2 each, Patiala & Chitradurga 1 each	Karaikal & Nagapattinam 21 each, Thanjavur 11, Port Blair 8, Kottayam 4	Karaikal 9, Bhopal & Nedumangad 4 each, Nellore 3, Cuddapah 1
7.	Ottapalam 8, Car Nicobar 4, Coimbatore & Chickmagalur 3 each, Hissar 2, Kailashshahar, Lucknow, Pendra & Raichur 1 each	Chennai 18, Karaikal 17, Car Nicobar 7, Konni 5, Satara 2	Nagapattinam 19, Cochi 9, Nellore 8, Tirupathi & Minicoy 4 each, Satna & Shajahanpur 2 each, Banswara 1
8.	Thalassery 7, Port Blair 6, Hassan 5, Kodaikanal 4, Shimla & Narsapur 3 each	Nagapattinam 15, Karaikal 14, Kaveli 8, Long Island 7, Alapuzha 6, Nellore 5, Chowari 3, Lakkireddipalli 2, Cumbum 1	Parangipettai 15, Ratnagiri 11, Nellore 9, Bhivani & Ratlam 5 each, Bir 4, Mahabaleshwar 3, Banda, Kota, Arogyavaram & Amini Divi 2 each, Nadaun 1
9.	Agartala & Bangalore 3 each, Kakinada 2, Nancowry, Dibrugarh, Palayamkottai & Punalur 1 each	Thiruvananthapuram 10, Car Nicobar & Long Island 7, Madurai 5, Amritsar & Tuni 2 each, Ranchi, Dharamsala, Ganganagar & Mangalore 1 each	Narnaul 17, Balachaur, 16, Sattur & Jhansu 14 each, Guler 8, Karwar 7, Aurangabad & Panjim 6 each, Lucknow, Gwalior & Mysore 5 each, Kakinada 4, Ramagundam & Bidar 3 each, Gopalpur, Katra & Bharatpur 2 each, Dehra Dun, Satna & Kurnool 1 each

TABLE 5 (*Contd.*)

(1)	(2)	(3)	(4)
10.	Jaigam 6, Karipur 5, Kondul 4, Ganganagar 3, Jamshedpur, Sirsa, Machilipatnam Tuticorin & Bagati 1 each	Shantiniketan & Minicoy 7 each, Long Island 6, Berthina 5, Nangal 4, Panjim, Radhanagari & Thiruvananthapuram 2 each, Muzzaffarnagar, Dehra Dun, Chandigarh, Srinagar & Karwar 1 each	Puri 10, Ambala 7, Bareilly, Coimbatore & Aryankavu 5 each, Gorakhpur & Dehra Dun 4 each, Gangtok, Kahu & Pendra 3 each, Ranchi, Patiala, Nagpur, Visakhapatnam & Krishnanagar 2 each, Long Island, Bharatpur, Gwalior & Mangalore 1 each
11.	Sikar 5, North Lakhimpur, Churu, Pendra, Tuticorin & Cochi 2 each, Purulia, Fatehabad & Nurpur 1 each	Chitradurga 9, Long Island 6, Bhuntar & Bijapur 3 each, Darjeeling, Panjim, Mahabaleshwar , Chennai & Karwar 2 each, Aurangabad 1	Domohani 8, Imphal 6, Mancompu 5, Silchar 3, Krishnanagar 2, Long Island & Chennai 1 each
12.	Thiruvananthapuram3, Narnaul, Palayamkottai & Panambur 2 each, Nancowry, Gangtok, Jodhpur & Guna 1 each	Bangalore 6, Kondul & Ahmednagar 5 each, Vengurla 4, Ghumarwin 3, Cooch Behar, Satna & Palyamkottai 2 each, Agartala, Udgir & Amini Divi 1 each	Nagapattinam 4, Ongole 3, Kozhikode 2, Gwalior & Tirupathi 1 each
13.	Tondi 6, Cochi 5, Gangtok 2, Kondul & Calcutta 1 each	Thane (Belapur) & Kurnool 5 each, Gadag 4, Sankalan & Ramagundam 3 each, Hut Bay, Tilpara & Chickmagalur 2 each, Patna, Mahabaleshwar, Cochi & Amini Divi 1 each	Nellore3, Nagapattinam2, Fatehabad & Gwalior 1 each
14.	Saoner 4, Tiruchirapalli, Cochi & Minicoy 3 each, Barmer, Udaipur & Mangalore 2 each, Jalpaiguri & Pendra 1 each	Ahmednagar 6, Vaijapur & Gadag 5 each, Kozhikode 4, Nancowry & Ramagundam 3 each, BaghDogra & Patna 2 each, Diamond Harbour 1	Kaveli 11, Digha & Karaikal 3 each, Minicoy, Raipur & Puri 2 each, Gorakhpur, Dehra Dun, Narwana & Dholpur 1 each
15.	Kodaikanal 6, Bhopal, Watrak Dam & Amini Divi 4 each, Kozhikode 3, Belgaum 1	Sudhagad 5, Chennai 4, Port Blair, Puri & Nasik 3 each, Hyderabad 2	Tuticorin 9, Khanitar 3, Dibrugarh & Paradip 2 each, Nancowry, Midnapore & Visakhapatnam 1 each
16.	Tasgaon & Karaikal 3 each, Chotan & Thiruvananthapuram 2 each, Banda, Ajmer, Bhopal & Belgaum 1 each	Nedumangad 9, Cuddalore 7, Sholapur 4, Nellore 2, Hut Bay, Jagdalpur & Ramagundam 1 each	Ongole 7, Anantpur 5, Tuticorin 4, Khammam 3, Minicoy 2, Bellary & Kozhikode 1 each
17.	Karaikal 7, Kozhikode 4, Tirupathi 2	Alapuzha 12, Cuddalore 7, Nellore 5, Tirupathi & Nancowry 4 each, Osmanabad 3, Bangalore 2, Parner 1	Ongole 25, Cannur 7, Akola 5, Ahmednagar & Kodaikanal 3 each, Kondul & Nalgonda 2 each, Bhopal & Parbhani 1 each
18.	Chennai 5, Panipat 3, Ludhiana, Batote, Udaipur & Ahmednagar 2 each, Tezpur, Guler, Ganganagar & Vaijapur 1 each	Visakhapatnam 6, Guna 5, Coimbatore 4, Car Nicobar, Jagdalpur & Jabalpur 3 each, Mangalore & Bangalore 1 each	Chennai 5, Kayamkulam 4, Minicoy 2, Kondul, Jharsuguda, Raipur & Gondia 1 each
19.	Cochi 5, Sinner 4, Jaisalmer & Nawalgarh 1 each	Cochi 9, Medak & Vellore 6 each, Mysore 5, Machilipatnam 4, Car Nicobar, Shimla, Latur, Akola, Arogyavaram & Amini Divi 3 each, Gaya, Pendra & Chandwad 2 each, Jamshedpur, Varanasi & Sagar 1 each	Thiruvananthapuram 5, Karaikal 4
20.	Nimrana 6, Narnaul & Jammu 5 each, Gargoti & Parbhani 4 each, Karaikal & Kottyam 3 each, Pusad 2, Nancowry, Nahan, Ganganagar, Jabalpur & Minicoy 1 each	Contai 5, Shimla, Pendra, Beed & Kalingapatnam 3 each, Balasore, Jabalpur, Sangli & Kozhikode 2 each, Port Blair & Cuddalore 1 each	Car Nicobar & Cuddalore 6 each, Kottayam 4
21.	Thanjavur & Munnar 5 each, Hut Bay, Bhiwani, Amritsar, Udhampur & Manora 3 each, Dharamsala & Kolhapur 2 each, Gorakhpur, Jhansi, Satna & Kandhar 1 each	Tiruchirapalli 7, Long Island 6, Gadag 5, Nizamabad 3, Thiruvananthapuram 2	Karipur 8, Nancowry & Karaikal 4 each, Bangalore 1

TABLE 5 (*Contd.*)

(1)	(2)	(3)	(4)
22.	Nancowry 10, Palayamkottai 9, Alapuzha 8, Minicoy 7, Gangtok & Osmanabad 4 each, Nagpur 3, Barsi 2, Bhuntar & Mysore 1 each	Hoshangabad & Aurangabad 4 each, Khammam & Pamban 2 each, Port Blair 1	Chalakudy 3, Karaikal 2, Kondul 1
23.	Coimbatore 16, Pandharkawada 9, Kinwat 8, Ramagundam & Chakamagalur 4 each, Sundernagar, Sholapur & Alapuzha 2 each, Bikaner, Sikar, Sagar, Pendra, Mangalore & Bijapur 1 each	Tirupathi 10, Machilipatnam 9, Sawai Madhopur & Cochi 5 each, Port Blair 4, Chennai 3, Lucknow & Narsingpur 2 each, Jhansi & Jabalpur 1 each	Nil
24.	Madurai 6, Manjeri 5, Gaya 4, Ranchi, Bhopal & Nagpur 3 each, Bankura, Puri, Sawai Madhopur, Satna, Cuddapah & Kolar Gold field 2 each, Nancowry, Hardoi, Rattia, Churu & Parbhani 1 each	Thalassery 13, Machilipatnam 10, Akola & Kodaikanal 4 each, Khammam 3, Manali & Sagar 2 each, Pendra & Jalgaon 1 each	Kayamkulam 1
25.	Salem 8, Hassan 6, Gaganbavda & Tirupathi 3 each, Belgaum, Billoli & Narsapur 2 each, Patna, Dehra Dun & Pendra 1 each	Kodaikanal &Karipur 10 each, Mangalore 9, Mysore & Minicoy 5 each, Tezpur, Fatehabad, Malkapur & Jogindernagar 2 each, Jodhpur, Ajmer, Pendra, Akola & Kakinada 1 each	Tuticorin 3, Visakhapatnam 1
26.	Chickmagalur 13, Satara 10, Nagapattinam 5, Vijapur 3, Hut Bay 2, Tezpur 1	Udhampur 14, Malkapur 6, Coimbatore 5, Lucknow, Dharamsala, Chitradurga & Minicoy 4 each, Mukteswar & Gohana 3 each, Shantiniketan, Mathura, Swai Madhopur, Yeotmal & Nidadavole 2 each, Coimbatore & Karwar 1 each	Kanker 3, Gopalpur 2
27.	Indapur 15, Kozhikode 9, Hingoli & Chennai 6 each, Vashim 4, Panjim & Machilipatnam 3 each, Bijapur 2, Car Nicobar, Phalodi, Indore, Nizamabad & Minicoy 1 each	Kathua 13, Chennai 12, Telegaon 6, Bharmaur 5, Mysore 4, Nellore 3, Nangal 2, Sankalan, Shantiniketan, Ranchi, Dehra Dun, Osmanabad, Nagpur & Bidar 1 each	Car Nicobar 6, Machilipatnam & Nagpur 1 each
28.	Punalur 7, Amini Divi 6, Nagpur & Machilipatnam 5 each, Mandla 4, Sagar & Edlabad 3 each, Soegaon & Tondi 2 each, Port Blair, Bhuntar, Ganganagar, Sawai Madhopur & Panjim 1 each	Pune & Soegaon 8 each, Chennai & Perumbavour 6 each, Khed, Buldhana & Mysore 2 each, Dibrugarh, Digha, Kurnool & Bijapur 1 each	Kondul 2, Ranchi & Sagar 1 each
29.	Konni 11, Udgir 6, Narnaul, Solapur, Shirali & Belgaum 5 each, Amraoti 4, Kalingapatnam 3, Sagar, Hyuderabad & Karaikal 2 each, Maya Bandar, Berthin & Anantpur 1 each	Nagapattinam 13 Dahanu, Amraoti & Ongole 3 each, Ratlam & Idar 2 each, Pune & Thiruvananthapuram 1 each	Pahalgam 3, Pendra 1
30.	Coimbatore 9, Lucknow 7, Nellore 5, Balasore, Koyna & Chitradurga 3 each, Patna, Hyderabad, Kurnool & Belgaum 2 each, Maya Bandar, Dharamsala, Srinagar, Bhopal, Satna & Chandwad 1 each	Purna 8, Nagpur 7, Bhopal, Bhadgaon & Nagapattinam 4 each, Jharsuguda & Thiruvananthapuram 3 each, Pendra, Vedaranyam & Amini Divi 1 each	Ghumarwin 9, Jagadhari 2, Mukteswar & Anantapur Sahib 1 each
31.	Kunnamkulam 9, Shirpur 8, Harnai 5, Honavar 4, Paradip, Tirupathi & Kanyakumari 3 each, Gangtok & Hassan 2 each, Long Island & Raipur 1 each	Nil	Kakinada 2, Nancowry 1

4.3.3. *Monthly rainfall*

In this month, the rainfall was excess in 31, normal in 1; deficient in 2 and scanty in 1 meteorological sub-divisions.

The rainfall was normal in Gujarat Region; deficient in Andaman & Nicobar Islands and Jammu & Kashmir and scanty in Saurashtra & Kutch. It was excess over the rest of the country.

4.3.4. *Temperature*

Severe cold wave conditions prevailed on 1 to 2 days in hills of west Uttar Pradesh, Himachal Pradesh & Jammu. Cold wave conditions prevailed on 1 to 7 days in Uttar Pradesh, Haryana, Punjab, Himachal Pradesh and Jammu. Night temperatures were appreciably below normal on 1 to 2 days in plains of Uttar Pradesh, Jammu and Saurashtra & Kutch and were below normal on 4 to 7 days in Bihar Plains, hills of west Uttar Pradesh, Himachal Pradesh and Jammu and on 1 to 3 days in West Bengal & Sikkim, Bihar Plateau, plains of Uttar Pradesh, Haryana, Punjab, Rajasthan, Saurashtra & Kutch and Konkan & Goa. They were appreciably to markedly above normal almost throughout the month in Madhya Pradesh, Madhya Maharashtra, Marathwada, Vidarbha, Andhra Pradesh and Karnataka and also over Assam & Meghalaya, Nagaland, Manipur, Mizoram & Tripura, Bihar, plains of Uttar Pradesh, Punjab and Rajasthan during first fortnight of the month.

The lowest minimum temperature over plains of the country was 0°C recorded at Amritsar in Punjab on 28 December and over hills -14°C on 31 December over Pahalgaon in J & K.

4.3.5. *Disastrous weather events and associated damages*

No significant damage occurred during the month of December 1997.