Mausam, (1991), 42, 1, 1-16

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Cyclones and depressions over the Indian seas during 1989*

1. Chief features

During 1989, 10 cyclonic disturbances (depressions and storms) developed over the Bay of Bengal and the Arabian Sea (north Indian Ocean). Their seasonwise distributions are: pre-monsoon season-1, monsoon season-5 and post monsoon season-4. Out of these 10 cyclonic disturbances, two were of the hurricane intensity developed in the Bay of Bengal one in pre-monsoon and the other in post monsoon season and one was of cyclonic storm intensity developed over the Bay of Bengal during monsoon season. Out of these two hurricanes, one formed over the north Bay of Bengal and the other over the Gulf of Thailand. The Arabian Sea remained comparatively dormant with only one deep depression which formed during the onset phase of the monsoon period. The tracks of these storms and depressions are shown in Fig. 1 and their details are given in Table 1. The monthwise frequency of these systems are shown in Table 2.

The special features of these cyclonic storms were that one which formed during the monsoon season was in a much southerly position as compared to normal and caused widespread rain over the entire length and breadth of the country.

The hurricane which formed over the Gulf of Thailand was also unique in the sense that it was of hurricane intensity over the Gulf of Thailand and it remained so up to its landfall over the coastal Andhra Pradesh. Also it was characterised by a very small core.

Satellite (INSAT) classifications of the two hurricanes and the cyclonic storm at different synoptic hours have been given in Table 3. The systems have been discussed individually under Sections 2 and 3.

2. The distribution of the Bay of Bengal system during pre-monsoon month

2. 1. *Balasore severe cyclonic storm with core of hurricane winds 23-27 May*

2.1.1. *Synoptic situation*

A cyclonic circulation in the middle tropospheric levels, was first observed over the central Bay on 18 May 1989. Under its influence a depression developed over east Central Bay and neighbourhood on 23rd morning. Initially the system followed a northerly course and then a northwesterly course and intensified into a cyclonic storm in the morning of 24th. Thereafter, it moved westwards and further intensified into a severe cyclonic storm (S.C.S.) over northwest Bay on 25th evening. Afterwards, it took a northerly course and became a S.C.S. with a core of hurricane winds by the next morning, off north Orissa coast. It crossed north Orissa-West Bengal coast about 40 km northeast of Balasore around 1500 UTC of 26th and became unimportant over northern parts of West Bengal and neighbourhood by 28th.

2. 1. 2. *The wind observations in the disturbance field*

Ship observations between 23 and 26 May are given in Table 4 and satellite classifications and positions at different synoptic hours are listed in Table 3. On 23rd, the wind observations of the ship *VWDG* (Table 4) were significant. It reported northerly 28 kt wind at 0600 UTC, when the system was a depression and northwesterly 40 kt wind when it concentrated into a deep depression at 1200 UTC of that day.

On 24th morning the observations of the ship *VWDG* (both at 0000 and 0300 UTC) indicated strong winds (55 kt) in the front quadrant of the system when it had intensified into a storm. Coastal stations of Orissa reported very light winds (02-05 kt). The wind observations of the ship *VWSZ* (0000 UTC) and stations on Orissa coast indicated that the areal extent of the storm was comparatively smaller. In the evening (1200 UTC) of the day, the storm came closer to the Orissa coast. However, there was no significant change in the winds at the

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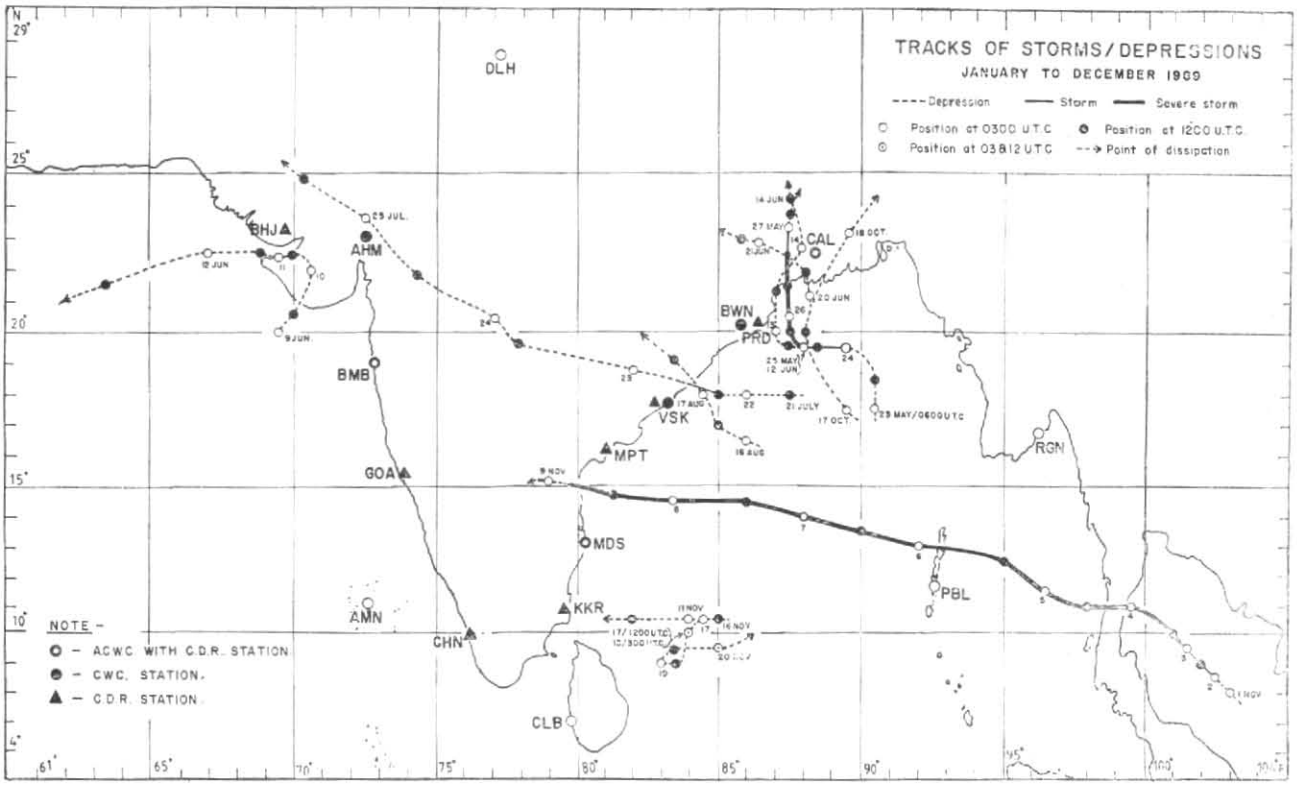

Fig. 1. Tracks of storms and depressions during January-December 1989

coastal stations of Orissa. They were of the order of 05 to 10 kt only. Off the coast the winds were high as indicated by the observations of the ships *VWDG*, *VWSZ* and *ATKI*.

On 25th morning, the observations of the ship *VWSZ*, indicated 45 kt winds in the left hand rear quadrant of the storm. At 0300 UTC the wind observation of Sandheads, which was 090°/40 kt showed that the winds in the right hand rear quadrant was equally strong. However, at 0300 UTC, the storm centre was hardly about 150 km away from the coast but the winds over the coastal areas of north Orissa were merely 10 to 15 kt from north. By the evening of 25th the storm further intensified into a severe one and came further close to Orissa coast. At 1200 UTC, ship *VWSZ* reported 40 kt wind, but Paradip and Sandheads winds were only N/20 kt and ENE/15 kt respectively. It was apparent from these observations that though the storm had intensified, the areal extent of the gale force winds remained small. The wind field in the outer ring of the storm, *i. e.*, about 150 to 200 km from the centre of the storm was asymmetric. From 25th evening the storm took a northerly course and headed for north Orissa-West Bengal coasts.

In the morning of 26th, the storm further intensified into a hurricane and its centre came further close to the north Orissa coast. It lay hardly 60 to 70 km away from Chandbali at 0300 UTC of the day. The coastal areas of north Orissa came under the direct influence of the storm from 25th night. The winds along the coast increased considerably in the morning of 26th. At 0300 UTC of the day, Paradip, Chandbali and Contai reported NW/45 kt, N/20 kt and NE/25kt winds respectively. However, along the coast just about 75 km southwest of Paradip, the wind at Puri, at 0300 UTC was NW/05 kt only. The observation of the ship *VTBN* (Table 4) and the aforesaid wind observations indicated that the wind strength in the SW-sector of the storm centre decreased very rapidly with distance. Continuing to move northwards the hurricane centre lay at 1200 UTC of 26th very close to north Orissa coast (about 30 km east of Balasore). At this hour, Balasore, Chandbali and Contai reported N/37 kt, W/25 kt and SE/25 kt winds respectively. However, in the open sea ship *VWSZ* (Table 4) reported 45 kt wind. It is very significant to note that the hurricane centre lay at 1200 UTC of 26th only 30 km east of Balasore, but the wind force at the stations was much less than the hurricane wind strength. Radius of maximum wind (RMW) in the hurricane appeared to be much less than 30 km and also the gale force wind strength had hardly extended beyond 30 to 35 km from the storm centre. At this hour the lowest pressure of 972.0

TABLE 1

Details of depressions/cyclonic storms over the Indian seas during 1989

Type of system	Life period	Point of crossing the coast with date	Lowest pressure recorded central pressure (hPa)	Maximum wind recorded	Highest T No. recorded
		Bay of Bengal			
(1) Balasore severe cyclonic storm with core of hurricane winds	23-27 May	On 26th May between 1500 & 1600 UTC about 40 km northeast of Balasore	Digha 970.4 hPa between 26th 1430 and 26th 1600 UTC	Balasore NW/60 kt from 1500 to 1600 UTC of 26th	4.0
(2) Deep depression	12-14 Jun	On the night of 13 Jun between Balasore and Contai	Balasore 987.8 hPa at 1200 UTC of 13th	Sandheads S/30 kt at 1200 UTC of 13th	—
(3) Depression	20-21 Jun	On the night of 20th near Contai	Contai 992.8 hPa at 1200 UTC of 20th	Sandheads SSW/25 kt at 1200 UTC of 21st	1.5
(4) Kalingapatnam cyclonic storm	21-26 Jul	Near Kalingapatnam between 1600 & 1700 UTC of 22nd	983.8 hPa recorded at Chandrapur & Pusad at 1200 UTC of 23rd	Oversea ship *SZBA* (15°N/86.5°E) 230°/55kt at 22nd 0300 UTC. Overland, Puri 090°/30 kt between 22nd 0900 & 22nd 1000 UTC	2.5
(5) Deep depression	16-17 Aug	Near Kalingapatnam around 17th noon	993.8 hPa by the ship *VTJR* at 16th 1200 UTC	*VTJR* (16.2 °N, 86.0 °E) 170°/35 kt at 16th 1200 UTC	2.5
(6) Depression	17-18 Oct	West Bengal - Bangladesh coasts near Long. 89.0 °E on 17th night	Jessore 1004.0 hPa at 0300 UTC of 18th	Ship *VSBS* (18.6° N/89.8°E) 100°/21 kt at 0000 UTC of 17th	2.0
(7) Kavali hurricane	1-9 Nov	South Andhra coast near Kavali at about 1900 UTC of 8th	Estimated 942.0 hPa at 1200 UTC of 8th	Mayabandar & Long Island Variable/46 kt at 0300 UTC of 6th	6.5
(8) Depression	11 Nov	Dissipated over southwest Bay off Tamil Nadu coast	—	Ship *ATIC* (11.7 °N, 84.6°E) 090°/40 kt at 11th 1200 UTC	1.0
(9) Deep depression	16-20 Nov	Dissipated over southwest and adjoining southeast Bay	—	Ship *ATJX* 050°/30 kt on 19th 0600 UTC & ship *ATKA* 010°/30 kt on 20th 0600 UTC	2.5
		Arabian Sea			
(1) Deep depression	9-12 Jun	Near Veraval around midnight of 9th	Veraval, 987.8 hPa at 1800 UTC of 9th	Veraval, WNW/35 kt and SW/35 kt at 0300 & 1200 UTC of 11th respectively	1.5

hPa in association with the system, was recorded at Balasore.

Hourly observations of Balasore (Fig. 4) indicated that the storm crossed north Orissa coast about 40 km northeast of Balasore after 1500 UTC of 26th. Chandipur reported 'calm' wind for 15 minutes from 1530 UTC and Basta, which is situated further to the north reported calm wind for 15 minutes from 1730 UTC of 26th. From these two observations it was apparent that the storm centre crossed coast between 1500 and 1600 UTC of the day and the 'eye' travelled across Chandipur and Basta.

Balasore reported 60 kt wind from 1500 UTC to 1700 UTC and the estimated wind speed at Basta was 65 to 75 kt at 1800 UTC of 26th. It was evident from these observations that the storm retained its hurricane force

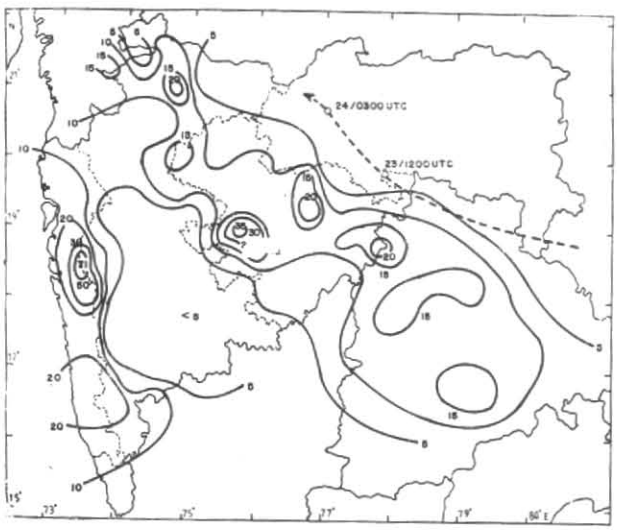

Fig. 2. Rainfall distribution at 03 UTC of 24 Jul 1989 (unit cm)

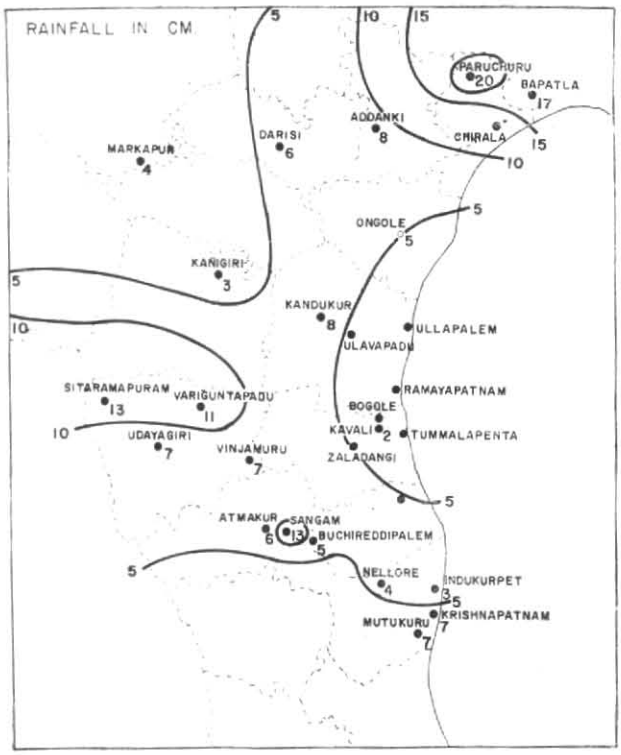

Fig. 3. Total rainfall due to Kavali hurricane from 8 to 10 Nov 1989

TABLE 2

Monthly frequency of cyclonic disturbances in the Bay of Bengal and Arabian Sea during 1989

Type of system	Jan-Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bay of Bengal										
Depression	—	—	2	—	1	—	1	2	—	6
Cyclonic storm	—	—	—	1	—	—	—	—	—	1
Severe cyclonic storm	—	—	—	—	—	—	—	—	—	—
Severe cyclonic storm with core of hurricane winds	—	1	—	—	—	—	—	1	—	2
Arabian Sea										
Depression	—	—	1	—	—	—	—	—	—	1
Total	—	1	3	1	1	—	1	3	—	10

wind strength over land at least up to 1800 UTC of this day. The severity of the storm was also felt over Midnapore district of West Bengal. Debra, Ramnagar, Digha & Egra of Midnapore district experienced gale force wind speed reaching 53 kt from the southeasterly direction. Sagar Island observatory also recorded a maximum wind speed of 49 kt in gust around 1800 UTC of 26th. The system moved northwards over land as a severe cyclonic storm till the midnight of 26th and thereafter weakened.

On 27th morning (0300 UTC) the system lay over Gangetic West Bengal as a cyclonic storm centred about 30 km northeast of Bankura. At this hour the winds around the storm over the land areas were about 20 kt, but was much higher over the sea as was evident from the wind observations of the ship *VWSZ* (Table 4) which was about 35 kt. By the evening of 27th system weakened into a depression with its centre lying just north of Sriniketan. At this time Satkhira in Bangladesh reported S/20 kt wind and Sabour reported NE/15

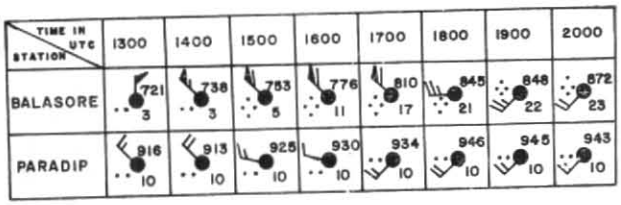

Fig. 4. Hourly observations from 1300 UTC to 2000 UTC of 26 May 1989

kt wind. By the midnight of 27th, it further weakened over the northern parts of Gangetic West Bengal and adjoining Bihar and Bangladesh and became unimportant by the next day morning.

2. 1. 3. *Main features of the hurricane*

In association with the system the highest wind speed and the lowest pressure were recorded at Balasore. The lowest pressure of 972.0 hPa was recorded there at 1200 UTC and maximum wind speed of NW/60 kt from 1500 to 1700 UTC of 26th. When the maximum wind speed was felt at Balasore, the system, as per the satellite imageries, had the intensity equivalent to T. No. 3.5/CI No. 4.0 which corresponds to 55/65kt. It attained its peak intensity of T 4.0 (65 kt) at 0300 UTC of 26th.

As per the reports, Chandipur, Bhograi and Basta in Balasore district experienced calm wind for about 15 to 20 min. at 1530, 1600 and 1730 UTC respectively of 26th followed by very strong winds (estimated) of the order of 65 kt to 75 kt. The storm developed an 'eye' which had travelled over these places during these hours. Satellite could locate 'ragged eye' of the system at 0900 and 1000 UTC of 26th. The Cyclone Detection Radar at Paradip detected an 'open eye' of the hurricane from 0300 UTC of the day.

In association with hurricane, the wind maximum of WNW/60 kt was observed at Bhubaneswar at 1.5 km a.s.l. on 26th, 1200 UTC, while that at Balasore was NW/60 kt at surface level from 1500 to 1700 UTC of 26th, when the storm was situated to the northeast of the stations. In Midnapore district surface wind speed of the order of 40 to 50 kt were experienced at several places. The areal extent of the storm was normal. The average diameter of the outermost closed isobar was 6 to 7 degrees. It was 4 to 5-degree in diameter before landfall.

The northerly movement of the storm was apparently due to the influence of a trough in the mid tropospheric westerlies. It came under the influence of these westerlies from the evening of 24 May.

2. 1. 4. *Cloud features*

Satellite imageries indicated rapid development of the system between 2100 UTC of 24th and 0330 UTC of 25th. During this period it developed by one T No. At 0330 UTC of 25th curved cumulus lines to the NE of the centre increased in numbers and showed greater curvature. Between 0600 and 0900 UTC of this day the clouds organised in the shape of a 'comma' cloud. By 0200 UTC of the next day the central dense overcast (CDO) clouds of about 2 degree diameter was observed. An indistinct 'eye' first appeared in the CDO in the imagery of 0600 UTC of 26th.

2. 1. 5. *Tidal waves and damages*

The impact of the storm was felt in Cuttack and Balasore districts of Orissa and Midnapore, 24-Parganas and Hooghly districts of West Bengal. Tidal waves of 3 to 6 m height were observed in the coastal areas of Balasore, Midnapore and 24-Parganas districts. In Balasore district, sea water entered into the low lying areas of Rajnagar, Rajkanika, Pattamundai and Mahakalpara through the adjacent rivers *Brahmani, Nuna, Birupa* and the tributaries of *Mahanadi.* Sea water of 5 to 6 feet height also entered through *Suvarnarekha* river in Baliapal block in the night of 26 May affecting a few villages. In Bahanaga block sea water entered about 6 km inland submerging low lying areas. In most of the places sea water submerged land areas 4 to 6 km inland along the coast and the river belts. 10 feet high water entered land areas near Panchupalli and Avana villages. At Khorasahapur, Avana and Ramthali villages saline water reached a height of 6 feet in the afternoon of 26th. Maximum tide level of 5.72 m was observed at the southern end of Sagar Island. However, Kakdwip did not experience any serious impact of the storm. The hurricane took a toll of 24 lives in Orissa and 37 lives in West Bengal and affected about 6.9 million population in these states. It damaged completely or partially about 53160 houses, perished 1000 cattle heads and affected about 3.2 million people in West Bengal. The corresponding number in Orissa were 92000, 1625 and 3.7 million respectively. Damages to crops were considerable in these States.

2. 1. 6. *Rainfall*

In association with the hurricane, the significant amounts of rainfall (cm) were as follows :

25 May : Raj Kanika & Paradip 6 each.

26 May : Paradip 22, Sandheads 15, Erasama 14, Aul, Chandbali & Mahakalpara 12 each, Balikuda & Pattamundai 11 each, Binjharpur & Kujong 10 each.

27 May : Balasore 26, Tahidi 22, Midnapore 20, Chandbali 18, Baliapal, Rajnagar & Pattamundai 16 each, Digha & Jaleswar 15 each. Basudevpur & Rasulpur 14 each, Basta & Bhadrak 13 each, Bhograi 12, Paradip 11.

28 May : Malda 9, Gangtok 7.

3. The disturbances in the Bay of Bengal during monsoon season

3. 1. *Deep depression, 12-14 June*

The system started as a cyclonic circulation in lower and middle tropospheric wind shear zone over the Bay of Bengal. It was the first depression of the season that

TABLE 3

Satellite positions and T-classifications of the storms of 1989 over the Indian seas

Date	Time (UTC)	Satellite INSAT) T-classifi-(cation/ C.I. No.	Co-ordinates of the centre given by satellite (INSAT) (Lat°. °N)	Long.° E)
		(1) Balasore hurricane		
23 May	0300	1.0	17.0	90.0
	1200	1.0	18.0	90.0
24 May	0300	2.0	19.5	88.5
	1200	2.0	19.5	88.5
	2100	2.5	19.5	87.0
25 May	0300	3.0	19.3	87.1
	0900	3.5	20.0	87.8
	1200	3.5	19.5	87.5
26 May	0300	4.0	20.4	87.1
	1200	3.5/4.0	21.7	86.8
	1500	3.0	22.0	86.9
27 May	0000	3.0	23.0	86.9
		(2) Kalingapatnam storm		
21 Jul	1200	1.0	—	—
22 Jul	1200	1.5	16.5	84.0
	1500	2.5	17.0	84.0
	1800	2.5	17.0	84.0
		(3) Kavali hurricane		
1 Nov	0430	1.5	8.0	102.5
	1200	2.0	8.0	103.0
2 Nov	0430	2.5	8.5	102.5
	1200	2.5	8.5	102.5
3 Nov	0430	4.0	9.7	101.5
	1200	4.0	10.2	100.8
	1500	4.5	10.4	100.5
4 Nov	0000	5.0	10.7	99.8
	0300	5.0	10.9	99.5
	1200	4.5/5.0	11.3	98.2
	2300	5.0	11.5	97.2
5 Nov	0300	5.5	11.7	96.5
	1200	4.5/5.0	12.4	94.8
6 Nov	0000	4.0/4.5	12.5	93.3
	0300	4.0	13.1	91.8
6 Nov	1200	5.0	13.5	90.1
7 Nov	0300	5.5	14.2	87.8
	0600	6.0	14.4	87.0
	1200	6.0	14.6	86.1
8 Nov	0300	6.0	14.8	83.2
	0900	6.5	—	—
	1400	6.0/6.5	14.9	81.8
	1800	5.5/6.0	15.1	80.1

TABLE 4

Ship observations from 23 to 26 May 1989

Call sign of the Ship	Hour of obsn. (UTC)	Position Lat. (° N)	Position Long. (° E)	Wind Direction (°)	Wind Speed (kt)	Remarks
		23 May				
VWDG	0000	17.1	91.0	180	10	
Do.	0600	17.9	90.5	010	28	
Do.	1200	18.6	89.9	320	40	Raining
ATVC	Do.	18.5	85.8	200	05	
VWSZ	Do.	16.0	83.2	190	20	
		24 May				
VWSZ	0000	17.7	85.0	180	12	Overcast sky
VWDG	0000	19.7	89.0	040	55	Raining
Do.	0300	19.8	88.9	040	55	
VWSZ	0600	18.5	85.8	180	12	
VWDG	Do.	20.1	88.8	120	35	
VWSZ	1200	19.3	86.7	010	32	Drizzling
ATKI	Do.	18.2	87.1	330	20	Overcast sky
		25 May				
VWSZ	0000	18.4	88.1	230	45	Raining
Do.	0600	19.1	89.1	180	45	Do
Do.	1200	20.1	89.1	150	40	
VTBN	Do.	17.8	84.7	260	08	
VWSZ	1500	20.1	89.3	130	40	Shower
		26 May				
VTBN	0000	18.4	86.1	260	14	Raining
VWSZ	Do.	20.3	88.5	200	35	
VWSZ	0300	20.1	89.3	170	35	Raining
VTBN	0600	18.6	87.1	270	06	
VWSZ	0900	20.2	89.5	220	53	Shower
Do.	1200	20.0	89.6	180	45	Raining

formed over the Bay of Bengal. It mainly took a northerly course, crossed north Orissa-West Bengal coast on 13th night and dissipated over central parts of Bihar and adjoining West Bengal.

A marked wind shear zone developed in the lower and middle tropospheric levels over the central Bay of Bengal on 11th. This was evident from the 0000 UTC wind observations of Port Blair and Visakhapatnam which reported WSW/50 kt and NE/15 kt winds respectively at the 700 hPa level. On 11th morning itself a low pressure area developed over the northwest and the adjoining west central Bay. The low concentrated into a depression over the northwest Bay by 0300 UTC of 12th. The 0300 UTC surface wind observations of Sandheads and Paradip were quite significant, which indicated the formation of an intense system over the northwest Bay of Bengal. At this hour Sandheads reported E/20 kt wind and Paradip NE/20 kt. The depression was centred near 19.5° N, 88.0° E. Moving initially in a westerly direction it headed towards Orissa coast and at 1200 UTC of 12 June, it lay centred near 19.5°N, 87.5°E. The monsoon current over the central Bay strengthened due to the presenec of depression as evidenced by the wind observation of a ship *VWGR* (14.2° N/85.5° E). The ship reported overcast sky and 250°/30 kt wind. Sandheads continued reporting E/20 kt wind. On 13th morning, at 0000 UTC, the ship *VWGR* (16.5°N, 84.1°E) continued to report strong winds of 250°/35 kt overcast sky and present weather as moderate rain. Also at 0300 UTC of the day Sandheads and Paradip reported S/25 kt and NE/15 kt winds respectively. At 1200 UTC of 13th, the system further intensified into a deep depression and lay centred just south of Balasore. The significant surface winds at this hour were S/30 kt at Sandheads, WSW/25 kt at Bhubaneswar and NE/10 kt at Balasore. Moving northwards the system crossed north Orissa-West Bengal coasts between Balasore and Contai in the night of 13th and lay at 0300 UTC of 14th as a deep depression with three closed isobars over Gangetic West Bengal and adjoining north Orissa and Bihar plateau centred about 50 km northeast of Midnapore. The system started weakening thereafter, and by the evening of 14th became a depression over Gangetic West Bengal and adjoining central parts of Bihar, where it further weakened by midnight. The remnant became unimportant over the same area on 15th.

The diameter of the outermost closed isobar (OCI) was maximum on 13th 0300 UTC, when it measured about 7 to 8 degrees and was minimum at 13th 1200 UTC, when it was about 2-degree. When the system intensified into a deep depression, *i. e.*, at 1200 UTC of 13th it had a minimim OCI. The minimum pressure was also recorded at Balasore at 1200 UTC of 13th, when the centre of the system was close to the station. The recorded pressure was 987.8 hPa. Incidentally, at this hour the maximum wind in association with the system was recorded at Sandheads. It was S/30 kt. However, over land the maximum wind speed recorded was 20 kt only at Paradip on 12th. Bhubaneswar on 13th and Purnea on 14th also reported a wind speed of 20 kt.

In the satellite (INSAT) imagery huge cloud mass to the west of the system extending between 13°N and 20°N was observed in the morning of 13th. However, as the depression started moving northwards, the cloud belt also moved to the northern sector of the system. At 1200 UTC of 13th, the main cloud mass lay over Orissa and adjoining Bay of Bengal, southern parts of Bihar plateau and adjoining Gangetic West Bengal and over Assam & Meghalaya and Nagaland, Manipur, Mizoram & Tripura.

The system moved initially westwards under the influence of upper tropospheric easterlies. On 13th morning, the tongue of a mid-latitude trough in the westerlies intruded towards south and came close to the system when it steered the system towards north.

The system advanced the Bay branch of the monsoon current over Orissa, West Bengal, Bihar plateau and southeast Madhya Pradesh and also caused heavy to very heavy rainfall for a couple of days over the land areas. The significant amounts of rainfall (cm) in association with the system were as follows :

12 June : Anandpur & Gopalpur 5 each.
13 June : Gopalpur 31, Berhampur 20, Mahendragarh 17, Kashinagar & Purushottampur 16 each, Mohana 12, Aska 9, Paradip 6.
14 June : Rajghat 18, Cherrapunji & Naraj 17 each, Bhubaneswar & Tikrapare 15 each, Puri 14, Balasore & Swampatna 13 each, Midnapore 10, Tadong & Sandheads 8 each, Kishanganj & Bahadurganj 7 each.
15 June : Cherrapunji 41, Purnea 32, Katihar 19, Baltara & Kishanganj 15 each, Hemgiri 13, Rupsi 12, Jalpaiguri & Taibpur 11 each, Araria, Balurghat, Telkoi & Thakurganj 10 each, Gangtok & Sriniketan 9 each, Maheshpur 7, Panagarh 6.

The characteristic features of the rainfall pattern was as follows :

(*i*) Up to the morning of 14th, the heavy to very heavy rainfall occurred over Orissa, *i. e.*, in the W/SW sector of the depression/deep depression.

(*ii*) Thereafter, the heavy rainfall belt shifted to the northern sector of the system.

3. 2. *Depression, 20-21 June*

The initial genesis of the depression took place from an upper air cyclonic circulation in the middle tropospheric levels on 18th over the north Bay of Bengal. In the morning of 19th the cyclonic circulation extended from the surface level to 400 hPa. The axis of the seasonal monsoon trough extended into the north Bay of Bengal. In the middle and upper tropospheric levels the subtropical anticyclone lay to the east of the circulation providing southeasterly currents in the area of the disturbance. By evening of this day, the circulation became more marked. In the morning of 20th the disturbance concentrated into a depression over head Bay and lay centred at 0300 UTC about 30 km north of Sandheads.

The depression initially took a northerly course and then a westnorthwesterly course, crossed north Orissa West Bengal coast near contai in the night of 20th and dissipated over Bihar plateau and adjoining northeast Madhya Pradesh.

The system moved along the southwestern periphery of the middle and upper tropospheric anticyclone that lay over eastern Tibet and southwest China.

The maximum pressure drop of 6 hPa in the depression field was observed at 0300 UTC of 20th, which became only 2 to 3 hPa at 1200 UTC of 21st. Departure of

pressure from normal was the lowest at 0300 UTC of 21st ranging between *minus* 3 hPa to *minus* 6 hPa in and around the depression. The diameter of the outermost closed isobar ranged from 5 to 8-degree between 0300 UTC of 20th and 0300 UTC of 21st, which became about 3-degree at 1200 UTC of 21st. The lowest pressure of 992.8 hPa was recorded at 1200 UTC of 20th at Contai, when the depression was close to Contai. The maximum wind in association with the depression was SSW/25 kt, recorded by Sandheads at 1200 UTC of 21st.

The significant amounts of rainfall (cm) were as follows :

20 June : Rajghat 18, Jaipur & Midnapore 13 each, Bankura, Balasore, Baripada, Diamond Harbour & Thakurmunda 8 each, Contai 7.

21 June : Balasore & Simdega 9 each, Jamsolaghat 8, Contai, Champua, Purulia & Ranchi 7 each, Baripada & Raigarh 6 each.

22 June : Karwi 13, Tensa 11, Katghora 10, Bagodar 9, Baikunthpur, Lohardaga & Pendra 8 each, Ambikapur, Ramanujgam & Sidhi 7 each, Damoh, Panposh, Palkot, Tadong & Tallital 6 each.

23 June : Panna 20, Khajuraho 16, Orai & Satna 13 each, Maihar 11, Rewa & Umaria 10 each, Chhatarpur, Kalpi & Lansdowne 9 each, Baheri 8, Ragaul 7.

3. 3. *Kalingapatnam cyclonic storm, 21-25 July*

The genesis of cyclonic storm started on 20 July morning as an upper air cyclonic circulation in the lower and middle tropospheric levels over north and adjoining central Bay. At the surface level Sandheads and Paradip winds at 0300 UTC of 20th were NE/10 kt and SE/05 kt respectively indicating the development of a monsoon disturbance over north and adjoining central Bay. At 0300 UTC of 21st, Paradip wind became 100°/15 kt. The satellite (INSAT) imagery report indicated a vortex over central and adjoining north Bay. By the evening of 21st the disturbance concentrated into a depression over west central and adjoining northwest Bay of Bengal. It took initially a westerly course, intensified into a cyclonic storm and crossed north Andhra-south Orissa coast near Kalingapatnam during the night of 22nd. Thereafter it weakened into a deep depression and moved in a westnorthwesterly direction and travelled right up to south Pakistan when finally it merged with the seasonal low.

At 1200 UTC of 21st a ship *ATIU* (12.0° N, 87.7° E) reported very strong wind of the order of 40 kt from the west over the central Bay. Also Paradip reported ESE/20 kt wind at the same hour. The satellite (INSAT) indicated a vortex over the central Bay with an intensity of T 1.0. The disturbance was declared at this stage as a depression. It lay centred near 18.0° N, 87.5° E. On 22nd the observations of the following ships were quite significant.

Also, at 0300 UTC of 22nd Sandheads and Gopalpur reported 090°/30 kt and 360°/20 kt winds respectively. All the stations of coastal Andhra Pradesh reported rain.

TABLE 5

Ship observations on 22 July 1989

Time (UTC)	Call sign of the ship	Position		Wind		Remarks
		Lat. (°N)	Long. (°E)	Dir (°)	Speed (kt)	
0000	ATIU	12.0	86.6	260	35	Overcast sky
0300	SZBA	15.0	86.2	230	55	Raining
0600	ATKD	17.1	84.5	260	10	Overcast sky
Do.	ATIU	12.1	86.2	260	40	Do.
Do.	ATAY	12.3	84.5	240	24	Do.

The system further intensified into a deep depression and lay centred near 18.0°N, 86.0°E. As per the ship observation given in Table 5, it was quite evident that very vigorous monsoon conditions prevailed over the west central Bay of Bengal. Further, the wind was comparatively weak in the southwestern sector of the system. At 1200 UTC of 22nd the system came further close to the north Andhra coast. The winds at the coastal observatories both to the north and to the south of the disturbance were of the order of 10 to 25 kt.

To its north the winds were 090°/15 kt at Kalingapatnam, 090°/25 kt at Gopalpur and 090°/25 kt at Paradip, while in the southern sector the winds were 330°/10 kt at Visakhapatnam, 270°/10 kt at Kakinada and 250°/20 kt at Machilipatnam. However, at 2.1 km a.s.l. Bhubaneswar reported ESE/55 kt wind. The pressure departures from the normal were —13 to —15 hPa along north Andhra coast. Satellite imagery of 1200 UTC indicated further intensification of the system. Considering these aspects the system was upgraded to a cyclonic storm at 1200 UTC of 22nd. At this hour the storm lay centred near 18.0° N, 85° E, about 150 km to the east of Waltair.

The surface level winds at Visakhapatnam, which were WNW/05 kt between 1200 UTC and 1600 UTC of 22nd, became SSW/05 kt at 1700 UTC. These observations indicated that the storm crossed coast between 1600 UTC and 1700 UTC of 22nd near Kalingapatnam. After crossing coast the storm weakened into a deep depression and lay at 0300 UTC of 23rd over north Andhra and adjoining southeast Madhya Pradesh centred about 50 km south of Jagdalpur. Winds along the north Andhra coast were SW/15 to 20 kt. However, in the lower tropospheric levels, the strength of westerlies and easterlies were quite strong. Within 2.5 degree latitude on either side of the deep depression the strength of the winds were about 40 kt. Moving in a westnorthwesterly direction, the system lay centred at 1200 UTC of 23rd about 50 km southeast of Pusad. It travelled about 400 km between 0300 and 1200 UTC (in about 9 hours) of the day, *i. e.,* at a speed of 45 kmph. Over land such a speed could be considered as rather high. At 1200 UTC of 23rd the surface winds in the southwestern sector of the system strengthened. The winds were SW/25 kt at Karwar, W/20 kt at Ratnagiri, W/15 kt at Bombay, SW/20 kt at Hyderabad and NNW/-0 kt at Aurangabad. From this point the deep depression

took a rather northwesterly course and lay at 0300 UTC of 24th centred very close to Akola. The speed of movement was rather slow during the night of 23rd. It covered in 15 hours about 150 km, *i.e.*, at a rate of 10 kmph only. The west coast winds continued to remain quite strong. At 0300 UTC of 24th surface winds were WNW/30 kt at Bombay, W/25 kt at Harnai, W/20 kt at Ratnagiri and SW/25 kt at Karwar. After 0300 UTC of 24th, the deep depression moved rather fast in a westnorthwesterly direction and lay at 1200 UTC of the day over north Madhya Maharashtra-south Gujarat region and neighbourhood with its centre about 50 km north of Nandurbar. Between the morning and evening of 24th the system moved about 300 km. At this time strong winds prevailed about 2 to 5-degree away from the centre of the deep depression. On the surface level the winds were WSW/30 kt at Aurangabad, WSW/25 kt at Dahanu, ESE/20 kt at Indore and Bhopal. Over the east central Arabian Sea ships reported quite strong monsoon current. Ship *ATUK* (17.5° N, 69.5° E) reported 270°/40 kt and *ATKA* (18.6°N,72.5°E) reported 260°/30 kt. The system weakened thereafter and lay at 0300 UTC of 25th as a depression over Gujarat with its centre about 60 km north of Ahmedabad. Only Veraval and Indore reported moderately strong winds which were S/20 kt at Indore and WSW/20 kt at Veraval. The winds reported by other stations varied from 5 to 10 kt. At 1200 UTC of 25th the depression lay over southeast Pakistan and adjoining Saurashtra & Kutch and southwest Rajasthan with its centre about 130 km southsouthwest of Barmer. The prevailing winds over Saurashtra & Kutch were moderately strong. They were W/20 kt at Veraval and SSW/15 kt at Rajkot and Bhavnager. Continuing to move in a westnorthwesterly direction it further weakened and lay as a well marked low pressure area over south Pakistan on 26th morning, where it became unimportant on 27th.

Throughout its life span the areal extent of the system was quite large. The outermost closed isobar (OCI) had a diameter of 7 to 8-degree at 1200 UTC of 22nd when it was a cyclonic storm. During the remaining period, the diameter of the OCI ranged from 8 to 12-degree. As a result, the rainfall belt was also quite extensive.

The highest wind of 230°/55 kt over the sea area was reported by the ship *SZBA* (15.0° N, 86.2° E) at 0300 UTC of 22nd. Over the land area throughout its life span strong to moderately strong surface winds were observed. The highest winds over land areas were observed at Bhubaneswar in the east coast and at Aurangabad & Bombay in western Maharashtra. In the east coast Bhubaneswar reported 090°/35 kt wind between 0900 and 1000 UTC of 22nd. At Bombay it was WNW/30 kt at 0300 UTC of 24th, while it was WSW/30 kt at Aurangabad at 1200 UTC of the day.

Maximum pressure drops of the order of 6 to 9 hPa were observed in the depression field on 22nd and 23rd. The departures from the normal were also maximum on these days. It was *minus* 15.1 hPa at Kalingapatnam at 22nd 1200 UTC. It ranged from *minus* 12 hPa to *minus* 15 hPa on 23rd. At 0300 UTC of 23rd the lowest departure of *minus* 15.3 hPa was recorded at Hyderabed and that at 1200 UTC was *minus* 15.2 hPa at Chandrapur. In association with the system the lowest pressure of 983.8 hPa was recorded at Chandrapur and Pusad at 1200 UTC of 23rd.

3. 3. 1. *Winds*

The circulation of the system extended on most of the days up to 300 hPa level and it had little tilt with height up to 500 hPa level. On the surface level strong westerly as well as strong easterly winds were observed almost throughout the life span of the system. However, on 22nd the highest easterly wind of 30 kt was reported by Sandheads at 0300 UTC, while at the same time the highest westerly wind of 55 kt was reported by the ship *SZBA*. At 0600 UTC of 22ad the ship *ATKD*, which lay about 150 km southwest of the deep depression centre reported only 10 kt westerly wind. These observations showed that the system had comparatively weaker wind strength in its southwest quadrant. In the afternoon of 22nd moderate to strong winds were observed in the south Orissa coast. The wind at 0600 and 0700 UTC of the day was 360°/30 kt at Gopalpur, 090°/35 kt at Bhubaneswar and 090°/35 kt at Puri at 0900 UTC and 090°/32 kt at 0800 UTC at Paradip. The strong easterly wind of 35 kt strength continued at Puri up to 1000 UTC of 22nd.

In the lower tropospheric levels the circulation of the system was quite strong. The strength of the westerly current was stronger than the easterly current. At 1200 UTC of 23rd, Machilipatnam reported WSW/60 kt winds both at 0.9 km and 1.5 km a. s. l., which became E/30 kt and NE/35 kt respectively at Nagpur. At 0000 UTC of 24th the strongest westerly and easterly winds WSW/60 kt at Hyderabad at 3.1 km a. s. l. and E/50 kt at Gwalior at 1.5 km a.s.l. were observed. It was apparent that there was very large horizontal shear in the circulation field. The middle and upper tropospheric anticyclone was positioned over the Tibetan plateau and neighbourhood throughout the period of disturbance. It moved along the southern periphery of this anticyclone.

3. 3. 2. *Rainfall*

The rainfall in association with the system had the usual typical pattern associated with a monsoon depression. Rainfall amounts to the north of the track were quite low, while they were exceptionally heavy in its southern sector. Exceptionally heavy rainfall amounts were recorded at 0830 IST of 23rd over the west and east Godavari, Krishna & Khammam districts of Andhra Pradesh. The very heavy rainfall occurred in a belt of about 100 to 200 km wide stretch at a distance of 250 to 350 km away from the centre of the deep depression. Fig.2 shows the rainfall analysis of 24th. It could be seen from the figure that the rainfall to the north of the track of the system was light to moderate. Rainfall was light to moderate up to a distance of 100 to 200 km from the centre in its southern sector. Beyond that there was a 100 to 200 km wide belt of heavy precipitation in the southern sector of the system. There was a sharp decrease in the rainfall up to the east of the Western Ghats. Again, there was very heavy rainfall over Konkan & Goa region.

The significant amounts of rainfall (cm) in association with the system were as follows :

22 July : Kalingapatnam 8, Mahendragarh 7.

23 July : Koderu 42, Nidadavole 39, Tiruvur 38, Chintalapudi 37, Kakinada 30, Paddapuram 26, Khammam 25, Narsapur 24, Rajamundry 23, Banswada, Koida & Madhira 21 each, Kothagudam 20, Jaggayyapeta, Gudiwada, Vijayawada AP & Bhimavaram 19 each, Nandigama 18, Medak & Yellandur 17 each, Machilipatnam 16, Yellamanchilli 15.

24 July : Bhira 71, Beed 35, Mahabaleshwar & Dungarwadi 33 each, Dawdi 30, Parkal 24, Parbhani 23, Sahuwadi 21, Dhule, Billoli & Ratnagiri 20 each, Karimnagar & Patoda 19 each, Bombay, Bodhan & Vaijapur 18 each, Jintoor & Nalagonda 17 each, Kalyan 16, Navapur, Kandhar, Kallam, Kamareddy & Yeola 15 each.

25 July : Chikhali 42, Valsad 30, Dungarwadi 29, Dawadi & Tamini 24 each, Bhira & Igatpuri 22 each, Dharavi 21, Bombay AP, Thakurwadi & Wangaon 19 each, Khand 18, Navsari 17, Veraval 13, Surat 12.

26 July : Naliya 20, Dungarwadi 13, Dawadi 12, Bhira & Igatpuri 11 each, Shingaon 10, Okha 7.

3. 3. 3. *Satellite observations*

The satellite (INSAT) picture at 0600 UTC of 21st showed curvature in the deep layer convective cloud clusters/bands over the central Bay of Bengal. On the basis of the imagery the intensity of the system could be classified as T 1.0. The intensification continued until 0330 UTC of 22nd, when a low level circulation centre was defined by curved cumulus line. This pattern disorganised during the day time. However, new convective bursts were noticed just before landfall at 1500 UTC of 22nd. The disturbance could be classified as T 2. 5 which continued to remain so at 1800 UTC of the day. Clouds associated with the vortex relatively disorganised by 2300 UTC of 22nd. Very intense convection was again noticed over Telangana, Marathwada and adjoining Madhya Maharashtra in the imagery of 1200 UTC of 23rd. At 0300 UTC of 26th the INSAT imagery showed a well defined circulation over southeast Pakistan with its centre near 26.5° N, 68.5° E.

3. 3. 4. *Floods and other disastrous events*

The unprecedented heavy rainfall over west and east Godavari, Krishna districts of coastal Andhra Pradesh and Khammam district of Telangana; Parbhani, Beed and Aurangabad districts of Marathwada; Dhule district of north Madhya Maharashtra and Raigad districts of Konkan caused severe floods in those areas. Apart from high floods there were high gusty winds, which aided to the destruction and devastation. The system also affected the coastal districts of south Orissa.

In Andhra Pradesh river *Godavari* and its tributaries were in spate. High floods occurred in lower Krishna basin. Heavy rain caused breach in irrigation tanks in west Godavari and Krishna districts of coastal Andhra Pradesh causing severe floods on 23rd. Yeluru town was submerged under water. Flood in river *Budameru* in Krishna district was worst since 1964. It submerged thousands of houses in the low lying areas of Vijayawada town. 23 villages in Krishna district were submerged under flood waters. Besides, extensive damages to crops and properties, the calamity claimed 140 lives in the State. In Maharashtra, Raigad and Beed districts were the worst affected area. Heavy rain, flash floods accompanied with high speed winds left a trail of death and devastation in western Maharashtra. There were high floods in the river *Bindusar* in Beed district. About 61 villages in Marathwada region were marooned. In Pune district of Madhya Maharashtra entire low lying areas of Kamshet was water logged due to floods in *Indrayani* river. About 14 villages in Pen-Vadkhal belt of Raigad district were marooned. In this devastation 916 human lives were lost and quite a large number of fishermen were missing in the State. It took a toll of 14,212 cattle heads and damaged about 99,283 houses in the State. Pen village, which is famous for its Ganesh idols in the whole of Maharashtra, was almost washed away by flash floods. There were flash floods in the rivers *Patalganga, Amba* and *Ulhas* in Raigad districts and neighbourhood. In a tiny hamlet called 'Bhaje' near Lonavla, a landslide on 23rd night crushed to death 40 members of a marriage party. Bombay city ramained cut off from the rest of the country for a day or two. Rail and road communication in several parts of the State remained dislocated. Damage to roads, buildings and power stations in rural areas was estimated over Rs. 91 crores in Maharashtra. A fishing vessel '*Durgadevi*' with eight fishermen abroad sank near Pardevi off Bombay harbour.

3. 4. *Deep Depression, 16-17 August*

The depression developed over the west central Bay on 16th. Taking a westnorthwesterly to northnorthwesterly course it crossed north Andhra-south Orissa coast near Kalingapatnam around noon time of 17th and dissipated over coastal areas of south Orissa and neighbourhood.

The disturbance was first located over the west central Bay as a circulation in the lower and middle tropospheric levels on 15th. Satellite (INSAT) observation at 0300 UTC of 16th indicated a vortex with T No. 1.0 over west central Bay. Kalingapatnam reported E/15 kt wind. The disturbance concentrated into a depression at 0300 UTC of 16th and lay centred near 16.5°N, 86.0°E. Moving in a westnorthwesterly direction, it further intensified into a deep depression and lay at 1200 UTC of 16th centred near 17.0°N,85.0°E. A ship *VTJR* (17.0°N, 86.1°E) reported 170°/35 kt wind. The upper winds at Visakhapatnam up to 1.5 km a. s. l. were NE/25 kt, and NE/30 kt at 3.1 km a. s. l. INSAT observation also indicated the intensification of the system. Thereafter, it moved northnorthwestwards and lay at 0300 UTC of 17th centred near 18.0°N, 84.5°E. The ship *VTJR* (16.2°N, 86.0°E) reported 180°/30 kt wind and Kalingapatnam E/20 kt wind. Pressure drop for the past 24-hr at Kalingapatnam was 4.5 hPa and the deparature from normal was —7.0 hPa. The ship *VTJR* (15.9°N, 85.9°E) continued to report strong wind of 230°/30 kt at 0600 UTC of 17th. Moderately strong easterly winds extended far to the north of the system. At 0600 UTC Bhubaneswar and Sandheads both reported SE/20 kt winds. The system crossed coast around noon-time of 17th near Kalingapatnam and lay as a depression at 1200 UTC of the day centred about 75 km eastnortheast of Koraput. Bhubaneswar reported SE/30 kt wind at 0.9 km a.s.l. The system further weakened by midnight of 17th over

south Orissa and adjoining southeast Madhya Pradesh. The remnant of the depression moved across central India and dissipated over central parts of Rajasthan by 21st.

The circulation of the deep depression extended up to 400/300 hPa level on both 16th and 17th. The system moved along the southern periphery of the Tibetan anticyclone in the middle and upper tropospheric levels.

The lowest pressure was recorded by the ship *VTJR* at 1200 UTC of 16th, which was 993.8 hPa. Incidentally the maximum wind was also recorded by the same ship at the same time. It reported 170°/35 kt wind in the evening of 16th.

Unlike the July system the areal extent of this depression was not large. The diameter of the outermost closed isobar was between 4 and 6-degree. In association with the system the maximum pressure drop and the minimum departure from normal were recorded at Kalingapatnam, at 0300 UTC of 17th, which were 4.5 hPa and *minus* 7.0 hPa respectively.

As per satellite (INSAT) observations the system intensified very rapidly between 0300 & 0900 UTC of 16th. From T 1.0 at 0300 UTC its intensity became T 2.0 at 0900 UTC of the day. The system attained its peak intensity of T 2.5 at 0300 UTC of 17th. At 17th 0600 UTC also the T-classification was T 2.5. Though T No.2.5 indicated a maximum sustained wind of 35 kt in the morning of 17th , no wind observation was more than 30 kt on that day. The winds along north Andhra-south Orissa coast during this period were of the order of 10 to 20 kt only.

The system augmented monsoon rainfall over coastal Andhra Pradesh, Telangana and Maharashtra. The significant amounts of rainfall (cm) were as follows :

17 Aug : Parbhani 18, Koderu 13, Amalapuram 12, Polavaram 9, Mahendragarh, Narsapur & Visakhapatnam 8 each, Perur, Suryapeth, Nidadavolu & Tuni 7 each.

18 Aug : Mulug 17, Utnoor 16, Perur & Kaleswaram 14 each, Chinnoor, Chintalapudi & Paderu 13 each, Mancherial, Nirmal, Sriramsagar, Shegaon & Umarkhed 10 each, Aheri, Eattapalli, Bhadrachalam, Asifabad, Sirpur, Huzurabad & Sirsilla 9 each, Narsapur, Visakhapatnam, Ratnagiri & Chikli 8 each, Sudhagad, Kalingapatnam, Koderu, Narsampet & Parkel 7 each.

19 Aug : Chalisgaon & Sudhagad 13 each, Billoli 12, Parole & Pachora 11 each, Edlabad, Jumner, Hingole & Mudhole 10 each, Jalgaon, Khamgaon & Yeotmal 9 each, Akola AP, Chandur, Nanded & Shirpur 8 each, Ashti, Bhira &Nizamabad 7 each.

4. The disturbances in the Bay of Bengal during post monsoon season

4. 1. *Depression, 17-18 October*

It was the first intense system of the post monsoon season. The system was first observed as a disturbance in the form of a cyclonic circulation in the lower tropospheric levels over north Andaman Sea and neighbourhood on 12th. From there it moved over to the central Bay on 14th. Under the influence of this circulation a depression developed a over the area on 17th. Taking a northnorthwesterly and then a northnortheasterly course, it crossed West Bengal-Bangladesh coast in the night of 17th and dissipated over eastern parts of Bangladesh and neighbourhood by 18th evening.

Though the satellite (INSAT) classification was T 1.5 from 0300 UTC of 16th, ship observations over west central and northwest Bay did not support the intensity of the system as a depression. On the 16th 0300 UTC a ship *ONCL* (19.2°N, 86.4°E) reported wind 340°/11 kt only. At 0000 UTC of 17th another ship *VSBS6* (18.6°N, 89.8° E) reported wind 100°/21 kt. The depression lay at 0300 UTC of 17th centred near 17.5°N, 89.5°E. Moving rather fast in a northwesterly direction, it lay centred at 1200 UTC of 17th near 20.0° N, 88 .0°E. The winds at the coastal stations of Orissa were light ranging from 02 to 05 kt. From this point it recurved northnortheastwards and crossed West Bengal-Bangladesh coast near Long. 89.0°E around midnight of 17th and lay over Bangladesh at 0300 UTC of18th centred about 50 km east of Jessore. Jessore reported the highest pressure fall (24 hours) and lowest departure from normal, which were *minus* 5.6 hPa and *minus* 8.3 hPa respectively. The system weakened over eastern parts of Bangladesh and neighbourhood by the same evening.

The lowest pressure in association with this system was recorded at Jessore at 0300 UTC of 18th, which was 1004.0 hPa. The maximum wind over the sea area was 100°/21 kt, reported by the ship *VSBS6* at 0000 UTC of 17th. The highest satellite (INSAT) classification was T 2.0 at 0300 UTC of 17th with the centre of the system around 18.0°N, 86.5°E. However, the synoptic centre of this system was around 17.5°N, 89.5°E. The cloud centre appeared to have been tilted westwards by about 3-degree. In, other words the convergence zone lay to the west of the depression. As the system approached coast the cloud organisation started weakening. At 1200 UTC of 17th the cloud organisation indicated T 1.0 stage of intensity. The winds in the western sector of the system were mainly continental northerly from the land areas.

On 17th morning the system lay to the south of the mid tropospheric sub-tropical ridge. However, by the evening of the same day it came under the influence of the middle and upper tropospheric westerly winds, which consequently steered the system in a northnortheasterly direction. The wind maximum in association with system was observed at 700 hPa level at 0000 UTC of 18th at Dhaka. Dhaka reported SE/50 kt wind at 700 hPa level.

The system did not cause any damage in the country. However, it caused heavy rainfall at one or two places in Gangetic West Bengal, Assam & Meghalaya on a couple of days. Significant amounts of rainfall (cm) associated with the system were :

18 Oct : Midnapore 8, Cherrapunji 6, Shillong 5, Jalpaiguri 4, Agartala AP, Aijawal, Calcutta AP, Diamond Harbour, Imphal & Kailashahar 3 each.

19 Oct : Shillong 13, Lumding 7, Dibrugarh AP & north Lakhimpur 5 each, Agartala AP & Tezpur 3 each.

4. 2. *Kavali hurricane, 1-9 November*

The hurricane developed over the Gulf of Thailand on 3rd. Initially it moved northwestwards for a day. Then moving westwards across south Thailand-south Burma it emerged into the Andaman Sea. Thereafter it took a westnorthwesterly to westerly course, crossed Andaman group of Islands and struck south Andhra coast near Kavali around midnight of 8th.

The hurricane was an unique one. The areal extent of the gale force wind hardly extended at any time beyond one degree from the centre of the hurricane. Moreover, it was one of the few most severe storms of this century. It was the second storm in 100 years that entered the Indian seas from the Gulf of Siam and neighbourhood. In the last 100 years, during the month of November about a dozen depressions formed over the Andaman Sea and neighbourhood but only a couple of them intensified into a storm there and both of them recurved. However, a few, which intensified into a storm further to the west, struck east coast of India. Further, it was the only storm in the Indian seas in the last hundred years that travelled west to westnorthwestwards over 2600 km over the sea waters.

In the morning of 1st organised convection, was visible in the satellite (INSAT) imagery over the Gulf of Thailand. The disturbance concentrated into a depression with its centre at 0300 UTC of 1st near 8.0°N, 103.0° E. The next morning, the depression intensified into a cyclonic storm over the Gulf of Thailand with its centre at 0300 UTC near 8.5°N, 102.5°E. The storm slowly moved northwestwards and lay at 0300 UTC of 3rd centred near 9.5°N, 101.5°E. Thereafter it rapidly intensified into a severe cyclonic storm in the forenoon of 3rd and continued to move slowly in a northwesterly direction. From the evening of 3rd it started further intensification and at 0300 UTC of 4th lay as a hurricane close to south Thailand-south Burma coast centred near 11.0°N, 99.5°E. However, the winds reported by stations Nergui (48110) and Victoria Point (48112) situated about 150 km to the northwest and southwest of the hurricane centre were light and of the order of 5 kt only. The upper winds at 1.5 km a.s.l. of coastal Thailand stations Sattahip (48477) & Chamthaburi (48480) and north Malaya stations at 0400 UTC were of the order of 10 to 15 kt only. The Thailand stations were hardly 150 km away from the hurricane centre. The hurricane crossed the land strips of Burma and Thailand and emerged into Andaman Sea and lay at 1200 UTC of 4th centred near 11.0°N, 98.0°E. At this time the wind was W/05 kt at Victoria Point, which was hardly 120 km to the southeast of the hurricane centre.

Moving in a westnorthwesterly direction the hurricane approached Andaman group of Islands. At 1200 UTC of 5th it lay centred about 250 km east of Long Island. The winds (surface) at the Andaman Islands stations and Coco Island were light to very light. Port Blair reported NNW/15 kt winds at 0.3, 0.6 and 1.5 km a.s.l. The hurricane crossed Andaman group of Islands in the early morning of 6th and lay at 0300 UTC of the day centred near 13.0°N, 92.0°E. As it approached the islands, the intensity of the hurricane weakened to some extent. It was observed in the cloud imageries of 5th evening and of 6th morning. However, at 0300 UTC of 6th, when the hurricane lay centred about 100 km (13.0°N, 92.0°E) west of Mayabandar and Long Islands, these two stations reported 40 kt variable winds. But Coco Island which is situated about 200 km northeast of the storm centre reported only E/15 kt wind. The hurricane started intensifying after 0500 UTC of 6th and moved in a westnorthwesterly to westerly direction. In absence of any ship data from the storm field, it was mainly tracked with the help of satellite imagery over the Bay of Bengal and Andaman Sea. In the morning (0300 UTC) of 8th, the hurricane further intensified and came nearer to north Tamil Nadu-south Andhra coasts. The T No. of the system was 6.0 and it lay centred near 14.5° N, 83.4° E. On this day at 0000 UTC a ship *VVKS* (16.2° N, 85.0° E), situated about 250 km northeast of the storm centre reported 110°/19 kt wind only. Coastal stations of north Tamil Nadu and south Andhra coasts reported 5 to 15 kt winds. In the evening of 8th, *i.e.*, at 1200 UTC the hurricane lay centred about 150 km eastnortheast of Nellore, *i.e.*, near 14.7°N, 81.3°E. The surface winds at the coastal stations were ENE/ 20 kt at Kakinada, NE / 15 kt at Machilipatnam, N/10 kt at Nellore, NNW/10 kt at Madras and ENE/ 10 kt at Pondicherry. The hurricane crossed south Andhra coast near Kavali around 1900 UTC of 8th and rapidly weakened. It lay at 0300 UTC of 9th as a depression over Rayalaseema and neighbourhood centred about 40 km southeast of Nandyal. It dissipated there around 0600 UTC of the day.

4.2.1. *Characteristic features of the storm*

The areal extent of the hurricane at all the time was quite small. On 4th morning (0300 UTC) when the hurricane lay over Gulf of Thailand close to south Burma-south Thailand coast, the surface wind at a distance of 150 km away from the centre both in the north as well as in the south were reported 5 kt only. The outermost closed isobar (OCI) at 0300 UTC of 4th, had a diameter of only 1 deg. to 1.5 degree. Almost throughout the life span of this hurricane the diameter of the (OCI) was between 2 and 3 degree.

4.2.2. *Central pressure*

Since the storm had extremely steep pressure gradient in the core region, no observation matched with that of the actual central pressure. The central pressure of the hurricane has been estimated with the help of known empirical formula. According to Mishra and Gupta's formula, at 0300 UTC of 4th, when the T-classification (INSAT) was 5.0, the estimated central pressure of the hurricane worked out to be 970.0 hPa. At 1200 UTC of 8th, the T-classification of the system was 6.0 the highest classification during its life period. The corresponding central pressure worked out to be 942.0 hPa.

4.2.3. *Satellite observations and intensification*

It was the first system in the last 100 years, which intensified into a hurricane over the Gulf of Thailand.

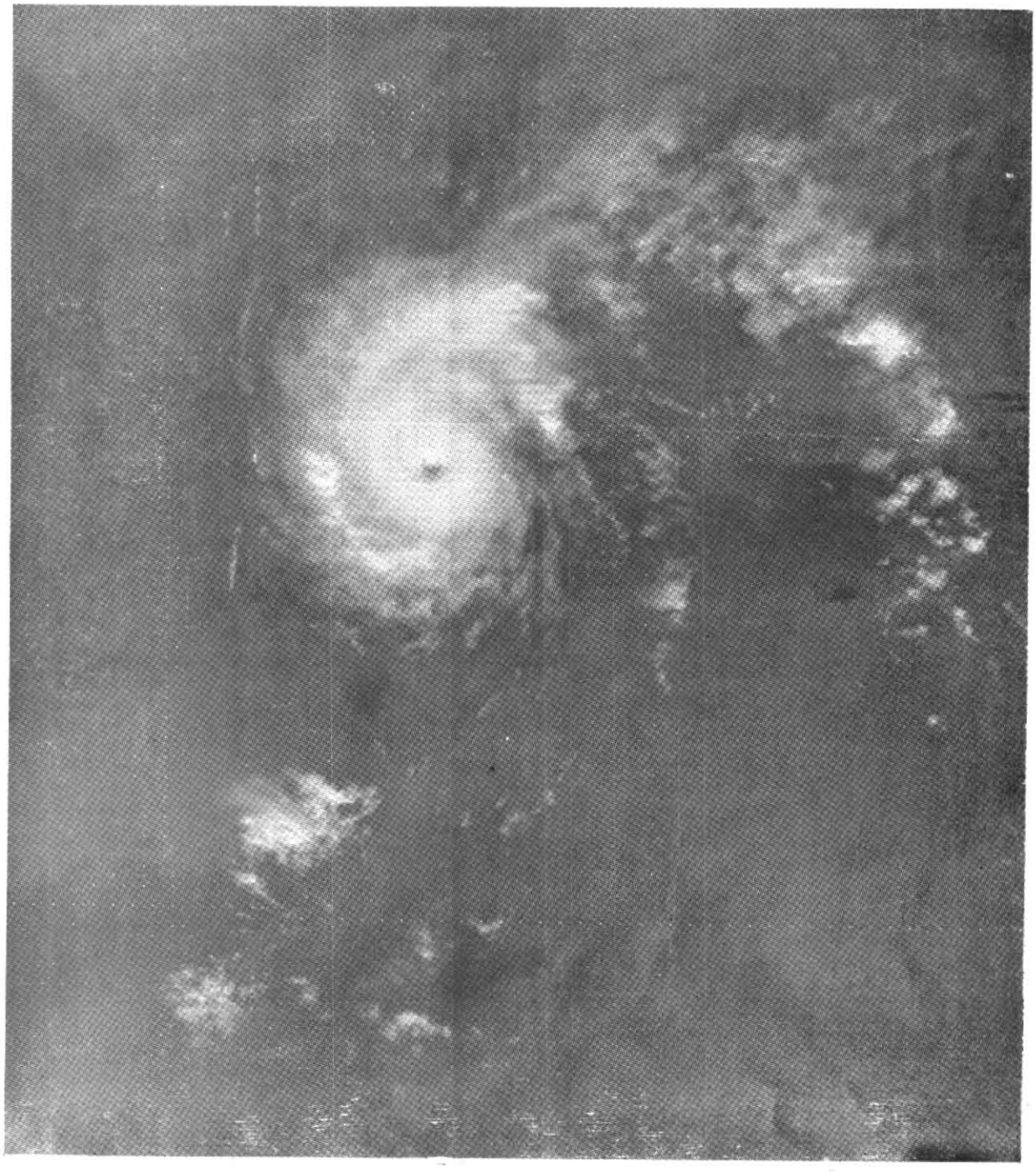

Fig. 5(a). INSAT-1B cloud picture of 8 Nov 1989 at 0600 UTC

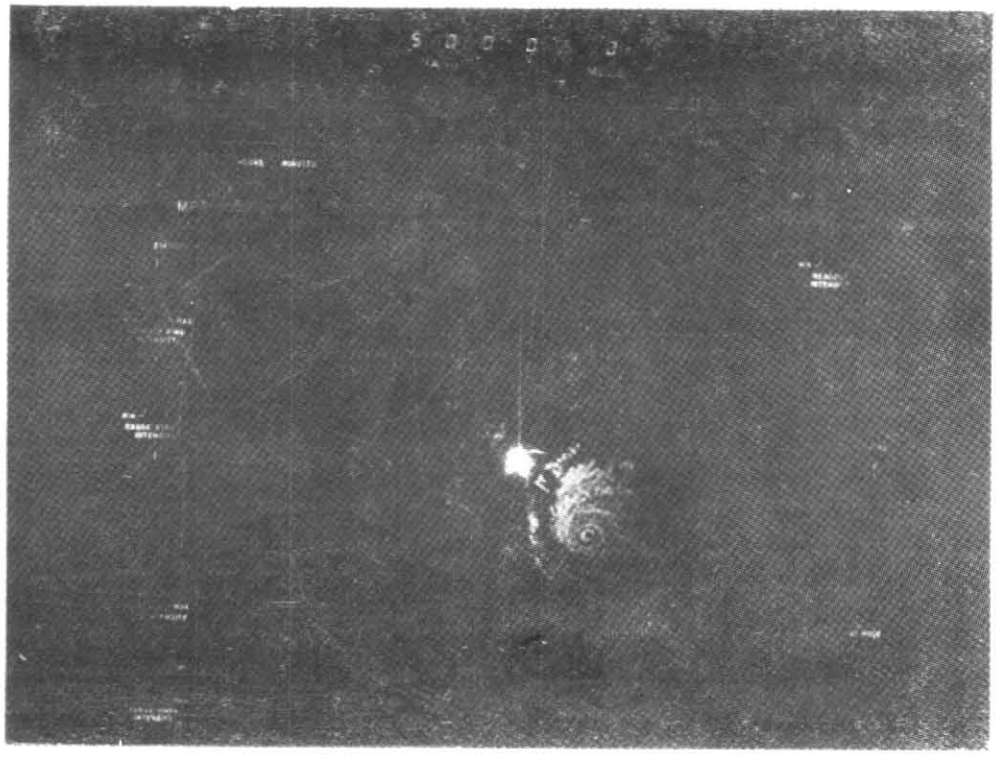

Fig. 5(b). CDR, Machilipatnam of Bay cyclone of 8 Nov 1989 at 0600 UTC

The initial genesis of the system was due to the persistence of intense to very intense convection over the Gulf of Thailand. The system had rapid intensification over there, where it intensfied by T 2.5 stage in about 24-hr between the morning of 1st and 2nd. The eye of the system appeared at 0430 UTC of 3rd when it was classified as T 4 in Dvorak's scale. It further intensified from T 4.0 to T 5.0 stage between 1200 UTC of 3rd and 0000 UTC of 4th. Subsequent interaction with Malaya Peninsula and adjoining south Burma-south Thailand land strips reduced the intensity of the hurricane. The convective organisation associated with the cyclone weakened as a result of the land effect. The system emerged into Andaman Sea at about 1000 UTC of 4th and re-intensified. From T 4.5 stage at 0600 UTC of 4th, the intensity reached T 5.5 stage at 0000 UTC of 5th. However, when it approached the Andaman Islands, its convective organisation again weakened and eye became 'oval shaped' covered with dense cirrus clouds at 0900 UTC of 5th. The intensity of the hurricane reached T 4.0 stage at 1500 UTC of 5th. After it crossed the Andaman Islands, the final stage of intensification started from 0500 UTC of 6th. By 1100 UTC of 6th 'faint eye' was detected and it reached T 5.0 stage at 1200 UTC of the day. Thereafter, while moving westwards until landfall, the intensity of the system rose to T 6.5 at 0900 UTC of 8th. The cloud picture taken by INSAT-1B of 0600 UTC (1130 IST) on 8 Nov 1989 is shown in Fig. 5(a). The corresponding radar of the cyclone taken by the CDR Machilipatnam is shown in Fig 5 (b). It displayed well organised eye. As the system approached north Tamil Nadu-south Andhra coasts, its intensity once again had a weakening trend. At the time of landfall near Kavali at about 1900 UTC of 8th, it had a faint eye when the intensity was T 5.5 in Dvorak's scale with its current intensity (CI) No. as 6.0.

4.2.4. *Winds*

When the hurricane crossed Andaman Islands, Mayabandar experienced high speed wind which was about 45 to 50 kt from the northeasterly direction. After it crossed the islands, Mayabandar and Long Island reported variable 40 kt winds at 0300 UTC of 6th. Over the mainland, the highest recorded wind was 290°/30 kt at Nellore at 1800 UTC of 8th. Because of a very narrow core of high winds, the actual wind speed could not be detected by the coastal observatory stations. However, from the destruction that the hurricane caused within a radius of about 10 km around Kavali the wind speed could be a estimated there at about 100 to 120 kt. Beyond 10 km and up to 17 km to the north of Kavali, the estimated wind speed was about 80 kt.

It was reported by the villagers of Thummalapentapalem, which is situated a few kilometres to the east of Kavali, that high speed wind and rain started at 2200 IST of 8th and lashed the coast up to about 0130 IST of 9th, then there was a lull period for about 15 minutes. Thereafter, the fury of rain and wind commenced again. The direction of the wind also changed after the interval of the lull period. The rain and strong wind lasted up to about 0230 IST of 9th. From these observations it could be inferred that the 'eye' of the hurricane passed over Thummalapentapalem. From the pattern of destructions around Kavali, the diameter of the 'eye' could be estimated to be about 10 km over the land.

4.2.5. *Rainfall*

In association with the system the very heavy rainfall was reported from one or two places in south coastal Andhra Pradesh. The total rainfall from 8 to 10 November 1989 is shown in Fig. 3. The significant amounts of rainfall (cm) were :

9 Nov : Parachur 18, Bapatla 17 Seetharamapuram 13, Varikuntapadu 11, Addanki 8, Kandukur, Muthukur & Vinjamur 7 each.

10 Nov : Bapatla, Chittoor & Tirupathi AP 5 each, Buchireddapalem, Cuddapah & Kurnool 3 each.

4.2.6. *Damages*

Over 4 lakh people in 836 villages in Nellore and Prakasam districts of Andhra Pradesh were affected by the hurricane. The fury of the hurricane was felt within a radius of 17 km around Kavali. According to reports 69 persons lost their lives and about 7100 cattle heads were perished. It damaged about 1.49 lakh pucca houses and huts and about 34,000 poultry birds were lost. Though the hurricane hit the coast at the time of low tide. 3 to 4 m high tidal waves lashed a stretch of 40 km of the coast. At Thummalapentapalem sea-shore up to 1/2 km inland was inundated. At Ramayapatnam, 17 km north of Thummalapentapalem, sea water entered the campus of the light house quarters which were about 200 m from the sea-shore. Jaladanki and Harijanwada villages, situated about 11 km west of Kavali were razed to the ground. Maximum wind damage reported up to a distance of 16 km to the north and 9 km to the south of the storm centre. Rail services between Madras and Vijayawada came to a standstill from the midnight of 8th. Railway tracks between Ulavapadu and Venkateswarapalem, a 40 km stretch were blocked by uprooted trees and electric traction masts. Standing crops in thousands of acres of land were damaged in Nellore and Prakasam districts.

While crossing Andaman Islands it took the life of one person and damaged about 709 houses. Electric supply in the islands was disrupted due to falling of about 80 electric poles. About 1000 trees were uprooted in the island.

4.2.7. *Movement of the hurricane*

The movement of the system, on an average was 6 to 10 kmph between the morning of 2nd and 4th. Thereafter it speeded up and moved at the rate of about 15 kmph for a day.

4.3. *Depression, 11 November 1989*

Immediately after the dissipation of the Kavali hurricane on 9 November, a low pressure area developed over the south Bay of Bengal on 10th evening. By the morning of 11th the low pressure area concentrated into a depression over southwest Bay and lay centred at 0300 UTC of the day near 10.5 °N, 84.0 °E. At

TABLE 6

Ship observations on 19 November 1989

Time (UTC)	Call sign of the ship	Position of the ship		Wind		Weather
		Lat. (°N)	Long. (°E)	Dir. (°)	Speed (kt)	
0000	ATJX	11.3	82.5	040	25	Overcast sky
0000	VSBS6	13.8	86.6	040	16	Shower
0600	ATJX	12.4	82.7	050	30	Do.
0600	VSBS6	12.5	85.8	090	10	Do.
1200	VBGQ	10.9	83.5	080	35	Overcast sky
1200	VSBS6	11.2	83.0	100	16	Rain

TABLE 7

Ship observations on 20 November 1989

Time (UTC)	Call sign of the ship	Position of the ship		Wind		Weather
		Lat. (°N)	Long. (°E)	Dir. (°)	Speed (kt)	
0000	VSBS6	9.0	83.6	320	21	Overcast
0600	VBGQ	10.1	85.1	050	20	Rain
0600	VSBS6	7.7	82.9	310	24	Shower
0600	ATKA	9.6	81.4	010	30	Cloudy
1200	VBGQ	9.2	84.2	050	18	Do.
1200	VSBS6	6.2	81.8	170	13	Do.

0600 UTC of 11th two ships over the southwest Bay reported strong winds. Ship *ATIU* (12.1 °N, 83.1°E) and ship *ATMS* (10.9 °N, 81.0° E) reported 110°/27 kt and 050°/22 kt winds respectively. At 0000 UTC of this day ship *VWXG* (14.0 °N, 82.7 °E) also reported 080°/20 kt wind and overcast sky. Pressure changes for past 24-hr and pressure departures from normal along north Sri Lanka - Tamil Nadu coasts at 0300 UTC of 11th were —3 to —4 hPa and —3 to —5 hPa respectively. Following a westerly course, the depression lay at 1200 UTC of 11th centred near 10.5° N, 82.0 °E. At that time ship *ATMS* (12.0° N, 80.7 °E) and ship *ATIU* (11.7 °N, 84.6 °E) reported 050°/22 kt and 090°/40 kt winds respectively. All the coastal stations of Tamil Nadu north of Lat. 10.0 °N reported overcast sky with present weather as rain. 24-hr pressure changes and pressure departures from the normal along south Tamil Nadu coast ranged from—2 to —4.6 hPa and —2 to —5 hPa respectively. In the satellite (INSAT) imagery of this evening very intense convection was observed over southwest Bay and north coastal Tamil Nadu. However, the system weakened on approaching coastal Tamil Nadu by 11th midnight and was seen as a well marked low pressure area over southwest Bay and adjoining Tamil Nadu coast by next day morning. In the satellite imagery of 0300 UTC of 12th broken intense to very intense convection was observed over coastal Tamil Nadu, north of Lat. 10 °N and adjoining Bay of Bengal. Though the vortex centre could not be identified, the intensity of the system could be classified as T 1.0. The remnant of the system moved away westwards across extreme south Peninsula and Lakshadweep area by 14th.

The system moved along the southern periphery of the sub-tropical anticyclone over southeast Asia.

The system caused heavy to very heavy rainfall on a couple of days over Tamil Nadu, south interior Karnataka and south Andhra Pradesh. The significant amounts of rainfall (cm) were :

12 Nov: Madras AP 18, Karaikal 16, Chidambaram 15, Parangipettai 13, Pakala, Tambaram & Vedaranyam 12 each, Nagapattinam 11, Sullurpeta 9, Cuddalore & Tirupathi AP 6 each.

13 Nov : Namakkal 13, Usilampatti 11, Kavali, Madras & Nagapattinam 8 each, Cuddalore, Karaikal, Parangipettai & Tambaram 7 each, Nellore & Sullurpeta 6 each.

14 Nov : Palamkottai 14, Hasangara 12, Kavali, Lingadahalli & Mulki 10 each, Puthur 9, Nellore & Tiruthuraipondi 8 each, Cannanore, Coonoor & Mangalore AP 7 each, Chitradurga, Shimoga & Sullurpeta 6 each.

4.4. *Deep depression, 16-20 November 1989*

There was persistent clouding over south Bay and over Andaman Sea from 14th. On 16th morning a low pressure area formed over southeast and adjoining southwest Bay. Satellite (INSAT) imagery at 0300 UTC of 16th identified a vortex near 10.6 °N, 86.5 °E with T 1.0. By 1200 UTC of 16th the low pressure area concentrated into a depression over southwest Bay and lay centred near 10.5 °N, 85.0 °E. The satellite classification of the vortex was T 1.5. The system moved slowly in a westerly direction and further intensified into a deep depression by 0300 UTC of 17th and lay centred near 10.5 °N, 84.5 °E. The INSAT classification of the system was T 2.0. From 17th morning the disturbance started moving in a southwesterly direction and lay at 1200 UTC of 17th centred near 10.0 °N, 84.0° E. The system entered in the COL region of subtropical anticyclone in the middle and upper tropospheric level (up to 9.5 km a.s.l.) during the evening of 17th and remained practically stationary there till the morning of 18th. In the morning of 18th a few ships sailing across the southern sector of the deep depression reported moderately strong westerly winds. A ship *ATKK* (8.8 °N, 81.6 °E) reported 260°/17 kt wind at 0300 UTC and another ship *ELAO 9* (5.8°N, 81.3 °E) reported 220°/22 kt wind at 0600 UTC of 18th. After 0300 UTC of 18th the deep depression moved slowly in a southsouthwesterly direction and lay at 1200 UTC of the day centred near 9.0 °N, 83.5 °E. At that time ship *ATJX* (8.8 °N, 82.3 °E) and ship *ATMS* (10.2 °N, 81.2 °E) reported 030°/25 kt and 080°/30 kt winds respectively. The clouds further organised during the night of 18th and on the basis of INSAT imagery of 2100 UTC, the intensity of the system was classified as T 2.5. However, at 0300 UTC of 19th the satellite classification became T 2.0. At that time the system lay centred near 9.0 °N, 83.0 °E. From the northern sector of the disturbance a few ship observations were received on this day. They are given in Table 6.

From the above ship observations it was apparent that the trade winds strengthened to the north of the system and the wind strength was much higher in the northwestern sector of the system than to its northeastern sector. The circulation of the system extended up to 7.6 km a.s.l. at 0000 UTC of 19th and the winds aloft were light south westerly to westerly. The system moved slightly to the northeast from its morning position and lay at 1200 UTC of 19th as a depression centred near 9.5 °N, 93.5 °E.

Under the influence of the upper tropospheric westerlies the system weakened and 0800 UTC INSAT imagery of 19th showed the intensity of the system as T 1.5, which became T 1.0 at 1500 UTC of the day. The depression lay centred at 0300 UTC of 20th near 9.5 °N, 85.0 °E, The following ship observations were quite significant on this day. (Table 7).

INSAT observations showed slight intensification of the system between 0300 and 0600 UTC of 20th. The system was classified as T 1.5 at 0600 UTC from T 1.0 at 0300 UTC.

The system remained practically stationary over southwest Bay during the day. The clouds in association with the system began disorganising from the evening of 20th and the depression weakened into a well marked low pressure area over southwest and adjoining southeast Bay by midnight of 20th. However, the remnant became less marked over southeast Bay and adjoining Andaman Sea by 26th.

There were several instances in the past, when intense systems weakened over the sea waters during the month of November. However, in the last one century no system had followed a path like this deep depression. It made an anticyclonic loop over southwest. Bay between 18 and 20 November. The track of the 16-28 November, severe cyclonic storm of 1964 was somewhat similar. It moved west to southwestwards, came close to north Tamil Nadu coast and then moved eastwards and dissipated over north Andaman Sea. But the system had no loop in its track.

The system caused a good spell of northeast monsoon rainfall over Tamil Nadu for a day or two. The significant amounts of rainfall (cm) were :

17 Nov : Nagapattinam 7.

18 Nov : Chidambaram, Parangipettai & Cuddalore 6 each.

19 Nov : Chidambaram 21, Karaikal 16, Cuddalore & Parangipettai 13 each, Mayiladuthurai 12, Nagapattinam, Vedaranyam&Pondicherry 10 each, Tiruvallur 9, Tiruthuraipondi 8, Kumbakonam & Mannargudi 7 each, Madras & Tambaram 6 each.

Satellite (INSAT) observations indicated that the system had attained its peak intensity of T 2.5 around 2100 UTC of 18th, but downgraded to T 2.0 at 0300 UTC of 19th. As per the satellite observation it was marginally a cyclonic storm between 18th 2100 UTC and 19th 0200 UTC but synoptic observations did not indicate that intensity.

5. The disturbances in the Arabian Sea

5. 1. *Deep depression, 9-12 June*

The system developed at the leading edge of the monsoon current over east central and adjoining northeast Arabian Sea on 9th. Initially taking a northerly course it entered land areas of Saurashtra and reached up to Lat. 22.5°N on 10th evening. Thereafter, it sharply changed its course to west and emerged into northeast Arabian Sea. It dissipated over northwest Arabian Sea by 12th night.

From 7th evening, moderately strong monsoon current was observed over east central Arabian Sea. At 0300 UTC of 8th, a ship *3EIP3* (15.6°N, 68.7°E) reported overcast sky and 240°/18 kt wind. A low pressure area with associated cyclonic circulation in the lower tropospheric levels could be identified over east central and adjoining northeast Arabian Sea off Maharashtra coast. However, INSAT imagery could identify a vortex over this area from 1800 UTC of 7th. The disturbance concentrated into a depression over east central and adjoining northeast Arabian Sea off north Maharashtra-south Gujarat coast on 9th morning centred at 0300 UTC around 20.0°N, 69.5°E. At this hour Veraval and Porbandar winds were significant. They were NE/10 kt and NE/15 kt respectively. Moving in a northeasterly direction, the system lay at 1200 UTC of the day centred near 20.5°N, 70.0°E. At this stage the strength of Veraval and Porbandar winds remained unchanged. However, Bhavnagar wind strengthened to S/20 kt. Bombay also reported strong wind at 850 hPa level, which was SW/45 kt. As per the wind observation of Veraval the depression crossed Saurashtra coast from the east of Veraval around 1800 UTC of 9th and entered the land areas. Surface wind at 1800 UTC of 9th was NNW/10 kt at Veraval. After entering land areas the depression further intensified into a deep depression and lay centred at 0300 UTC of 10th about 50 km southsouthwest of Rajkot. The surface winds over Saurashtra became quite strong. The fact was evident from the following wind observations. The winds were WNW/35 kt at Veraval, S/25 kt at Bhavnagar, E/20 kt at Rajkot and WNW/20 kt at Porbandar. From 10th morning the deep depression sharply changed its course and started moving in a westnorthwesterly direction. At 1200 UTC of 10th the deep depression lay over the land areas of Saurashtra & Kutch with its centre very close to Jamnagar. The significant surface winds were SW/35 kt at Veraval, SE/25 kt at Rajkot and NNE/20 kt at Kandla. From 10th evening the movement of the deep depression became very slow till next day evening and it started moving dead west.

At 0300 UTC of 11th, the deep depression lay mainly over Saurashtra & Kutch with its centre about 50 km east of Dwarka. The prevailing surface winds over this area was of the order 15 to 25 kt. By the evening of 11th the system emerged over northeast Arabian Sea and lay centred about 25 km northnorthwest of Dwarka. The wind distributions were WSW/05 kt at Dwarka, SW/10 kt at Porbandar, WSW/25 kt at Veraval and NE/15 kt at Naliya. After 11th evening, the deep depression started moving rather fast and by 0300 UTC of 12th lay over the northeast Arabian Sea

centred near 22.5°N, 67.0°E. As the system moved away from the Saurashtra & Kutch coast the winds along its coastal areas also weakened and became of the order of 05 to 10 kt. Thereafter moving in a westsouthwesterly direction it rapidly weakened over northwest Arabian Sea and neighbourhood around midnight of 12th.

The diameter of the outermost closed isobar of the system was 4 to 5-degree throughout its life span.

The largest pressure fall (24-hr) of 8.6 hPa was observed at Rajkot at 0300 UTC of 10th and the highest departure of pressure from the normal was *minus* 10.2 hPa at 1200 UTC of 11th. From 1200 UTC of 9th to 1200 UTC of 11th the 24-hr pressure changes in the inner circle of the depression were —4 to —7 hPa and the departure from normals were between —5 to —10 hPa.

In association with the system the lowest pressure was recored at Veraval. It was 987.8 hPa at 1800 UTC of 9th. This lowest pressure was observed when the depression centre was close to Veraval. The next lowest pressure of 989.2 hPa was recorded at Dwarka at 1200 UTC of 11th.

Initially the system moved northwards with the advancing monsoon current and then sharply turned westwards under the influence of easterly current generated by the anticyclone in the lower and middle tropospheric levels over Pakistan and neighbourhood. The system came under the influence of dry continental northerly winds in the lower and middle tropospheric levels from Arabia and Iran on 12th and weakened very rapidly over the sea waters of northwest Arabian Sea.

On the basis of satellite (INSAT) imageries, intensity of the system could be classified as T 1.0 at 1100 UTC of 7th and remained so till 0600 UTC of 9th. During this long period, the disturbance hardly intensified further. Its intensity could be assessed as T 1.5 at 0900 UTC of 9th and remained so till it entered land areas. After emergence over the sea again the highest satellite classification was T 1.5.

The system advanced the Arabian Sea branch of monsoon current into Gujarat and caused heavy rainfall over Saurashtra & Kutch. The significant amounts of rainfall (cm) in association with the systems were :

9 June : Valsad & Deesa 6 each.

10 June : Porbandar 8, Veraval 7, Rajkot 4, Bhavnagar 2.

11 June : Porbandar 26, Dwarka 9, Bhuj 8, Veraval 5, Surat 4, New Kandla 3.

12 June : Dwarka 6, Bhuj 4.

The rainfall feature was characteristic of a monsoon disturbance. The main rainfall was in the western sector of the system. The other characteristic feature of the rainfall was that it was confined to a limited area of western parts of Saurashtra and Kutch. There was hardly any rainfall over Gujarat region in association with this system.