Mausam, (1991), **42**, 3, 227-240

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Cyclones and depressions over the Indian seas and neighbourhood during 1990*

1. Chief features

During the year 1990, eleven cyclonic disturbances (depressions and cyclones) formed over the Indian seas and adjoining land areas, of which 7 were depressions (D), 2 were deep depressions (DD), one was severe cyclonic storm (SCS) and one was severe cyclonic storm with a core of hurricane winds SCS(H).

During the pre-monsoon months (March to May) a disturbance originating from the Bay of Bengal intensified into a severe cyclonic storm with a core of hurricane winds in the month of May. In May a short lived land depression also formed.

In 1990 monsoon season (June-September), only four cyclonic disturbances formed against the seasonal normal of 7 to 8 such disturbances. Three out of these four formed in the Bay of Bengal and one over the land. Out of three systems in the Bay two were deep depressions and one was of depression intensity. The fourth one was a land depression. The month of July was free from monsoon depression in 1990.

During the post monsoon season (October-December) 1990, there were three depressions, one deep depression and one severe cyclonic storm over the Indian seas. Out of these five systems four developed in the Bay of Bengal and one in the Arabian Sea. The system in the Arabian Sea also originated in the Bay of Bengal as a depression. It weakened over the land after crossing east coast, but re-intensified into a depression after emerging into the Arabian Sea.

The tracks of depressions and cyclones in 1990 over the Indian seas are shown in Fig. 1. Details of these systems are given in Table 1. Their monthly frequency is given in Table 2. Based on INSAT data the intensity classifications for the May and December cyclones are given in Table 3. The systems have been discussed in sections 2, 3 and 4 in the text.

2. Systems in Bay of Bengal

2.1. *Pre-monsoon season*

2.1.1. *Machilipatnam severe cyclonic storm with a core of hurricane winds 5-11 May*

The system appeared as a low level circulation over southeast Bay on 3rd morning. By 4th evening, it became a well marked low pressure area. It concentrated into a deep depression over southwest Bay on 5th morning. Moving initially in a westnorthwesterly direction, it intensified into a severe cyclonic storm with a core of hurricane winds by 6th evening. After 7th morning, it moved in a northerly direction and crossed south Andhra Pradesh coast about 40 km southwest of Machilipatnam around 1330 UTC of 9th.

On 4th evening, the system was classified as T 1.5 in Dvorak's scale based on INSAT cloud imagery. But no other observation supported to declare the system as a depression. The system intensified into a deep depression by 0300 UTC of 5th and was centred near 10° N, 85.5° E. The system further intensified into a CS centred at 1200 UTC of 5th near 10.0° N, 84.5° E. The ship's observations in the storm field are listed in Table 4. Moving in a westnorthwesterly direction, it further intensified into a SCS and lay centred at 0300 UTC of 6th near 10.5° N, 83.5° E. The system further intensified into a severe cyclonic storm with a core of hurricane winds and was centred at 1200 UTC of 6th near 10.5° N, 83.0° E. Moving further westnorthwestwards system was nearer to north Tamil Nadu coast centred at 0300 UTC of 7th near 11.0° N, 82.0° E. North coastal Tamil Nadu winds strengthened from 5 to 15 kt ship *ATSO* (centred about 250 km northnorthwest of the storm centre) reported 30 kt wind. The storm then recurved to the north and was centred at 1200 UTC of 7th near 11.5° N, 82.0° E. Continuing its northerly course rather fast it lay at 0300 UTC of 8th near 13.3° N, 81.8°E (*i.e.*, about 200 km east of Madras), at 1200 UTC of 8th near 14.2° N, 81.2° E and at 0300 UTC of 9th near 15.0°N, 80.9° E. At this hour (0300 UTC of 9th), Machilipatnam reported strongest winds of 35 kt from northeast. While approaching coast the system weakened slightly but was still a SCS(H) and was centred at 1200 UTC of 9th close to south Andhra coast near 15.8° N, 81.0° E. The winds reported by coastal observatories at this hour are given below:

Nellore —W/10 kt, Machilipatnam —E/55 kt,
Ongole —NW/20 kt, Kakinada —E/15 kt,
Gannavaram —NE/30 kt, Visakhapatnam—NE/20 kt.

These alongwith ships observations around the cyclone field showed that the gale force winds were confined to a narrow belt close to the centre of the storm

*Prepared by: S/Shri G.R. Gupta, D.S. Desai and N.C. Biswas, Meteorological Office, Pune.

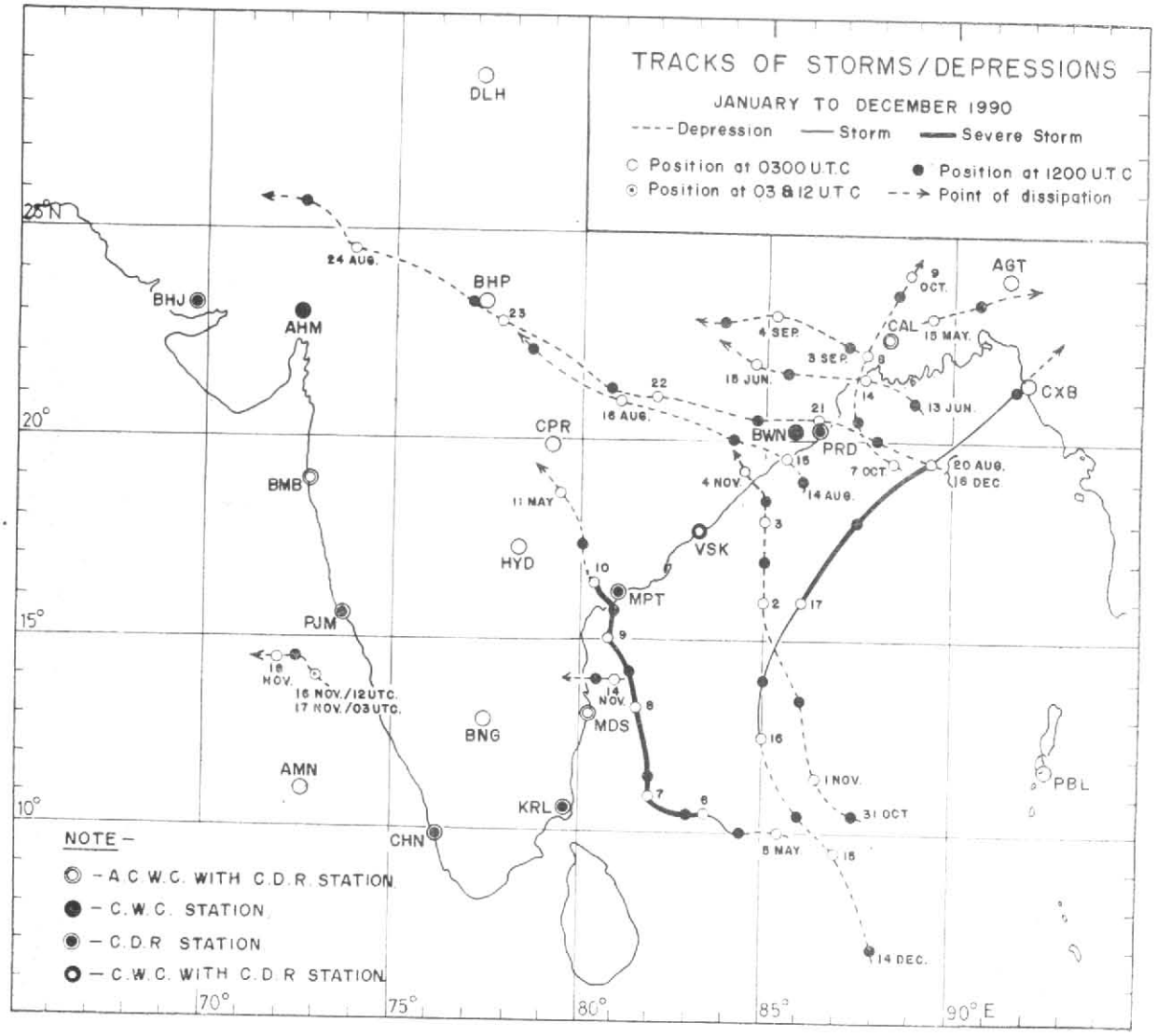

Fig. 1. Tracks of storms and depressions during January-December 1990

The system crossed south Andhra coast at about 40 km southwest of Machilipatnam around 1330 UTC of 9th and maintained its severity several hours over the land. In the morning (0300 UTC) of 10th it weakened into a SCS over land centred at about 30 km west of Gannavaram (Vijayawada) when Gannavaram reported winds of SE/50 kt. As the system moved further inland it weakened rapidly into a depression which was centred at 1200 UTC of 10th just south of Khammam (17° 15′ N, 80° 09′ E) and at 0300 UTC of 11th about 30 km south of Ramagundam (18° 46′N, 79° 26′E) in Andhra Pradesh. The system further weakened over north Andhra and adjoining Vidarbha and dissipated over Vidarbha and adjoining south Madhya Pradesh on 14th. The cyclone moved at a speed of 8-9 kmph before recurvature and 12-13 kmph after recurvature.

2.1.1.1. *Central pressure*

The cyclone attained its peak intensity on 8th when from the INSAT cloud imageries, the intensity of the system was fixed as T 6.5. Corresponding central pressure using Mishra-Gupta's formula computed to be 918 hPa at 1200 UTC of 8th May.

The ship "*Viswamohini*", which was sailing from Singapore to Madras went into the core of the cyclone on 8th. It recorded pressure of 917 hPa at 1130 UTC on 8th from the core of the storm. At 1200 UTC the ship lay in the eye region of the storm and recorded pressure of 912 hPa. The observed lowest pressure and the estimated lowest central pressure at 1200 UTC of 8th were comparable. The captain of the ship further informed that around 1200 UTC the ship was in the eye region, where the wind speeds were between 7 & 16 kt. He estimated the maximum wind in the storm field around 150 kt and the wave height around 10 m.

Machilipatnam observatory situated at a distance of 40 km from the cyclone centre, recorded the lowest pressure of 964.5 hPa at 1330 UTC of 9th. Further inland, Bapatla observatory recorded the lowest surface pressure of 963.0 hPa at 1745 UTC, when the cyclone centre lay at a distance of about 26 km from the station

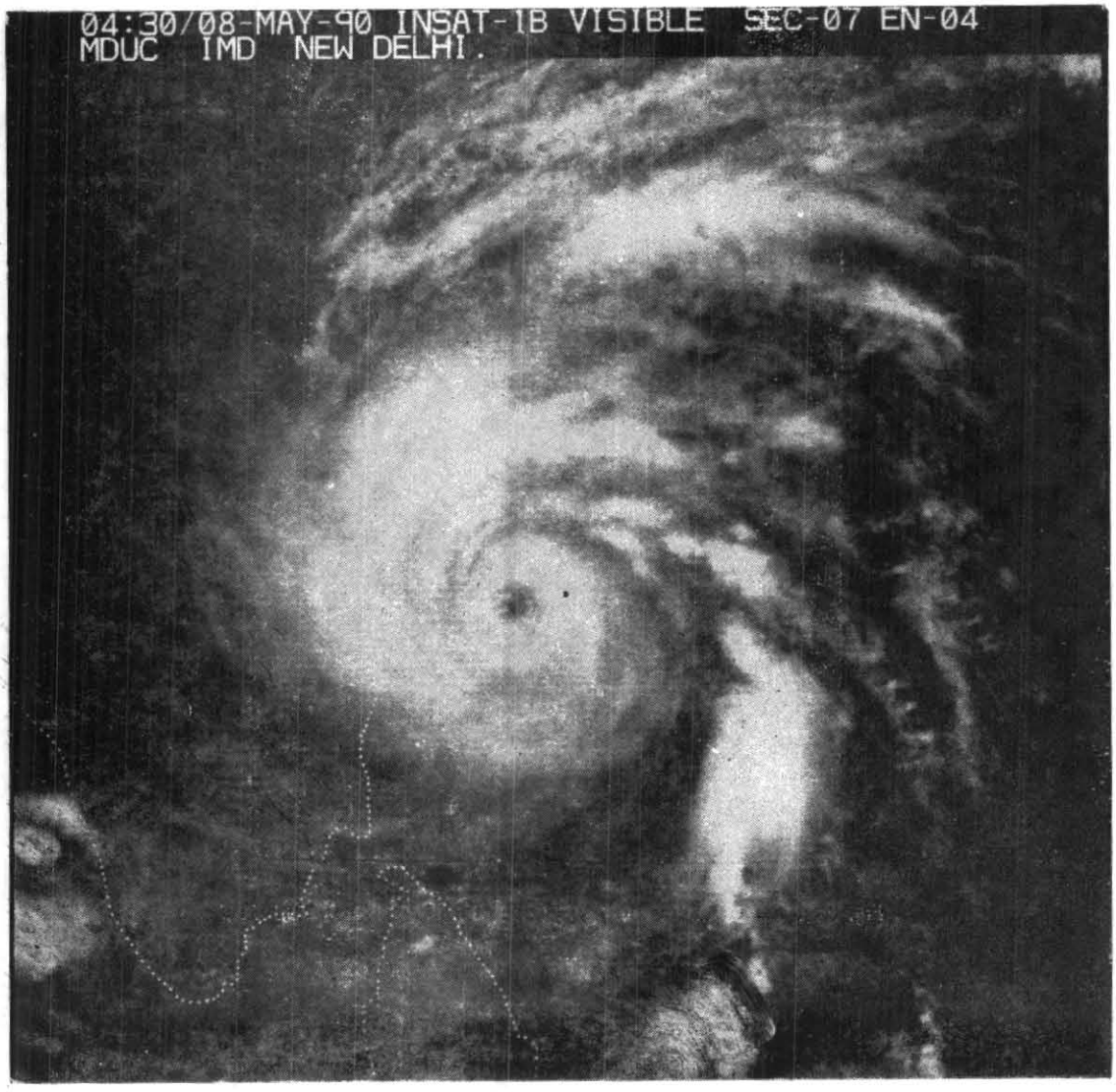

Fig. 2(a). INSAT-1B cloud picture of 8 May 1990 at 0430 UTC

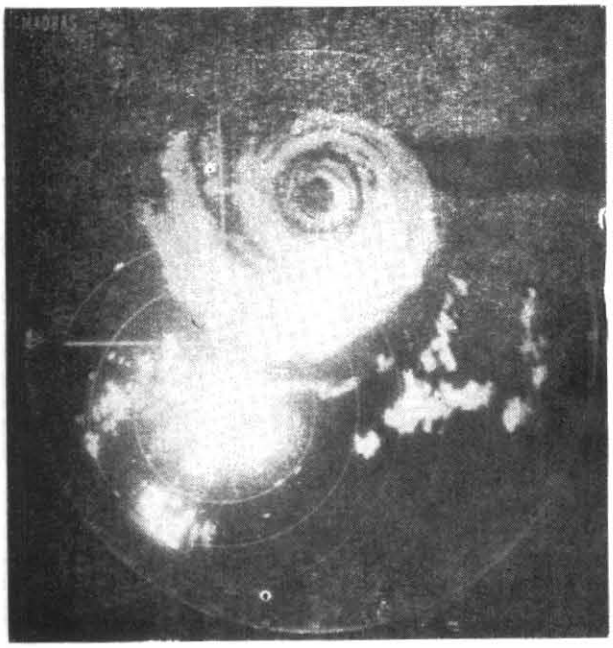

Fig. 2(b). CDR, Madras of Bay cyclone of 8 May 1990 at 2243 UTC

TABLE 1

Details of depressions and cyclonic storms over the Indian seas and neighbourhood during 1990

S. No.	Type of system	Life period	Point of crossing the coast with date	Recorded lowest pressure/ central pressure (hPa)	Recorded maximum wind	Highest T-No. recorded
1	SCS (H)	5-11 May	About 40 km southwest of Machilipatnam around 1330 UTC of 9th	912 hPa at 1200 UTC of 8th by ship '*Viswamohini*' (*ATSO*)	At MPT—E/70 kt at 1400 UTC of 9th	6.5
2	Depression	15-16 May	Land depression	—	Comilla (41933) E/30 kt at 1200 UTC of 15th	1.0
3	Deep Dep.	13-15 Jun	Near Contai in the afternoon of 14th	BLS—985.3 hPa at 0300 UTC of 14th	NW/40 kt at BLS at 0300 UTC of 14th	1.5
4	Dep.	14-16 Aug	Between Gopalpur and Puri around noon time of 15th	GPL—994.0 hPa at 0900 UTC of 15th	Ship *ATKK* (19.3°N, 86.5°E) 190°/29 kt at 0600 UTC of 15th	—
5	Deep Dep.	20-24 Aug	Just north of Paradip around noon time of 21st	PRD—991.2 hPa at 0300 UTC of 21st	(*i*) Over sea 180°/40 kt at 0600 UTC of 21st by ship *ATJY* (20.2° N,87.4°E) (*ii*) Over land Paradip S/45 kt at 0310 UTC of 21st	2.0
6	Dep.	3-4 Sep	Land depression	MDP—994.9 hPa at 1200 UTC of 3rd	—	—
7	Dep.	7-9 Oct	Near Contai in the morning of 8th	Berhampore—999.8 hPa at 1200 UTC of 8th	Dhaka ESE/20 kt 080300 UTC Bogra, Mymensingh, Rangpur E/20 kt at 081200 UTC. Mymensingh E/20 kt at 0903 UTC	2.0
8	Deep Dep.	31 Oct -4 Nov	South of Gopalpur between 0000 and 0100 UTC of 4th	VSK—1000.2 hPa at 1200 UTC of 3rd	Ship *VVPL* (17.2°N, 84.3°E) 040°/37 kt at 0300 UTC of 2nd	2.0
9	Dep.	14 Nov	About 50 km south of Nellore	MDS—1008.8 hPa at 1200 UTC of 14th	—	1.5
10	Dep.	16-18 Nov	Dissipated over EC Arabian Sea	Ship, *VRIN*—1008.8 hPa at 0000 UTC of 17th	Ship *VRIN*—040°/35 kt at 0000 UTC of 17th	2.0
11	SCS	14-18 Dec	Bangladesh coast near Cox's Bazar on 18th night	Estimated central pressure 997 hPa at 0300 UTC of 17th	Ship *VTPP* N/40-50 kt at 0500 UTC of 16th	3.5

TABLE 2

Storms/depressions statistics (monthwise)

Name of the system	Jan to Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bay of Bengal										
Depression	—	—	1	—	2	—	2	1	—	6
Cyclonic storm	—	—	—	—	—	—	—	—	—	—
Severe cyclonic storm	—	—	—	—	—	—	—	—	1	1
SCS (H)	—	1	—	—	—	—	—	—	—	1
Total	—	1	1	—	2	—	2	1	1	8
Arabian Sea										
Depression	—	—	—	—	—	—	—	1	—	1
Cyclonic storm	—	—	—	—	—	—	—	—	—	—
Severe cyclonic storm	—	—	—	—	—	—	—	—	—	—
SCS(H)	—	—	—	—	—	—	—	—	—	—
Total	—	—	—	—	—	—	—	1	—	1
Land										
Depression	—	1	—	—	—	1	—	—	—	2
Total	—	2	1	—	2	1	2	2	1	11

2.1.1.2. *"Eye" of the storm*

Faint 'eye' of the storm was seen by the satellite (INSAT) at 2000 UTC of 6th, when the intensity of the storm was T 5.0 and a clear 'eye' at 0000 UTC of 7th when the intensity of the storm was also T 5.0. The 'eye' of the storm was clearly visible in the satellite imageries till 1500 UTC of 8th. A satellite cloud picture of this cyclone in its most intense stage is shown in Fig 2 (a). It obliterated at 1800 UTC of 8th. The cyclone detection radar (CDR) at Machilipatnam observed the 'eye' till 1100 UTC of 9th, while CDR Madras observed it upto 1400 UTC of the day, when the storm centre lay over the land. The diameter of the 'eye' as estimated by CDR Machilipatnam ranged from 20 to 35 km on 8th and 9th.

CDR's Madras and Machilipatnam observed 'double walled eye wall' or concentric eye wall of the cyclone in some of their observations. The Madras radar reported the inner eye wall diameter ranging from 25 to 35 km and a thickness (or width) of 15 to 20 km. The outer eye wall was asymmetric most of the time and had a diameter of 130 km on an average. This is an interesting feature of the system. Fig. 2 (b) shows the radar picture of concentric eye wall. The concentric eye walls are reportedly common in the Atlantic hurricane.

2.1.1 3. *Satellite (INSAT) feature*

The central dense overcast (CDO) of about 1.5° diameter appeared in the cloud pattern at 1000 UTC

TABLE 3

Satellite observations of storms over Indian seas 1990

Date and Time (UTC)	Satellite (INSAT-1D) T-Classification /C.I. No.	Co-ordinates of the centre given by sat. Lat. (°N)	Long. (°E)	Assigned intensity of the system
		Machilipatnam SCS (H), 5-9 May		
050000	2.0	10.0	85.5	D
050300	2.5	10.2	85.2	DD
051200	3.0	10.1	84.5	CS
060000	3.5	10.7	83.3	CS
060300	4.0	10.5	83.5	SCS
061200	4.5	10.2	82.9	SCS(H)
070000	5.0	11.3	82.3	SCS(H)
070300	5.5	11.3	82.0	SCS(H)
071200	6.0	11.4	81.7	SCS(H)
080300	6.5	13.5	81.7	SCS(H)
081200	6.5	13.9	81.1	SCS(H)
090000	5.0/6.0	15.1	81.0	SCS(H)
080300	5.0/6.0	15.4	81.0	SCS(H)
091200	5.0/6.0	15.9	81.0	SCS(H)
091500	4.5/5.0	16.2	80.7	SCS(H)
		Bangladesh SCS, 14-18 Dec		
141200	1.5	8.0	88.0	D
150000	2.0	9.0	87.5	D
150300	2.0	10.0	87.0	D
151200	2.0	10.5	86.0	DD
160000	2.5	12.0	85.0	DD
160400	3.0	12.8	85.4	CS
161200	3.0	14.4	86.0	CS
170300	3.5	16.2	86.7	SCS
171200	3.0/3.5	18.2	87.5	SCS
172200	3.5	20.7	91.2	SCS

TABLE 4

Ship observations on 5-9 May 1990

Call sign of the ship	Date and Time (UTC)	Position of the ship Lat. (°N)	Long. (°E)	Wind Dir. (°)	Speed (kt)	Remarks (PPPP)
ATSO	050300	8.4	90.1	240	16	1008.5
ATSO	050600	8.6	89.6	240	16	1007.5
ATKK	050600	16.6	86.1	020	20	1008.2
ATMS	051200	12.0	85.0	190	06	1005.4
ATSO	051200	9.2	88.5	210	14	1006.0
9VMR	051200	5.9	87.4	210	13	1005.9
ATSO	060300	10.5	85.8	230	25	1005.5
VVM6	060430	11.5	84.5	Ely	35	1003.2
ATSO	060600	10.8	85.2	240	28	1004.7
ATSO	070300	13.0	81.5	080	30	1003.5
ATMS	070300	5.8	80.2	240	16	1006.3
PHRE	070600	5.4	82.1	260	28	—
VSBX3	070600	6.0	87.7	210	25	1008.6
ATZM	070600	13.2	80.5	030	24	1005.5
ATSO	070900	13.2	81.4	050	41	1001.0
PFOP	071200	11.3	84.2	140	20	1001.8
ATZM	071200	14.0	81.0	040	24	1003.1
VSBX3	080000	5.9	84.1	210	30	1007.9
VWWR	080000	16.4	85.0	120	30	1004.4
ATZM	080300	15.3	83.0	070	30	1002.7
ATZM	080600	15.2	83.3	080	30	1003.7
VWWR	080600	15.4	85.6	130	27	1004.2
ATKE	080600	8.3	82.0	150	13	1004.8
ATMS	080600	8.3	81.8	210	14	1004.6
ATZM	080900	15.3	85.3	090	32	1002.2
VWWR	081200	14.6	86.2	150	25	1001.2
ATMR	081200	14.6	85.6	160	25	1002.0
YTFI	090300	14.1	85.8	180	30	1003.0

of 5th. It became more organised at 0000 UTC of 6th when the intensity of the system was T 4.0. Faint "eye" appeared at 2000 UTC of 6th at T 5.0 stage and clear eye at 0000 UTC of 7th (T 5.0). At 0600 UTC of 7th a clear "eye" and well defined spiral bands appeared (T 6.0). It attained the intensity of T 6.5 at 2100 UTC of 7th. The cyclone sustained this intensity till 1400 UTC of 8th. Thereafter, it started weakening. The infrared cloud imageries data did not show an "eye" at and after 1500 UTC of 8th. The current intensity (CI) of the cyclone was 5.5 at the time of the landfall.

2.1.1.4. *Gale force winds in association with the cyclone*

Gale force (34 kt or more) winds over sea never reached a distance beyond 200 km from the storm centre as was evidenced from the ship observations (Table 4). In the southwest quadrant of the storm the wind speeds were minimum. When the storm crossed the coast, the maximum wind associated with it was assessed by the touring officer on the basis of the nature of structural and other damages. The estimated maximum wind speed associated with the storm was around 200 kmph or slightly more on the basis of the Saffir-Simpson damage potential scale as applicable to Indian conditions. The estimated maximum winds over land are shown in Fig. 3, where wind speeds of 200 kmph or more was confined to 15 to 25 km on either side of the storm centre. The 100 kmph wind speed extended about 115 km to the right hand quadrants of the storm, while the extension of the same was 55 km to its left quadrants. Machilipatnam observatory reported maximum wind E/70 kt at 1400 UTC of 9th. It was E/56 kt at 1300 UTC of the day.

Extensive damage due to gale force wind was observed mainly in Guntur and Krishna districts of Andhra Pradesh.

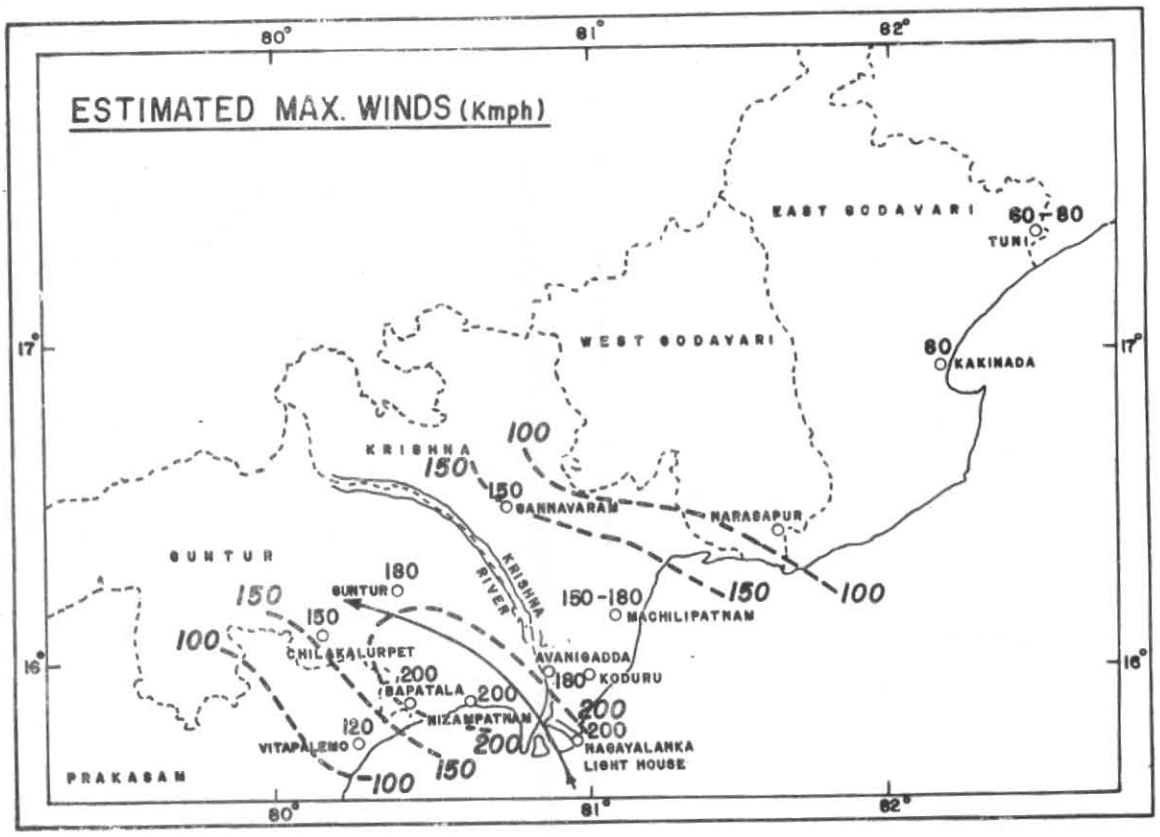

Fig. 3. Isotach of estimated maximum winds (kmph)

2.1.1.5. *Storm/surge and sea water inundation*

As per the report of the touring officer, the maximum surge associated with the cyclone was of the order of 3 to 4 m above the normal tide level at the time of landfall. The peak surge and areas of inundation have been shown in Fig 4.

At Nagayalanka light house wave heights of the order of 5 m were reported at the time of the landfall. During the passage of the hurricane the sea level rose thereby about 12 to 15 ft above the normal tide level. At Edirumundi, level of *Krishna* river rose by 10-12 ft, Nagayalanka, which is situated about 20-25 km north of Edirumundi, the level of *Krishna* river rose by 9-10 ft

Away from the cyclone centre to the northeast, the surge was of the order of 2-3 m above normal tide level up to Narsapur. The cyclone hit the coast during the high tide period. The saline inundation at Machilipatnam-Challapalli sector extended about 20 to 25 km inland from the coast line. Near Koderu village, northeast of Avanigada, the saline inundation was 10-12 km inland. Further to the north, near Machilipatnam sea water entered 5 to 8 km inland and near Narsapur in west Godavari districts it entered 3 to 5 km inland. As per reports in the media, around 54,000 hectares of agricultural land was inundated by sea water and was sand cast in another 62,000 hectares of land.

2.1.1.6. *Rainfall distribution*

During 8 to 13 May a number of stations in coastal Andhra Pradesh, reported exceptionally heavy rainfall. Using districtwise normals for May, the percentage departures of rainfall during this cyclone period ranged from 340 to 1189 percent in coastal Andhra Pradesh. Rainfall figures of some stations and isohyetal lines for the period 9-12 May are shown in Fig.5. Exceptionally heavy rainfall of 52.5 cm was recorded at Yeleswaram (ELS) in east Godawari district on 11 May. A total of 110 cm was recorded at this station during the period 9-11 May.

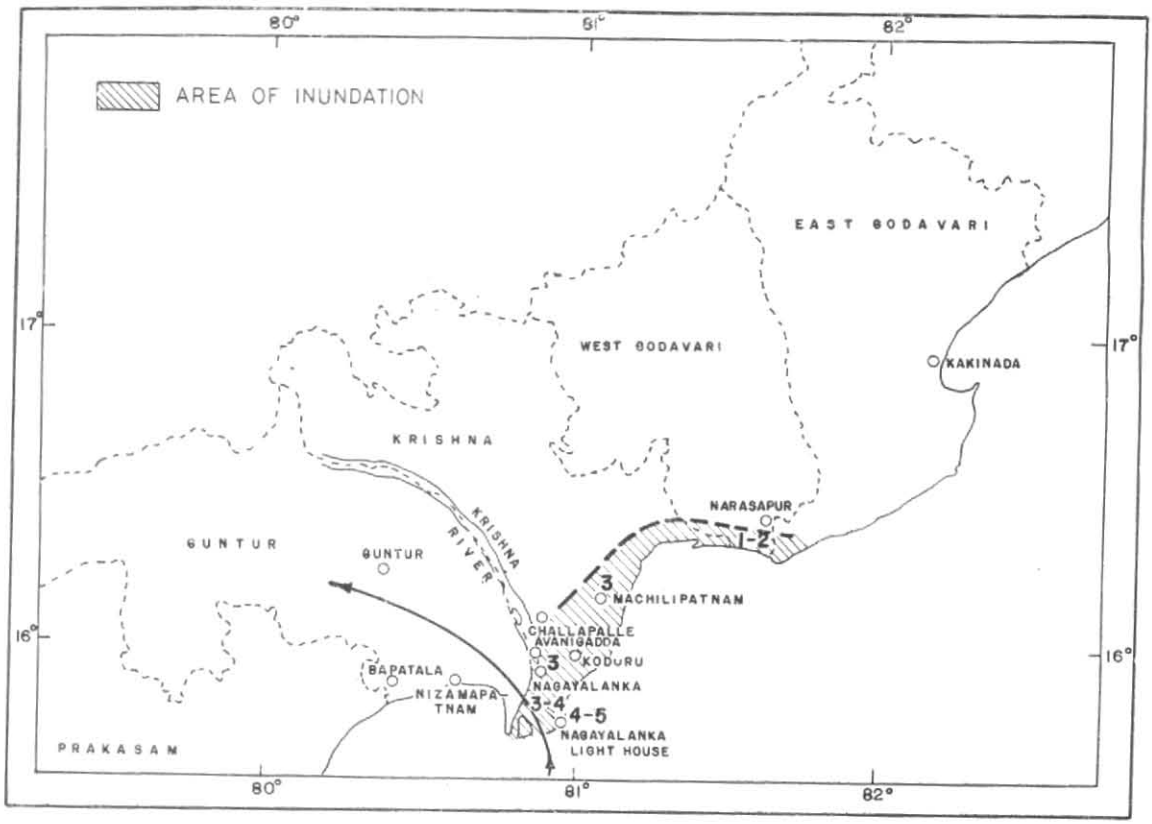

Fig. 4. Surge height (m) and area of inundation

The significant amounts of rainfall (cm) are given below :

8 May : Madras 15, Venkatagiri 12, Chambarambakkam & Nayudupeta 11 each.

9 May : Yeleswaram 27, Kakinada & Vidavalur 23 each, Allur & Pithapuram 21 each.

10 May : Yeleswaram 53, Bapatla 49, Narsipatnam 40, Tuni 36, Ponnuru & Nagaram 31 each, Prathipadu 30, Guntur & Koderu 26 each, Gollaprolu & Kakinada 25 each, Nagayalanka 23, Eluru 22, Vijayawada AP 21, Visakhapatnam AP 18.

11 May : Reddigadan 40, Yeleswaram 31, Gollaprolu & Prathipadu 28 each, Peddapuram 27, Bobbili & Narsipatnam 25 each, Ramchandrapuram & Kotakanda 22 each, Rajmundry 21, Koderu & Polavaram 19 each, Dowleswaram 18.

12 May : Repalla 19, Bapatla 14, Jaggaiahpet 13.

2.1.1.7. *Comparative study with Nov. 77 Chirala cyclone*

Machilipatnam cyclone was one of the severest cyclones in the Bay of Bengal. Andhra coast was earlier struck by an equally interse cyclone near Chirala in November 1977. The peak intensity of November 1977 Chirala cyclone was estimated as T 7.0 in Dvorak's scale. The peak intensity of the present storm assessed by INSAT was T 6.5.

Diviseema islands at the estuary of the river *Krishna* and the main coast south of Machilipatnam were affected by the Chirala cyclone of 1977 as well as by the present cyclone. In the case of Chirala cyclone the sea water inundation extended up to a maximum of 12 km inland, while in the present cyclone the inundation was up to 25 km inland. In the 1977 case the havoc mainly caused by saline inundation while in the present cyclone it was due to saline inundation as well as due to unprecedented heavy rains and associated floods. The loss of human lives in Chirala cyclone was more than 10,000. In the present cyclone timely warnings helped Govt. machinery to evacuate more than 6.5 lakhs people from the vulnerable coastal areas, as a result, the loss of human lives were comparatively much less (967). However, the damage caused by the present cyclone to properties and crops were as high as in the case of Chirala cyclone.

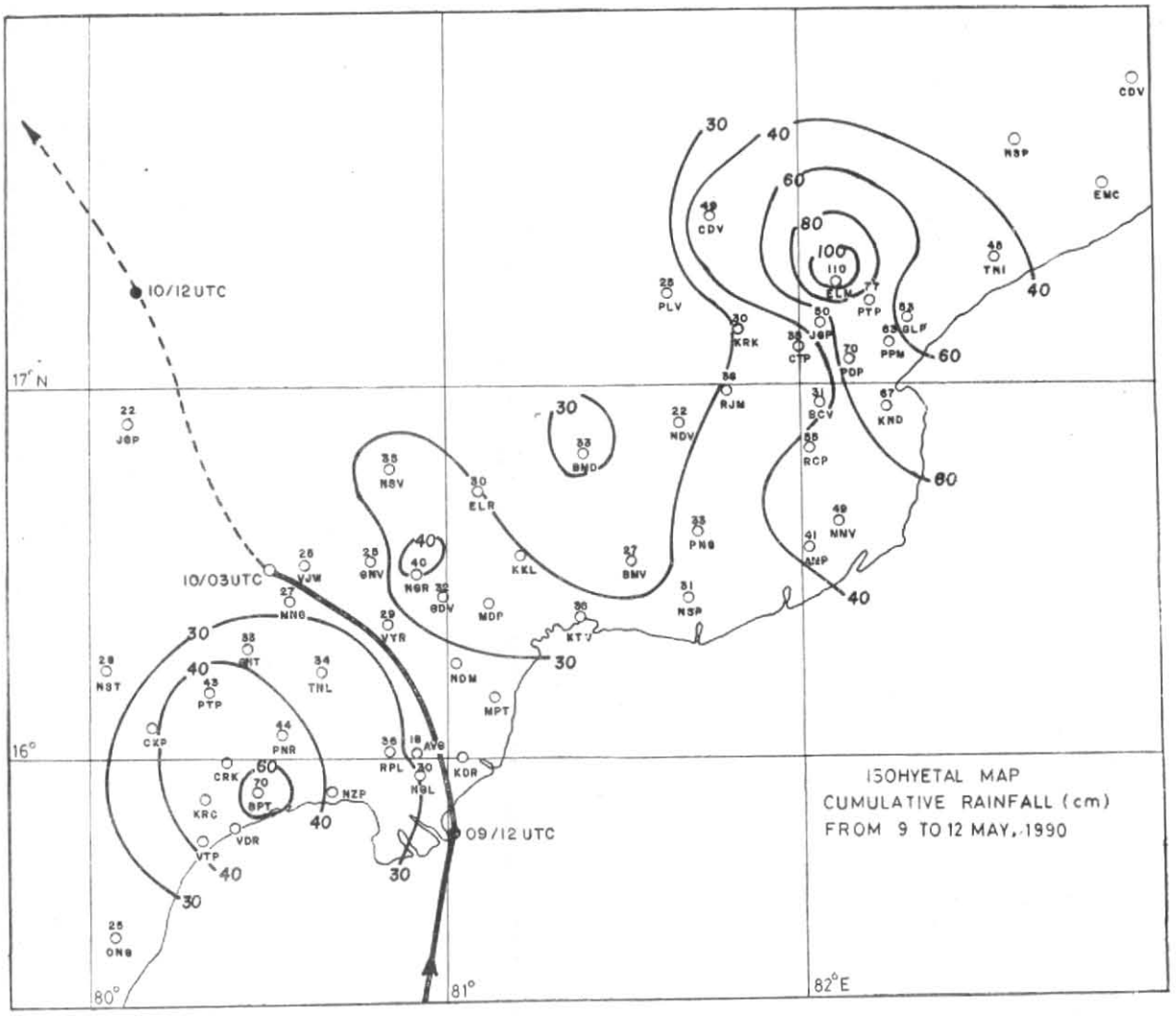

Fig. 5. Isohyetal map of cumulative rainfall (cm) from 9 to 12 May 1990

2.1.1.8. *Damage caused by the cyclone*

The cyclone hit the Andhra coast with an estimated gale force wind reaching 200 to 250 kmph. Also the unprecedented heavy rains over coastal Andhra Pradesh caused floods making the situation grave. The loss of human lives in this cyclone was minimised by timely warnings issued and appropriate precaution taken. About 6.5 lakhs people were evacuated to safer places from 546 coastal villages. Even then the loss of human lives was 967. Diviseema island formed by the two arms of the river *Krishna* was worst affected. It was completely marooned. The highest number of death occurred in Guntur district (343) followed by Krishna (218) and Visakhapatnam (157) districts. The death toll in east Godavari district was 110 and in west Godavari district was 41. Heavy rain caused floods in *Tammileare, Rammileru* and *Vegavethi* rivers and in the river *Budamerur*. Flood waters and sea waters inundated vast stretches of paddy field. Machilipatnam town was under 3 to 6 ft of water for 3 to 4 days and Visakhapatnam airport was under water for about a week. Ankapalla town was flooded by overflowing *Sarada* river and the town was engulfed under 4 to 5 ft of water. Road traffic between Machilipatnam and Vijayawada remained closed for 2 days.

Gale force winds completely destroyed banana plantation over a vast stretch of land and severely damaged

mango crops. It twisted and felled coconut trees in Krishna district. Havoc had been caused on the 74 km stretch from Machilipatnam to Vijayawada.

Besides causing floods, the heavy rainfall also caused breaches in roads and railway tracks at many places in Godavari and Visakhapatnam districts. The rail traffic between Visakhapatnam and Tuni remained suspended for more than three weeks.

The storm affected a population of about 7.78 million in 5160 villages in Andhra Pradesh. It had fully or partly damaged about 16 lakh houses in 10 districts of the State. As per reports about 3.61 million live stock was perished and about 3.08 lakh hectares crops were affected. Horticulture crops in 55,000 hectares of land were damaged. Bapatla meteorological observatory was damaged and the multimet radar antenna and the cups of the anemometer of high speed wind recorded at Machilipatnam were blown off by gale winds.

The storm also caused some damages in the extreme north coastal Tamil Nadu. At Ennone the sea waves damaged the Kasiviswanath temple and washed away a few fishermen colonies in Pulicat.

As per the Andhra Govt. report the estimated cost of the damages in the State was about Rupees 2289.63 crores under the following heads :

		Rs. in crores
(*i*)	Damages to private dwelling units	550.00
(*ii*)	Damages to agriculture crops	289.34
(*iii*)	Damages to horticulture crops	530.35
(*iv*)	Damages to irrigation Dept.	173.85
(*v*)	Damages to Panchayat Raj Dept.	246.00
(*vi*)	Damages to Transports, roads and buildings Dept.	138.50
(*vii*)	Damages of Forest energy and environment Dept.	118.31
(*viii*)	Damages to Industry, social welfare and other Dept.	243.28
	Total	2289.63

The remnant of the storm caused heavy rainfall in Koraput and Ganjam districts of Orissa. Heavy rains caused floods in the river *Vasandhara* in Ganjam district causing damages to roads and crops. In Koraput district also rabi crops suffered damages due to heavy rain.

2.2. *Monsoon season*

2.2.1. *Deep depression, 13-15 June*

The system initially appeared as an upper air disturbance over west central Bay on 7th. Under its influence a low pressure area formed on 10th, which subsequently concentrated into a depression over the northwest Bay on 13th evening. It moved in a westnorthwesterly to westerly direction crossed north Orissa, West Bengal coasts and weakened over north Orissa and adjoining east Madhya Pradesh on 15th evening.

The depression lay centred at 1200UTC of 13th near 21.0° N, 89.0 °E. At this hour Sandheads and Khepupara (41984) reported surface winds NNW/25 kt and E/15 kt respectively. At 0.9 km a. s. l. the winds at Calcutta and Bhubaneshwar were ENE/35 kt and N/25 kt respectively at 0000 UTC of the day. The satellite (INSAT) classification at 0300 UTC was T 1.0. At 0300 UTC of 14th, it became a deep depression over the northwest Bay and neighbourhood centred near 21.5° N,87.5° E. At this hour the surface winds at Sandheads and Balasore were S/35 kt and NW/40 kt respectively. The winds at 0.9 km a.s l. at Calcutta and Bhubaneshwar were E/25 kt and W/35 kt respectively at 0000 UTC of 14th. The system crossed coast near Contai in the afternoon of 14th and weakened into a depression and was centred about 50 km northnortheast of Keonjhargarh at 1200 UTC of 14th when the Keonjhargarh reported WNW/20 kt wind. At 0300 UTC of 15th the depression lay centred about 50 km south of Rourkela. Thereafter, the system weakened by evening of 15th into a well marked low pressure area over north Orissa and adjoining Bihar plateau and east Madhya Pradesh. The remnant remained stationary over the area for a couple of days and became unimportant over northeast Madhya Pradesh and neighbourhood on 18th.

In association with this system maximum pressure change (24 hours) —7.6 hPa and pressure departure 11.8 hPa were recorded at Sandheads at 0300 UTC of 14th. The highest wind speed of NW/40 kt was recorded at Balasore at this hour. The circulation of the system extended up to 9.5 km a. s. l. on 14th morning. In other days it extended up to middle tropospheric levels only.

In association with this sytem the southwest monsoon advanced over Orissa, West Bengal, Bihar and adjoining east Madhya Pradesh.

The system did not cause any damage in Orissa, east Madhya Pradesh and Gangetic West Bengal. On 16th June, however, Bombay (Colaba) recorded 421.2 mm of rainfall. It was the highest ever rainfall in 24 hours in the month of June in 104 years. The torrential rains disrupted air, rail and road communication and also the power supply in Bombay. The flood water was as much as 3 feet deep in King's Circle. Nearly 45 lakh commuters in central and western railway services were stranded due to the complete breakdown. The rain took a toll of 22 human lives in Bombay and 7 in Thane district. Telephone services were also disrupted in the city for a day or two.

The significant amounts of rainfall (cm) are given below :

14 Jun : Sandheads 49, Balasore 12.

15 Jun: Igatpuri 17, Paint 13, Dibrugarh AP & Nawapur 8 each.

16 Jun: Bombay 42, Dharavi (Bombay) 28, Alibag 20, Bombay AP 15, Devgarh & Tulsi 12 each, Amgaon & Poladpur 10 each, Gaya AP Gondia, Mahabaleshwar & Ratnagiri 7 each.

17 Jun: Lonavala 20, Bombay 15, Alibag & Bhira 14 each, Yeotmal 11, Nagpur AP 10, Mahabaleshwar & Wardha 9 each, Gondia & Rajgarh 7 each.

2.2.2. *Depression, 14-16 August*

The system was initially seen as an upper air disturbance over west central and adjoining northwest Bay on 12th and further into a depression on 14 evening. Moving westnorthwestwards it crossed south Orissa coast between Gopalpur and Puri around 15th noon and weakened over southwest Madhya Pradesh and adjoining Vidarbha on 16th night. In the evening of 14th, when the system concentrated into a depression over northwest and adjoining west central Bay centred near 19.0° N, 86.0° E, the surface winds at Puri and Bhubaneshwar were E/15 kt and NE/10 kt respectively. Bhubaneshwar wind at 0.9 km a.s.l. was E/30 kt at this hour. The 24 hours pressure changes and pressure departures at the coastal stations between Kalingapatnam and Puri were — 3 to —5 hPa and — 3 to — 6 hPa respectively. Moving slightly northwestwards the depression lay at 0300 UTC of 15th close to coast, centred near 19.5° N, 85.5°E. At this hour Puri and Gopalpur reported SE/10 kt and NW/10 kt surface winds respectively. However, at 0600 UTC ship *ATKK* (19.3° N, 86.5° E) lying about 100 km east of the depression centre reported 190°/29 kt wind.

Moving in a westnorthwesterly direction the system crossed south Orissa coast between Gopalpur and Puri around noon of 15th and lay at 1200 UTC over Orissa centred near 20.0° N, 84.0° E (about 90 km east of Bhawanipatna). At this hour ship *ATKK* (18.3°N, 85.4°E) continued to report 200°/29 kt wind. Also Visakhapatnam reported W/15 kt wind at this hour. In the morning (0300 UTC) of 16th the depression lay over southeast Madhya Pradesh and adjoining Vidharba centred near Rajnandgaon (21° 06′ N, 81° 02′ E) (about 65 km southwest of Raipur). Winds in the field of the depression were between 5 and 10 kt. However, it maintained strong monsoon conditions over the sea area as was evidenced from the 0600 UTC observation of the ship *VWKZ* (16.9° N, 83.2°E), which reported 220°/28 kt wind. In the evening the system lay over central Madhya Pradesh and adjoining Vidarbha centred close to Chindwara (22° 06′ N, 79° 00′ E). Continuing to move in a westnorthwesterly direction, it weakened into a well marked low pressure area over southwest Madhya Pradesh and neighbourhood on 17th morning. The system further moved westwards and merged with the seasonal low over south Pakistan and adjoining west Rajasthan on 19th. INSAT did not show any organisation to assign any T-number to the system. Pressure departures on 15th morning along north Andhra-south Orissa coasts were between —6 to —7 hPa. The diameter of the outermost closed isobar (OCI) of the system was 10 to 12 degree till the morning of 16th. It reduced to 4 to 5° in the evening of that day. The circulation in association with the system extended to middle tropospheric levels without any tilt with height till the evening of 15th. In association with the system the lowest pressure of 994.0 hPa was recorded at Gopalpur (19°16′ N, 84° 53′ E) at 0900 UTC of 15th. The highest wind 190°/29 kt was recorded over sea by ship *ATKK* (19.0°N, 86.5°E), when it was about 100 km east of the system.

The depression caused active monsoon conditions over Orissa, Maharashtra, Gujarat, north Andhra Pradesh and north interior Karnataka on a couple of days. Heavy rains in north interior Karnataka caused floods in the rivers in Raichur, Gulbarga, Bidar and Belgaum districts. At least 13 villages in Bidar district were marooned and 13 people lost their lives. It disrupted road transport system in these districts. Also floods/heavy rains claimed 23 lives in Maharashtra and 10 in Andhra Pradesh.

The significant amounts of rainfall (cm) were :

15 Aug: Khandala 31, Bombay 26, Lonavala 24, Vikarabad 20, Koida 17, Polavaram 10, Tuni 9.

16 Aug: Bhira 37, Lonavala 30, Bhadravati 23, Mahabaleshwar 21, Perur 18, Hinganghat 16, Banswada 14, Wardha 13, Chandrapur & Tumsar 10 each, Bombay & Nagpur 9 each.

17 Aug: Koyna 42, Mosali 38, Ratnagiri 28, Rajapur 25, Bulsar 24, Bulchana & Mahabaleshwar 22 each, Jalgaon 17, Poladpur 15, Baroda 14, Bhavnagar AP 13.

18 Aug: Veraval 30, Bhavnagar AP 20, Lonavala 16, Gandhinagar, Mahabaleshwar, Rajapur & Surat 13 each, Diu 10.

2.2.3. *Deep Depression, 20-24 August*

A depression formed in the morning of 20th August out of an upper air cyclonic circulation over the north adjoining central Bay. It crossed north Orissa coast around noon of 21st as a deep depression and further moving in a westnorthwesterly direction weakened and merged with the seasonal low over west Rajasthan.

On 20th morning (0300 UTC) the disturbance concentrated into a depression over northwest and adjoining central Bay centred near 19.5°N, 89.0°E. At that hour wind of Sandheads was NE/20 kt. Moving in a westnorthwesterly direction the depression lay at 1200 UTC of this day centred near 20.0°N, 88.0°E. At this hour winds of ship *VTJR* (20.0°N, 88.9°E) was 170°/15 kt and Sandheads was 090°/15 kt (INSAT) at 1200 UTC of 20th gave T1.0. The system lay as a deep depression at 0300 UTC of 21st centred close to Paradip (20.4° N, 86.4° E). At 0000 UTC of this day the winds of ship *VTJR* (20.1° N, 88.9° E) was 190°/20 kt. At 0300 UTC the surface winds at Paradip and Chandbali were NW/20 kt and SE/20 kt respectively. At 0600 UTC winds of ship *ATJY* (20.2°N, 87.4°E) was 180°/40 kt.

The deep depression crossed north Orissa coast just north of Paradip around noon of 21st. However, winds recorded by HWSR at Paradip indicated the crossing of the deep depression in the morning of 21st. It reported the following winds, 0300 UTC-SSW/28 kt, 0310 UTC-S/45 kt, 0320 UTC-S/40 kt and 0340 UTC-S/25 kt.

At 0600 UTC winds at Paradip was NW/30 kt. In the evening of 21st, the deep depression lay centred about 60 km east of Phulbani (20°29′N, 84°16′E). At that time, wind at Puri and Bhubaneshwar area were SSW/20 kt and S/25 kt respectively. At 0300 UTC of 22nd, it weakened into a depression over southeast Madhya Pradesh and neighbourhood centred about 70 km ESE of Raipur. The inland winds at this time were of the order of 02 to 05 kt, whereas, in the south coastal Orissa and north coastal Andhra Pradesh

winds were of the order of 10 to 15 kt. The depression at 1200 UTC of 22nd centred about 60 km west of Raipur and at 0300 UTC of 23rd about 30 km northwest of Pachmarhi. At that hour the wind at Bhopal was NE/15 kt. The depression moved in a westnorthwesterly direction up to west Rajasthan by 25th and weakened further and merged with the seasonal low by 26th. The system moved along the monsoon trough. In association with the system, the lowest pressure of 991.1 hPa was recorded at Paradip at 0300 UTC of 21st, when the system lay close to Paradip. Maximum pressure change (—8.9 hPa) and the pressure departure (—10.6 hPa) was also observed at 0300 UTC of 21st at Bhubaneshwar. On all the days the associated cyclonic circulation extended up to 7.6 km a.s.l with southerly tilt with height except on 21st, when the circulation had hardly any tilt with height. Over the sea area ship *ATJY* (20.2°N, 87.4°E) reported maximum wind of 180°/40 kt at 0600 UTC of 21st, while over land it was NW/30 kt at Paradip at that hour. However, high wind speed recorder (HWSR) Paradip reported S/45 kt at 0310 UTC of 21st.

The system caused heavy to very heavy rainfall in Orissa, Madhya Pradesh, Maharashtra, Gujarat and in Telangana region of Andhra Pradesh. Heavy rain caused floods in Maharashtra, Gujarat and Andhra Pradesh. As per media reports most of the rivers in south Gujarat region were in spate and many villages in low lying areas remained cut off. The entire communication and transport system were disrupted in the southern districts of Gujarat. Damage to roads, private and public properties was estimated at about Rs. 200 crores in the State.

Heavy rain/floods claimed 114 lives in the State. Floods in the river *Godavari* claimed 36 lives in Andhra Pradesh. In Vidarbha region of Maharashtra 60 persons died due to heavy rain/floods. Amravati town was cut off as the bridge on the river *Wardha* was submerged.

The significant amounts of rainfall (cm) are given below :

21 Aug : Puri 17, Navipet 14, Gopalpur & Nizamabad 11 each, Aheri & Armora 10 each.

22 Aug : Dawdi 20, Brahampuri 19, Lonavala 17, Rajnandgaon 13, Chandrapur 12, Jagdalpur & Mahabaleshwar 9 each.

23 Aug : Khandwa 25, Betul 23, Chandrapur 21, Wardha 19, Dhar 17, Indore 13, Asifabad & Bhopal 11 each, Ratlam 10.

24 Aug : Gandhinagar 33, Bayad 32, Idar 27, Ahmedabad 24, Dohad 23, Dhar 19, Deesa 14, Valsad 11, Indore 10, Khandwa 9.

25 Aug : Mansa 19, Mahansa 17, Bhuj AP 15, Surendranagar 12, Mandvi & Paint 11 each, Ahmedabad, Baroda & Gandhinagar 10 each.

26 Aug : Rajapur 10, Baroda 7.

2.3. *Post-monsoon season*

2.3.1. *Depression, 7-9 October*

The depression formed from the remnant of the Pacific storm 'IRA' which moved from the east and emerged as a low pressure area into east central Bay on 6th. It concentrated into depression over north West Bay on 7th. Moving north it crossed west Bengal coast and weakened over northwest Bangladesh and adjoining West Bengal.

The intensity of the system was estimated as T 1.5 from the INSAT cloud observation in the evening of 6th when it was over the east central Bay though other observations indicated only well marked low pressure area. It concentrated into a depression over northwest Bay and neighbourhood at 0300 UTC of 7th when it was centred near 19.5°N, 88.5°E. Satellite estimate of its intensity at this stage was T 2.0. At 0.9 km a.s.l. Balasore wind, backed from ENE/10 kt to NNE/30 kt at 0000 UTC of 7th and Calcutta wind strengthened from 10 kt to ESE/35 kt. Moving northwards, the system crossed West Bengal coast near Contai in the morning of 8th and lay centred at 0300 UTC close to but north of Contai.

At this hour the surface winds at Dhaka was ESE/20 kt, at Mymensingh (41886) E/20 kt and at Bogra (41883) E/15 kt. Continuing to move northward, the depression lay centred at 1200 UTC of the day about 20 km north of Krishnanagar. At that time S/15 kt winds were reported from Jessore and Dhaka and E/20 kt winds were reported from Bogra, Mymensingh and Rangpur. In the morning of 9th the depression lay over northwest Bangla Desh and adjoining West Bengal centred about 50 km, southsoutheast of Bogra (41883) when 3 closed isobars at an interval of 2 hPa could be drawn. At that time the surface winds at Bogra were NE/10 kt, at Mymensingh E/20 kt and at Chittagong SE/15 kt. The system remained practically stationary and weakened further into a well marked low pressure area over the same region in the evening of 9th. The remnant dissipated over Assam and neighbourhood on 12th. In association with the system the lowest pressure 999.8 hPa was recorded at Berhampore at 1200 UTC of 8th, when the system lay near the station. Maximum wind of 20 kt were reported by several stations in Bangla Desh on 8th and 9th. Pressure departures of the order of—4 to—9 hPa in the depression field were observed on 8th.

The highest satellite (INSAT) classification was T 2.0 from 1200 UTC of 6th to 0900 UTC of 7th.

The system caused heavy rain in Orissa, West Bengal and Assam on a day or two causing floods. As per reports, floods inundated vast areas of human habitations and standing crops in Brahamputra valley. Road communication between Assam and the rest of the country disrupted on 9 October as high floods submerged National highway-37 between Dhupdhara and Rangjuli in lower Assam. Torrential rain on 8th submerged vast areas of Calcutta and neighbourhood. About 384 villages in Midnapore districts and 938 villages in Nadia districts were badly hit by floods. Thousands of people were marooned by the floods. Birbhum, Burdhwan, Hooghly, Howrah and Murshidabad districts of Gangetic West Bengal also experienced damage due to floods.

TABLE 5

Ship observations on 2 November 1990

Call Sign	Time (UTC)	Position		Wind		Remarks
		Lat. (°N)	Long. (°E)	Dir (°)	Speed (kt)	
YSKI	0000	18.6	88.1	070	18	Raining
ATIU	0000	9.8	88.8	250	26	Raining
VUPL	0300	17.2	84.3	040	37	PPPP 1006.9hPa
YSKI	0500	17.6	87.4	080	39	Raining

The significant amounts of rainfall (cm) are given below :

7 Oct: Sandheads 20, Nampong 13, Silchar 12, Puri 9, Paradip 7.

8 Oct: Sandheads 19, Beki Road Bridge 12, Kohima & Khowang 11 each, Agartala AP, Kailashahar & Puri 8 each, Chouldagnat, Kakatpur & Paradip 7 each.

9 Oct: Goalpara & Sandheads 19 each, Beki Road Bridge 11, Mathanpuri & Shillong 10 each, Sagar Island 9, Guwahati AP 8, Agartala AP 7, Calcutta & Chouldaghat 6 each.

10 Oct: Cherrapunji 37, Kailashahar & Matijuri 8 each, Maibat & Tezpur 7 each, Golaghat & north Lakhimpur 6 each.

2.3.2. *Deep depression, 31 October-4 November*

The depression formed over southeast Bay on 31st October. Moving in a northnorthwesterly direction it crossed north Andhra-south Orissa coast on the morning of 4th and dissipated there. A depression formed over southeast Bay at 1200 UTC of 31st near 10.5° N, 87.5° E when satellite intensity classification was T 1.5 and ship *DICK* (5.9° N, 87.5°E) reported wind 270°/32 kt. Moving northwestwards the depression lay centred near 11.5°N, 86.5°E at 0300 UTC of 1 November. At 0000 UTC ship *DICK* (5.6° N, 84.2° E) and ship *GDGX* (5.7°N, 83.1° E) reported winds of 260°/28 kt and 260°/20 kt respectively. The system intensified into a deep depression in the night of 1st/2nd November over the west central Bay. Ship observations received are given in Table 5.

Continuing to move northwards, the deep depression lay centred near 17.0° N, 85.0° E at 1200 UTC of 2nd. At this hour the surface winds at Visakhapatnam and Srikakulam were N/20 kt and NE/20 kt and the winds at 0.9 km a.s.l. at Bhubaneshwar and Visakhapatnam were E/45 kt and NE/35 kt respectively.

Moving in a northerly direction the deep depression was centred at 0300 UTC of 3rd near 18.0° N, 85.0° E and at 1200 UTC of 3rd very close to north Andhra-south Orissa coasts centred near 18.5° N, 85.8° E. Thereafter moving northwestwards the system crossed north Andhra-south Orissa coasts south of Gopalpur between 0000 and 0100 UTC of 4th and weakened. Gopalpur surface wind, which was NE/15 kt at 0000 UTC, became SSW/15 kt at 0100 UTC of 4th. On 4th morning (0300 UTC) it lay over south Orissa and neighbourhood centred about 50 km west of Gopalpur. Over land, it rapidly weakened into a low pressure area by mid-day of 4th over south Orissa and neighbourhood. The remnant of the system lay over Orissa and neighbourhood till 6th and then moved away eastwards across north Bay. INSAT showed well organised clouds at 1200 UTC of 31st October and assessed the intensity at T 1.5. The system attained the peak intensity of T 2.0 at 1500 UTC of 1 November. At 1400 UTC of 2 November the cloud organisation became weak and the centre could not be fixed. In the morning of 4th, the cloud clusters shifted to the northeastern quadrant of the system. Pressure departures along north Andhra-south Orissa coasts were maximum on 3rd evening and 4th morning. The highest pressure departure was —10.8 hPa at Gopalpur at 0300 UTC of 4th and maximum wind 040°/37 kt was by ship *VVPL* (17.2° N, 84.3° E) at 0300 UTC of 2nd.

The system caused heavy to very heavy rainfall on a couple of days over Orissa. It caused severe floods in Ganajam district of Orissa claiming 100 human lives and causing immense damage to crops and properties. A population of 6 lakhs in 341 villages was seriously hit by the flash floods. Aska town was virtually under flood water. Thousands of houses were washed away by the flood waters of the rivers *Rushikulya* and *Badanadi* rendering lakhs of people homeless.

The significant amounts of rainfall (cm) in association with the system are given below :

3 Nov: Gopalpur 18, Puri 17, Bhubaneshwar 14, Purshottampur 13, Naraj 11, Kalingapatnam 10, Mohana & Paradip 9 each, Surada 8, Mahendragarh 6.

4 Nov: Mohana 32, Mahendragarh 17, Madhabarida 16, Berhampur 15, Gopalpur & Surada 13 each, Purshottampur 10, Puri 9, Visakhapatnam 6.

5 Nov: Kotraguda 6, Kalingapatnam 5.

2.3.3. *Depression, 14 November*

A low pressure area was observed over the Andaman sea on 10th. Moving westwards it concentrated into a depression over west central and adjoining southwest Bay off south Andhra-north Tamil Nadu coasts on 14th and lay centred at 0300 UTC near 14.0°N, 81.0° E. The satellite (INSAT) classification at this hour was T 1.5. Moving westwards slowly it lay close to the coast in the evening (1200 UTC) centred near 14.0° N, 80.5° E. It crossed coast about 50 km south of Nellore around midnight of 14th and weakened over north Tamil Nadu and neighbourhood. The remnant moved across the south Peninsula and emerged into the Arabian Sea on 16th. In association with the system, Machilipatnam reported NE/35 kt wind at 0.9 km a.s.l. on 14th evening. Surface winds along north Tamil Nadu-south Andhra coasts ranged from 5 to 10 kt on 14th.

The significant amounts of rainfall (cm) are given below :

15 Nov : Kavali 15, Ongole 13, Sulurpet 8, Kundukar 6, Ponneri 5, Nellore 3.

TABLE 6

Ship observations on 14-18 Dec 1990

Call sign of the Ship	Date and Time (UTC)	Position of the ship		Wind		Remarks
		Lat. (°N)	Long. (°E)	Dir. (°)	Speed (kt)	
Y5KB	141200	6.1	91.2	190	30	PPPP—1000.0 hPa Overcast sky
ATUJ	141200	7.3	82.1	020	22	Raining
ATLH	150000	10.9	83.7	020	17	Overcast sky
VTRG	150300	10.1	83.1	NNE	15	Do.
ATNG	151200	14.6	84.3	010	24	Do.
C6JO9	151200	6.0	88.0	180	15	Rain-shower
S2XL	160430	15.9	86.6	NE	30	Do.
VTPP	160500	16.1	83.1	N	40-50	Overcast
VVGC	160600	13.7	82.9	020	28	—
VVPL	160600	9.4	83.2	310	21	—
VVGC	161200	14.7	83.1	020	28	—
VTPP	161200	14.7	82.8	NNW	40	—
VTDV	161200	10.7	81.6	340	36	PPPP—1007.3
H3PX	171200	17.0	92.5	100	14	PPPP—1009.0
H3PX	180000	18.5	90.5	150	40	PPPP—1003.3

2.3.4. *Bay severe cyclonic storm, 14-18 December*

The system developed over southeast Bay on 14th evening. Initially it moved in a northwesterly direction and then recurved to northeasterly direction. While moving northeastwards, it intensified into a SCS over west central Bay on 17th. Before crossing Bangla Desh coast on 18th night, it weakened into a depression.

The disturbance was initially observed as a low pressure area over southeast Bay and adjoining Andaman sea on 13th morning. It concentrated into a depression in the evening of 14th and lay centred near 7.0° N, 88.0° E. Ship observations in association with this system are given in Table 6. Moving northnorthwestwards, the system intensified into a deep depression and lay centred near 10.5° N, 86.0° E at 1200 UTC of 15th. The system further intensified into a cyclonic storm and centred near 12.5° N, 85.0° E at 0300 UTC of 16th. Several ship observations (Table 6) reported 30 kt wind strength extending up to a distance of 450 km from the centre. Recurving northwards, it lay centred near 14.0° N, 85.0° E at 1200 UTC of 16th. During the night time, the storm further intensified and lay as a SCS centred near 16.0° N, 86.0° E at 0300 UTC of 17th and near 18.0° N, 87.5 °E at 1200 UTC of 17th.

In the morning of 18th, the system weakened and lay as a cyclonic storm centred near 19.5° N, 89.5° E. At 0000 UTC of 18th ship *H3PX* reported SSE/40 kt wind (Table 6). At 1200 UTC of 18th, the system lay about 60 km WSW of Cox's Bazar (21.3° N, 91.5° E) as a depression. At that time, the surface winds were NE/20 kt at Cox's Bazar N/10 kt at Khepupara and NE/25 kt at Sandheads. The system crossed Bangladesh coast near Cox's Bazar in the night of 18th and weakened over central Myanmar and neighbourhood.

The lowest central pressure estimated according to Misra and Gupta formula (1976) was 997 hPa at 0300 UTC of 17th, when it attained its peak intensity of T 3.5.

The system initially was to the south of the sub-tropical ridge. However, it came under the influence of mid and upper tropospheric westerlies from 17th morning when it took a northeasterly course. The cloud organisation shifted to the northeastern sector of the system on 17th. The clouds showed weakening from 18th morning. The diameter of the outermost closed isobar (OCI) was 8 to 10° up to 0300 UTC of 17th. Thereafter, it reduced to 4 to 5°. Galeforce wind was not reported from any coastal station of India.

The average speed of movement of the system was about 17 kmph from the morning of 15th to the morning of 17th. However, it moved at an average speed of 23 kmph during the next 36 hrs after recurvature.

The system weakened over the sea under the influence of strong westerly winds in the middle and upper tropospheric levels, which sheared the cloud development.

The cyclone did not affect Indian weather adversely. However, as per reports, it caused considerable damage in coastal Bangladesh.

3. Arabian Sea

3.1. *Post monsoon season*

3.1.1. *Depression, 16-18 November*

The remnant of a Bay depression moved across the south Peninsula and emerged into east central Arabian Sea on 16th morning. It concentrated into a depression in the evening of 16th and remained quasi-stationary for two days over east central Arabian Sea off north Karnataka-Goa coast and then weakened.

0300 UTC Satellite (INSAT) imagery of 16th showed well organised cloud clusters over north coastal Karnataka and adjoining sea areas, when the intensity of the system was estimated as T 1.5. However, the conventional data didn't indicate the intensity of the system as such. In the evening of 16th, the system concentrated into a depression and lay centred near 14.0°N, 73.0°E. At

that time, at 0.9 km a.s.l. Goa reported wind ESE/20 kt. At the surface level Agatti wind was WNW/10 kt. The system remained stationary there during the whole night and was centred at 0300 UTC of 17th near 14.0° N, 73.0°E. At 0000 UTC of 17th ship *VRIN* (14.7°N, 72.5°E) reported winds 040°/35 kt overcast sky and rain/shower with thundery conditions. The same ship at 0300 UTC from 15.1° N, 71.6° E reported 040°/13 kt wind only. Agatti wind at this hour was WSW/10 kt. Moving northwestwards, it lay at 1200 UTC of the day, centred near 14.5°N, 72.5°E and at 0300 UTC of 18th near 14.5° N, 72.0°E. Thereafter, the system weakened over the east central Arabian Sea during the afternoon of 18th.

The lowest pressure of 1008.8 hPa and maximum wind 040°/35 kt was reported by the ship *VRIN* at 0000 UTC of 17th.

Associated circulation extended up to 9.6 km a.s.l. without any tilt at 0000 UTC of 17th. The diameter of the OCI was 2 to 4° during the first 24 hrs which shrunk further in the morning of 18th.

Satellite (INSAT) classified the system as T 1.5 and T 2.0 at 0300 UTC and at 0900 UTC on 17th. The same intensity continued upto 1200 UTC of 17th.

While moving across the Peninsula, as a low pressure area it caused heavy rainfall over Karnataka. At depression stage over Arabian Sea, it caused heavy rainfall over coastal Karnataka on 17th only.

The significant amounts of rainfall (cm) are given below :

17 Nov : Shirali 10, Honavar 7.

18 Nov : Narsimharajapura 5, Channagiri 4.

4. Land depression

4.1. *Pre-monsoon season*

4.1.1. *Depression, 15 May*

There is no past record of the formation of a depression over the land areas during the month of May. The present depression is first land depression to form in May.

Strong southwesterly winds of the order of 30 kt to 45 kt were observed in the lower tropospheric levels at Visakhapatnam and Bhubaneshwar on 13th. A low pressure area developed over north Orissa and adjoining Bihar Plateau and Gangetic West Bengal on 14th morning. It moved over northwest Bay in the evening. At 1200 UTC of 14th the winds at Khepupara and Jessore (Bangladesh stations) were SE/15 kt and ESE/20 kt respectively and at Sandheads they were SSW/25 kt. The ship *ATKK* (19.2° N, 87.0° E) reported 220/30 kt wind. In the evening Satellite (INSAT) imagery vortex was seen over northwest Bay.

In the morning (0300 UTC) of 15th the system concentrated into a depression over Bangladesh and neighbourhood and was centred about 30 km north of Barisal (Bangladesh). At this hour 3 closed isobar at an interval of 2 hPa could be drawn. At 0000 UTC, of 15th Dhaka and Chittagong reported very strong winds in the lower tropospheric levels. They were E/40 kt at 850 hPa and NE/50 kt at 700 hPa levels at Dhaka and SSW/50 kt and SSW/60 kt in the respective levels at Chittagong. Moving eastwards depression lay at 1200 UTC of 15th centred about 40 km northwest of Chittagong. At this hour Comilla (41933) reported E/30 kt and Chittagong S/10 kt winds. Maximum wind of ENE/55 kt was reported at 2.1 km a.s.l. at Dhaka. It dissipated over Mizoram and neighbourhood in the night of 15th.

The system developed in the westerly current to the north of the sub-tropical ridge and was steered eastwards by it. Dhaka reported a maximum pressure fall of 10.3 hPa for the past 24 hrs at 0300 UTC of 15th. The system caused heavy rainfall in northeast India on 15th.

Significant amounts of rainfall (cm) are given below :

15 May: Cherrapunji 12, Sandheads 11, Agartala AP 8, Chaparmukh, Diamond Harbour & Silchar 7 each, Aizwal & Imphal 6 each, Calcutta & Shillong 5 each.

16 May: Aizwal & Kailashahar 5 each, Agartala AP 3.

4.2. *Monsoon season*

4.2.1. *Depression, 3-4 September*

The remnant of the northwest Pacific typhoon 'BECKY' moved westwards across central Myanmar and emerged as a low pressure area into northeast Bay on 1st. It concentrated into a depression over Gangetic West Bengal and neighbourhood on 3rd. Taking a westnorthwesterly to westerly course it weakened over east Madhya Pradesh and neighbourhood on 4th night.

On 3rd morning the low pressure area, which was over northeast Bay moved over Gangetic West Bengal as a well marked low pressure area. It concentrated into a depression over Gangetic West Bengal and was centred about 30 km south of Midnapore by evening. At 0.9 km a.s.l. the winds at Calcutta, Dhaka and Chittagong were S/25 kt. At 0300 UTC of 4th the system lay over Bihar plateau and neighbourhood centred about 100 km westsouthwest of Jamshedpur. The surface winds in the depression field were 5 to 10 kt at that time. However, 0000 UTC wind at 0.9 km a.s.l. was ESE/25 kt at Patna and WSW/40 kt at Jabalpur. Moving westwards it lay at 1200 UTC of 4th over east Madhya Pradesh and adjoining Bihar plateau and north Orissa centred near Jashpurnagar. At this time, Ranchi reported surface wind of E/10 kt. But Patna at 0.9 km a.s.l. reported E/30 kt wind. It weakened during the night over east Madhya Pradesh and lay by next morning (0300 UTC) as a low pressure area over east Madhya Pradesh. The remnant moved slowly westnorthwestwards and dissipated over northwest Rajasthan and neighbourhood on 10th morning.

On an average the diameter of the OCI was 5 to 7°. The maximum pressure departure in the depression field was of the order of —4 to —6 hPa at 1200 UTC of 3rd. Associated cyclonic circulation extended on both the days up to 7.6 km a.s.l. with usual southward tilt. The lowest pressure 994.9 hPa in association with the system was recorded at Midnapore in the evening (1200 UTC) of 3rd.

Satellite (INSAT) indicated cloud clusters over the land without any vortex. The system caused heavy to very heavy rainfall on a couple of days in Gangetic West Bengal, Orissa, Bihar plateau and in Konkan region.

The significant amounts (cm) of rainfall in association with the system are given below :

3 Sep: Tiring 25, Rajghat & Sagar Island 21 each, Sandheads 16, Jamshedpur 13, Digha 11, Contai & Durga Chack 10 each, Baripada, Dhanbad & Purulia 9 each, Midnapore 8, Calcutta 7.

4 Sep: Baripada 15, Balimundali 14, Panposh 11, Jaipur, Mohanpur & Thakurmunda 9 each, Uluberia 8, Chaibasa & Rajapur 7 each.

5 Sep: Koyna & Rajapur 13 each, Mahabaleshwar 11, Devgarh & Sudhagad 9 each, Chiplun & Lonavala 8 each.