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Cyclones and depressions over the Indian seas in 1984

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1. Chief features

The Bay of Bengal and the Arabian Sea were quiet during the pre-monsoon season of 1984.

Three severe cyclonic storms developed over the Bay of Bengal during the post-monsoon period. There were three monsoon depressions and another in post-monsoon period. Of the monsoon depressions, two developed over the Bay of Bengal and one over the Arabian Sea. The post-monsoon depression formed over the Arabian Sea.

The tracks of these storms and depressions are shown in Fig. 1.

2. Bay of Bengal

2.1. *Deep depression, 30 July-6 August*

A cyclonic circulation in the middle tropospheric levels formed over west central and southwest Bay and adjoining land areas on 25 July. While developing further, it slowly moved northnortheastwards and lay over west central and adjoining northwest Bay on 29th. Under its influence a depression formed over northwest and adjoining west central Bay on 30th morning. Moving west to westnorthwestwards it intensified into a deep depression over northwest Bay in the evening of 31st and crossed Orissa coast between Puri and Paradip in the early hours of 1 August. Continuing to move westnorthwest to westwards across the country it weakened into a depression over north Madhya Pradesh in the evening of 2nd and thereafter entered into southeast Pakistan on 6th. It, further, moved westwards and weakened over north Arabian Sea and adjoining southwest Pakistan by 7th morning. The remnant of the system entered Oman on 8th.

On 30th, 0000 GMT ship *VTJR* (20.5 deg. N, 88.6 deg. E) reported wind eastnortheast/20 kt and at 0600 GMT ship *VRGR* (20.2 deg. N, 89.8 deg. E) reported SSE/25 kt. The depression at 30th 0300 GMT lay centred at 18.5 deg. N, 88.5 deg. E. Another ship *VTKL* (16.6 deg. N, 86.3 deg. E) at 0600 GMT reported wind 270 deg./30 kt indicating strong monsoon condition over west central Bay. The system remained practically stationary upto 1200 GMT. At this time ship *VTJR* (19.7 deg. N, 88.9 deg. E) reported wind 090 deg./24 kt and Sandheads 090 deg./27 kt. The winds over west central Bay as reported by a few ships were of the order of 40 kt.

At 0300 GMT of 31st the depression lay centred near 19.5 deg. N, 88.0 deg. E. The following ship observations were significant :

Ship	Time of obsn. (GMT)	Position		PPP in hPa	Wind direction speed (°/kt)
		Lat. (°N)	Long. (°E)		
ATJZ	0300	20.3	87.6	994.5	050/25
ATJZ	0600	20.7	88.0	995.2	080/23
VTJR	0600	21.2	88.1	996.3	090/20
ATUJ	0600	19.2	88.2	992.3	130/15
ATJV	0000	16.1	85.2	997.5	270/45

The monsoon current was strong to vigorous over west central and southwest Bay. At 1200 GMT *VTJR* (19.5 deg. N, 87.0 deg. E) reported wind 150 deg./15 kt when the system lay centred near 19.5 deg. N, 86.5 deg. E. Winds along Orissa-north coastal Andhra Pradesh coasts were of the order of 10 to 15 kt. But at 0.6 km and 0.9 km a.s.l. Bhubaneswar reported winds ENE/35 kt and ENE/30 kt respectively indicating that the system was of deep depression strength. The 24-hour pressure changes along Orissa coast at this time were —5 to —6 hPa and departures were —5 to —7 hPa. The satellite classification on this day was T 1.5. At 31st, 1800 ship *VTJR* (19.5 deg. N, 86.5 deg. E) reported wind 200 deg./35 kt.

After crossing the coast between Puri and Paradip, in the early hours of 1 August, the deep depression lay at 0300 GMT about 30 km south of Angul. Surface winds in the depression field were 05-15 kt. 24-hr pressure changes in the area were —4 to —5 hPa and departures were —7 to —9 hPa. 3 closed isobars at an interval of 2 hPa and an odd isobar could be drawn. By evening the deep depression lay about 40 km south of Sambalpur. At this time the coastal winds in Orissa were quite strong. They were SSE/35

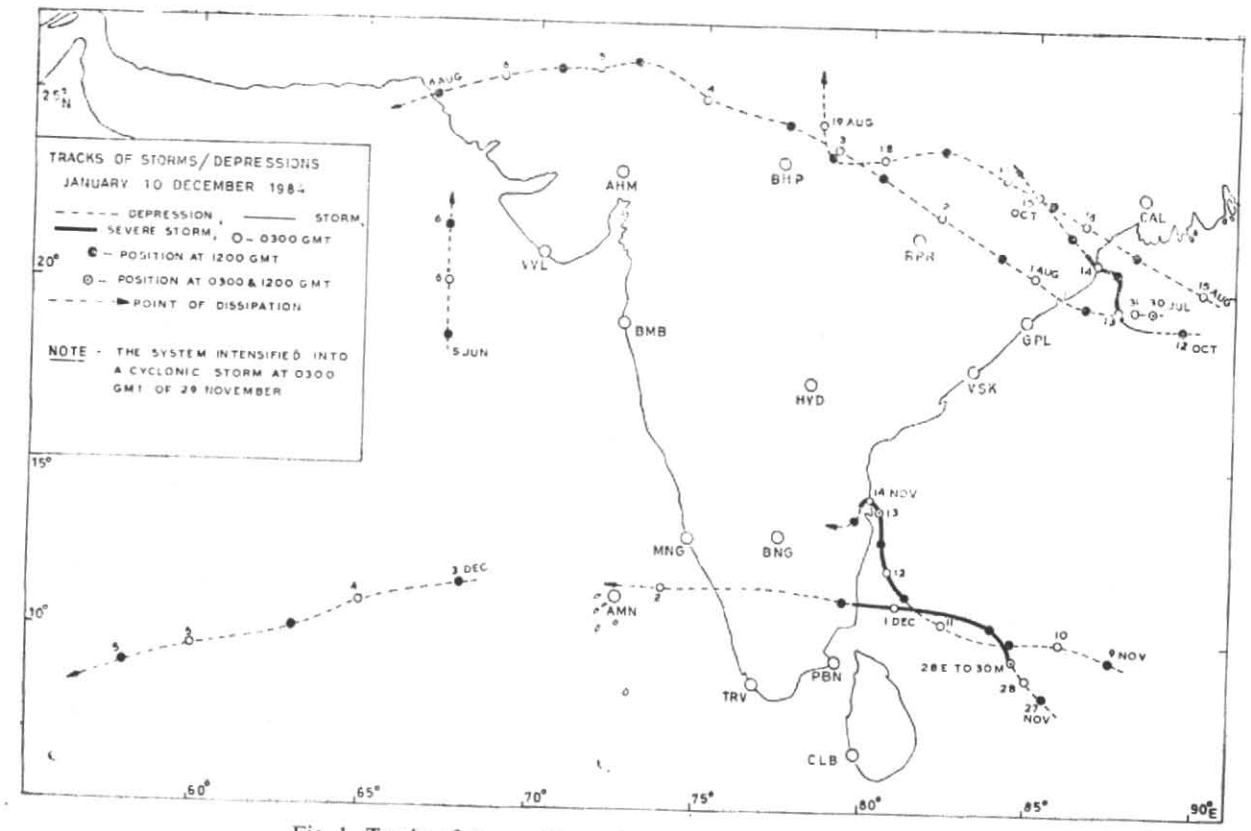

Fig. 1. Tracks of storms /depressions, January to December 1984

kt at Puri, S/30 kt at Gopalpur and S/20 at Bhubaneswar. Past 24-hr pressure changes in the deep depression field at 1200 GMT were —4 to —5 hPa and the departures were —6 to —9 hPa.

At 0300 GMT of 2nd the deep depression was over east Madhya Pradesh centred about 80 km northeast of Raipur. Past 24-hr pressure changes in the area were —3 to —4 hPa and departures were —4 to —7 hPa. 3 closed isobars at an interval of 2 hPa could be drawn. By evening it weakened into a depression and lay centred near Mandla, which recorded the lowest pressure of 990.1 hPa. Pressure changes for the last 24-hr in the area were —1 to —2 hPa. However, departures were of the order of —4 to —8 hPa. Surface winds in the area were of the order of about 05 kt only.

On 3rd morning its centre was close to and SE of Sagar, while in the evening it was about 50 km northwest of Sagar. In the morning the pressure changes for past 24-hr in the depression field were —3 to—4 hPa and departures were —5 to —7 hPa which became —1 to —3 hPa and —3 to —4 hPa respectively in the evening. However the winds on this day around the system at 0.9 km a.s.l. were of the order of 15 to 30 kt. The depression continued its westnorthwestwards journey and lay centred at 0300 GMT of 4th about 40 km southeast of Bhilwara (approx. 25 deg. N, 75 deg. E) and at 1200 GMT about 50 km south of Jodhpur. 24 hours pressure changes and departure continued to be —2 to —4 hPa and —5 to—7 hPa in the depression field.

On 5th morning the depression lay about 50 km east of Barmer, with 3 closed isobars at an interval of 2 hPa. By evening the depression lay about 70 km west of Barmer. The INSAT-1B picture at 1200 GMT indicated a vortex centre at about 25.5 deg. N and 69.7 deg. E. At this time the winds over Saurashtra & Kutch were southwesterly 20-25 kt.

Thereafter, the system entered Pakistan and lay at 0300 GMT of 6th centred near 25.5 deg. N and 69.0 deg. E and at 1200 GMT near 25.0 deg. N, 67.0 deg. E. By 7th morning the depression further weakened over north Arabian Sea and adjoining southwest Pakistan. Satellite pictures indicated that the remnants of the system entered Oman on 8th.

The circulation of the system throughout its life span had extended upto 7.6 km a.s.l. or above. The depression moved like a typical monsoon system along the well established trough in the lower tropospheric levels.

The characteristic features of rainfall distribution associated with the system were that (*i*) it was predominant in left quadrants and in the right rear quadrant upto 2nd morning, (*ii*) which shifted to left forward quadrant on 3rd and 4th and again & (*iii*) the rainfall belt had spread over the left quadrants on 5th and 6th.

The system caused vigorous monsoon conditions on 1 to 2 days in west Madhya Pradesh, Gujarat State, Vidarbha, coastal Andhra Pradesh and Telangana and active monsoon condition on 1 to 3 days in Sub-Himalayan West Bengal, Sikkim, Orissa, Bihar Plateau, east Rajasthan, Madhya Pradesh, Gujarat State,

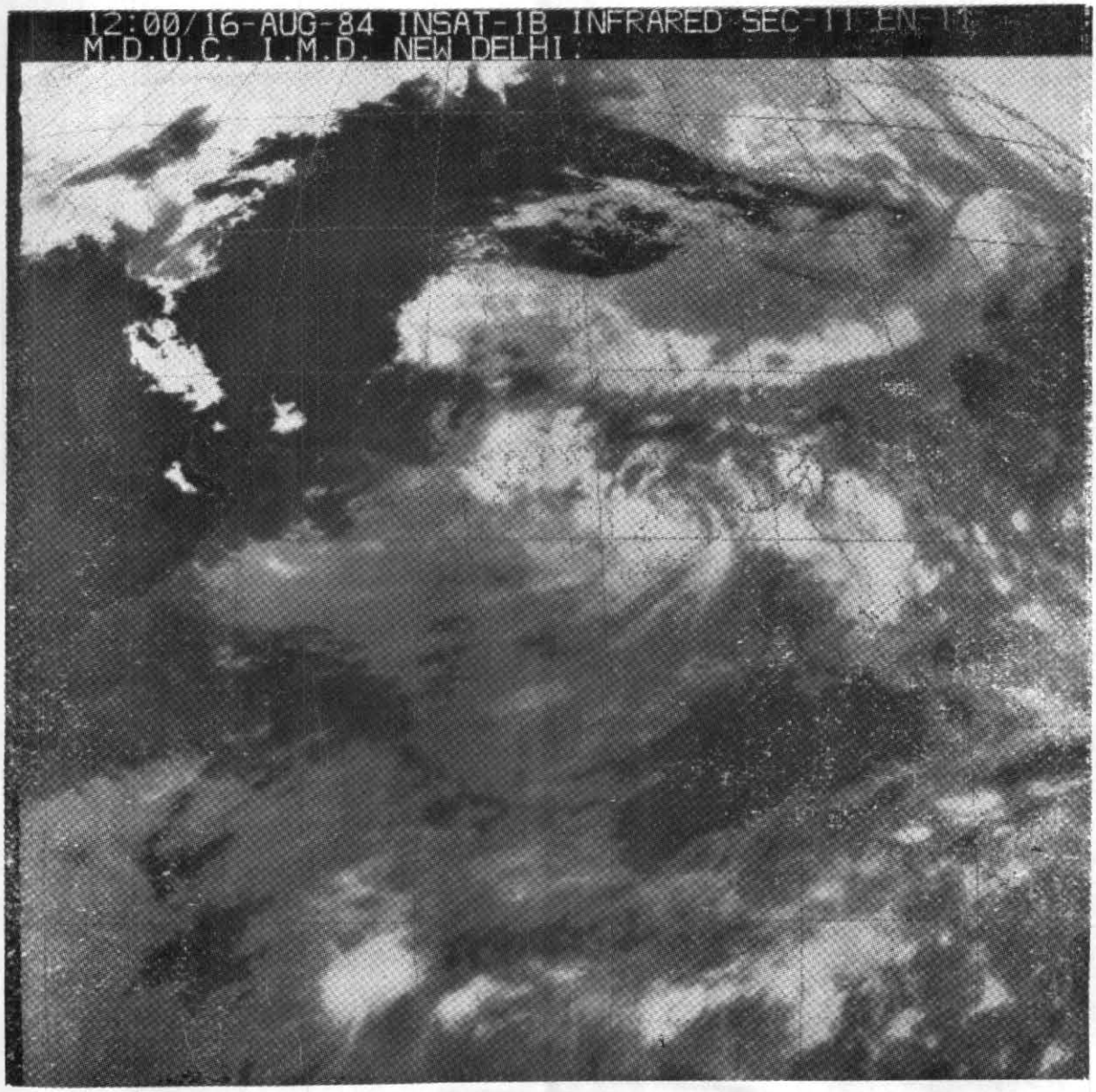

Fig. 2. INSAT-IB picture of 1200 GMT of 16 August 1984

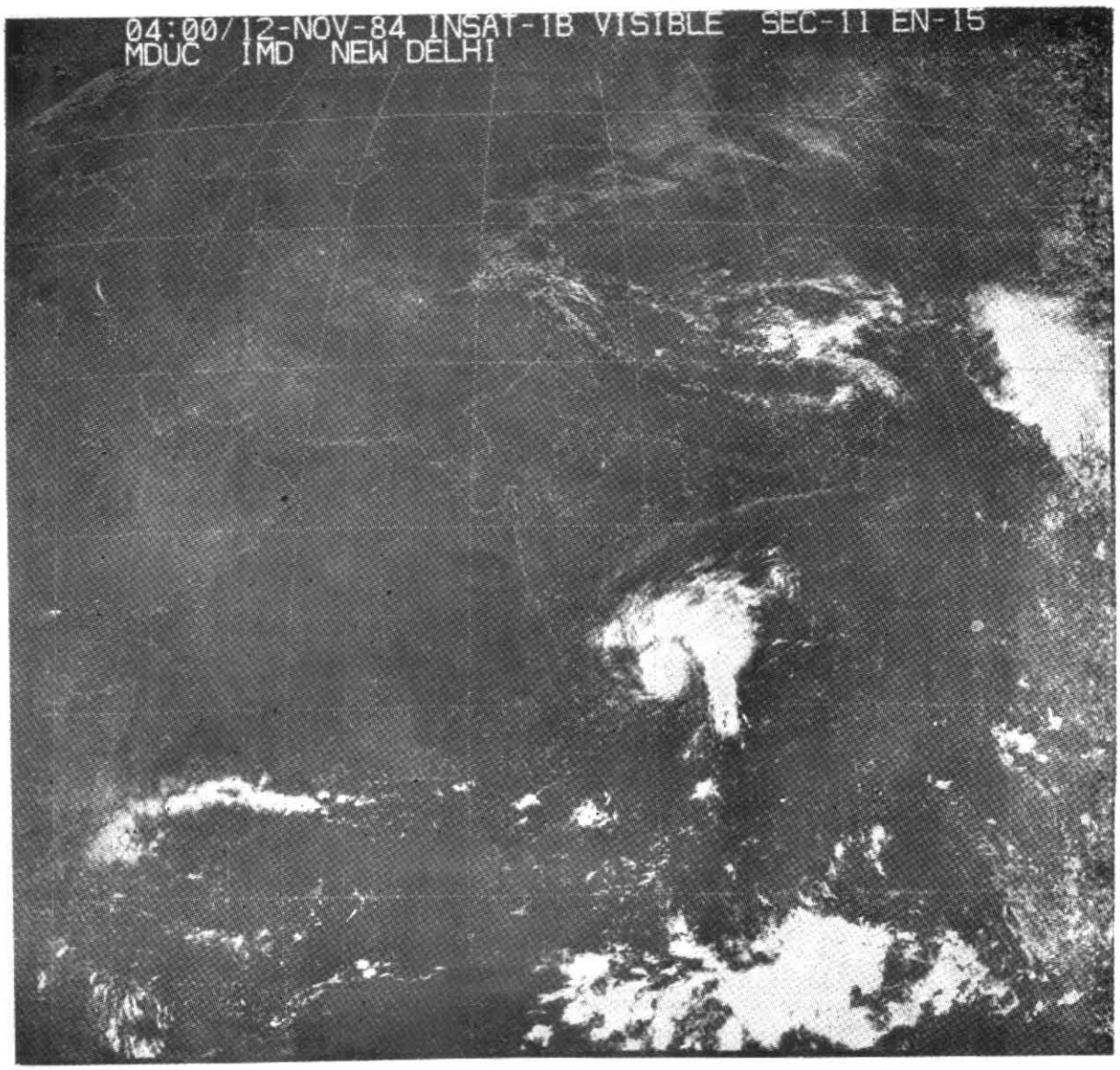

Fig. 3. INSAT-IB picture at 0400 GMT of 12 November 1984

Konkan & Goa, Marathwada, Vidarbha and coastal Andhra Pradesh. Generally widespread rainfall also occurred on 1 to 3 days in West Bengal & Sikkim, Bihar and west Uttar Pradesh. Significant amounts of rainfall (cm) were : Bolangir 12, Motihari 7, Midnapore 5 on 31 July; Tandur 12, Uluberia, Medak & Kalingapatnam 10 each; Midnapore 5 on 1 August; Balurghat 19, Brahmapuri 15, Paikmal 11, Durg 10, Jogipet & Jashpurnagar 9 each, Bolangir, Chandrapur, Medak & Sandheads 8 each on 2nd; Seoni & Betul 18 each, Shajapur & Sawner 14 each, Hoshangabad 12, Bhopal 11, Amraoti 9 on 3rd; Sagwara 21, Garhi 20, (Rajasthan) Ratlam 18, Kishangarh (Rajasthan), Ujjain & Ahmadabad 14 each, Bhilwara 11, Abu 10, on 4th; Abu 24, Igatpuri 15, Idar 13, Bhira 12, Porbandar & Jodhpur 9 each, Garhi & Ahmadabad 8 each on 5th; Abu & Jashpurnagar 14 each, Igatpuri 9, Chotau and Kherwara (Rajasthan) 8 each on 6th.

The systems caused floods in Madhya Pradesh, Maharashtra and Gujarat. River *Indravati* was in floods in Bastar on 2 August disrupting road communications. Rivers *Kolab* and *Indravati* with their tributaries were also in floods in Koraput district of Orissa. River *Sabri* (in Madhya Pradesh) was in spate affecting low lying areas. In Maharashtra State river *Wainganga* was in floods at Badnera and Pauni on 3 and 4 August. Heavy rain/floods affected districts of Pune, Sindhudurg, Ratnagiri, Raigad, Kolhapur, Bombay, Thane, Amraoti, Nanded and Yeotmal. Heavy rainfall over north Gujarat State marooned several villages and breached many roads and cut off all communications.

2.2. *Deep depression, 15-19 August*

A low pressure area formed over north Bay on 11th. It gradually concentrated into a depression on 15th morning and into a deep depression by the same evening. Moving westnorthwestwards it crossed north Orissa coast near Balasore and moved over east Madhya Pradesh on 17th. From 17th evening it moved westwards till the evening of 18th. Thereafter it took a northerly course and weakened over northwest Madhya Pradesh and adjoining south Uttar Pradesh by next day evening.

At 0300 GMT of 15th, when the system was a depression centred near 20 deg. N, 90 deg. E, Sandheads reported NNW/20 kt wind and pressure 990.1 hPa. INSAT picture indicated broken to solid intense convection over Arakan coast, central and adjoining north Bay. The easterly winds at 0.9 km over Calcutta and coastal Bangla Desh strengthened at 0000 GMT. They were of the order of 20 to 30 kt. By evening, the system further intensified into a deep depression and lay centred at 1200 GMT near 21 deg. N, 88 deg. E. At this hour the wind at 0.9 km a.s.l. at Balasore was ESE/40 kt. Sandheads (21.0 deg. N, 88.3 deg. E) reported 30 kt southerly surface wind and pressure 985.5 hPa. It crossed north Orissa coast near Balasore around mid-night of 15th (Sat. Met., New Delhi did not assign any T-Number for the system on 14th and 15th).

At 0300 GMT of 16th the deep depression lay over Orissa centred near (21.7 deg. N, 86.5 deg. E) close to but west of Baripada. At this hour Balasore reported surface wind SSE/40 kt and pressure 989.6 hPa. A few ships over northwest Bay reported southwesterly wind of 30 kt. However the INSAT pictures indicated an overall weakening of the system after 15th, 1800 GMT. At 1200 GMT of 16th the deep depression lay centred about 35 km southwest of Chaibasa. At this time the Bhubaneswar wind at 200 hPa (WSW/15 kt) suggested that the vertical extension of the cyclonic circulation associated with the system was upto that level. It appeared that the system was exhibiting a marked outflow at this level from northern and southern sectors—a characteristic feature of a developing storm. However, the winds at the surface and 0.9 km a.s.l. did not indicate storm intensity. At surface level the winds were 5 to 10 kt around the system, though they were southerly to southwesterly 10 to 20 kt along the Orissa coast and southerly 30 to 40 kt over northwest Bay. At 0.9 km a.s.l. also the available winds around the system were of the order of 10-35 kt (Balasore SE/35 kt and Pendra NNW/10 kt). At this time pressure changes for past 24 hrs in the area were —2 to —3 hPa and the departures were —4 to —7 hPa. Fig. 2 shows INSAT-1B picture at 1200 GMT of 16 August 1984.

On 17th morning it was over Jashpurnagar and in the evening about 80 km SSE of Sidhi (SDI). On this day, the surface winds around the system continued to be 5 to 10 kt and pressure departures —4 to —6 hPa, but the pressure changes for past 24 hrs became —1 to —2 hPa.

On 18th, 0300 GMT, the deep depression lay between Umaria and Jabalpur and at 1200 GMT close to and SSE of Sagar. The surface winds around the system continued to be light, but the pressure changes for past 24-hr in the depression field became —3 to —4 hPa and departures —6 to —9 hPa on 18th morning, however, at 1200 GMT they became —1 to —2 hPa and —4 to —6 hPa respectively. Thereafter the system weakened and lay as a depression on 19th, 0300 GMT centred about 30 km south of Lalitpur. By the evening it further weakened into a well marked low pressure area over northwest Madhya Pradesh and adjoining southwest Uttar Pradesh. The system merged with the seasonal trough over west Uttar Pradesh and adjoining east Rajasthan by 21st morning. Under its influence monsoon was active to vigorous on 2 to 4 days in Gangetic West Bengal, Orissa, Madhya Pradesh, Gujarat region and Vidarbha. Significant amounts of rainfall (cm) were : Pendra 13, Bhubaneswar & Champa 9 each, Sohella (Orissa) 8 on 15th; Chandbali 33, Naraj 20, Akhuapada 19, Dhenkanal & Balaghat 18 each, Bermal 16, Daitari 13 on 16th; Sandheads 30, Rampur 28, Rajkishorenagar 23, Sambalpur 18, Raipur 16 on 17th; Jabalpur 16, Mandla & Raisen 15 each, Raigarh & Hoshangabad 14 each, Saoner 11 on 18th; Tarana & Sandheads 24 each, Shajapur 18, Pachmarhi 17, Bhopal & Ujjain 15 each, Hoshangabad & Ratlam 14 each on 19th; Bhilwara 11, Shivpuri 8, Abu 7 on 20th.

Following heavy rain from 15th to 17th floods affected 3260 villages in Cuttack, Balasore, Puri, Phulbani, Dhenkanal and Keonjargarh districts, where 14 human lives were reported to have been lost and extensive cropped areas were submerged. The river *Narmada* at Hoshangabad was reported to be flowing above danger level from 18 to 21 August. It also submerged a road bridge at Mandla in Madhya Pradesh from 16 to 19 August 1984 disrupting road communication. It was in floods at Broach in Gujarat region on 19 August

1984. In Vidarbha also river *Wainganga* at Bhandara and river *Pauni* were in floods on 18 and 19 August. Traffic was suspended on National Highway No. 6 at Bhandara on 19th.

2.3. *Bay severe cyclonic storm, 12-15 October*

Under the influence of a cyclonic circulation in the lower tropospheric levels a low pressure area formed over southeast Bay and adjoining Andaman Sea on 9th morning. It gradually moved northnorthwestwards and concentrated into a depression over north and adjoining central Bay by the afternoon of 12th and lay centred at 1200 GMT near 19.0 deg. N, 89.5 deg. E. Thereafter it moved in a westnorthwesterly direction and rapidly intensified into a severe cyclonic storm with a core of hurricane winds over northwest Bay on 13th morning. For next 9 hours it moved northwards and afterwards in a northwesterly direction and crossed north Orissa coast just north of Chandbali around 0400 GMT of 14th. It weakened over northeast Madhya Pradesh and adjoining areas of Orissa and Bihar Plateau on 15th evening.

On the basis of INSAT picture of 12th, 0630 GMT, the system could be classified as T 1.5 with the vortex centre near 18.6 deg. N, 90.2 deg. E. Paradip cyclone Detection Radar (CDR) could locate spiral bands from 0300 GMT onwards. An open 'eye' was visible from 12th, 2100 GMT till 13th, 0000 GMT and a 'closed eye' at 13th, 0100 GMT. Fig. 3 shows INSAT-1B picture at 0400 GMT of 12 November 1984.

But at 0300 GMT of 13th no 'eye' could be observed. The T-classification at this hour was 2.0 on the basis of INSAT picture. Ship *VWWF* (20.5 deg. N, 87.6 deg. E) reported at 0400 GMT of 13th wind 020 deg./19 kt and ship *ATKH* (17.0 deg. N, 86.8 deg. E) reported at 0000 GMT wind 200 deg./35 kt. On 13th, 0300 GMT the system had been adjudged as severe cyclonic storm with core of hurricane winds centred near 19.5 deg. N, 87.5 deg. E only on the basis of 0100 GMT radar observation, though other available data were not supportive of the view. However, subsequent observations from the proximity of the system confirmed that the storm was of hurricane strength. On 13th, 1200 GMT the hurricane lay centred near 20.5 deg. N, 87.5 deg. E when the intensity of the system was T 2.5. Paradip radar could only detect spiral banding. However, at this time, ship *ATKH* (18.5 deg. N, 88.1 deg. E) reported wind 260 deg./50 kt and Sandheads from 21 deg. 39′ N, 88 deg. 03 E reported wind NNE/20 kt. Oil India drilling rig stationed off Paradip port reported at 1700 IST of 13th wind NW/45 kt. However, the winds along the north Orissa coast were 05 to 10 kt only but pressure departures were —6 to —9 hPa. Again at 1500 GMT, Paradip radar reported an open eye at 20.2 deg. N, 87.8 deg. E.

At 0300 GMT of 14th the hurricane lay very close to north Orissa coast centred near 20.7 deg. N, 86.8 deg. E. Paradip radar indicated 'closed eye' at 0000 GMT and 'open eye' at 0100 GMT and 0200 GMT of 14th. At 0300 GMT Paradip reported surface wind 290 deg./45 kt, pressure 996.1 hPa and pressure change for past 24 hrs —6.8 hPa. The corresponding values at Chandbali were 230 deg./50 kt, 991.2 hPa and -11.5 hPa and at Balasore were NNE/10 kt, 998.6 hPa and —4.4 hPa respectively. At this time Sandheads stationed at 21 deg. 39′N and 88 deg. 03′E reported wind SSE/10 kt. All these wind observations indicated that the storm was about to cross the coast just north of Chandbali. The following observations of 14th, 0600 GMT were interesting.

S. N.	Ship	Position		Wind direction and speed (°/kt)
		Lat. (°N)	Long. (°E)	
1	ATKH	24.4N	88.5E	230/40
2	Oil India drilling rig	Off paradip port		SSW/67
3	VAWF	20.4N	88.4E	190/22

As per INSAT pictures the intensity was T 3.0 from 13th, 2100 GMT to 14th, 0000 GMT which was the highest assigned T-number for the system. At 14th, 0300 GMT it was classified again as T 2.5.

After crossing coast it weakened and lay at 1200 GMT as a deep depression about 100 km, NW of Chandbali. At this time the winds at Chandbali and Sandheads were SSW/30 kt and SSE/20 kt respectively. The inland winds around the system were of the order of 5 to 10 kt. The winds at 0.9 km a.s.l. were WNW/45 kt at Bhubaneswar and SSE/35 kt at Balasore.

The system further weakened into a depression and lay at 0300 GMT of 15th about 40 km northeast of Rourkela. At this time the pressure changes for past 24 hours showed a rising tendency, though the departures in the field were —4 to —5 hPa. By evening it became a well marked low pressure area over northeast Madhya Pradesh and adjoining areas. It became unimportant over Bihar plains and adjoining east Uttar Pradesh on 18th.

The hurricane was of very small extent. The system moved along the southern periphery of the anti-cyclone over central Burma and neighbourhood. One of the characteristic features of this system was very rapid intensification into a hurricane from depression stage within 12 hours.

The highest wind speed reported over land was 120 kmph from Chandbali of Balasore district and adjoining Rajnagar block of Cuttack district between 0700 and 1000 IST of 14th. The cyclone brought heavy rain in Cuttack, Keonjhargarh and Balasore districts. It pulled down mud houses, uprooted trees and snapped telephone lines in parts of Cuttack and Balasore districts. Standing paddy and Biri crops were sub-merged and partially damaged in Rajnagar, Rajkanika, Aul and Chandbali blocks in Orissa. Under its influence 10 people were injured in Midnapore district, where several trees were uprooted and roofs of about 500 huts were blown off.

However, the rainfall caused by the system elsewhere was welcomed as it brought considerable benefit to the standing crops in Orissa and Gangetic West Bengal.

The significant amounts (cm) of rainfall were : Sandheads 38 on 13th; Rajkanika 20, Chandbali 17, Aul 12, Paradip & Nawana 8 each on 14th; Cuttack

41, Anandapur 16, Bouth 14, Daitari 11, Akhuapada 10, Jenapur 8, Tensa, Telkoi, Darjeeling & Ranchi AP 7 each on 15th.

No tidal wave inundation of coastal areas has been reported. INSAT classification was lower than the intensity of the system.

2.4. *Shriharikota severe cyclonic storm, 9-14 November*

INSAT-1B imagery showed good cloud clustures around equator between 80 deg. E & 95 deg. E on 6 November. The cloud clustures showed northward progression and by 8th the eastern parts of the clustures lay over southeast Bay and adjoining Andaman Sea. By the morning of 9th a well marked low pressure area developed over southeast Bay, which concentrated into a deep depression by evening and lay centred near 9.5 deg. N, 87.5 deg. E at 1200 GMT. The T-classification at this time was 2.0. The system moved westnorthwestwards for next 36 hours without any apparent intensification. The T-classification from INSAT-1B satellite imagery continued to be 2.0 till 0330 GMT of 11th. On this day at 0300 GMT, the system lay over southwest Bay centred near 10.5 deg. N, 82.5 deg. E. The system showed the sign of intensification thereafter. On this day at 0600 GMT ship *ATKK* (7.4 deg. N, 81.9 deg. E) and ship *UDTX* (12.0 deg. N, 80.6 deg. E reported winds 220 deg./30 kt and 040 deg./25 kt respectively. On the 11th at 0000 GMT both Madras and Karaikal reported winds NNE/30 kt at 0.9 km a.s.l. The pressure changes for past 24-hr and the departures at 0300 GMT of 11th along Tamil Nadu coast, however, were of the order of —1 to —2 hPa. But the T-classification of the system was 2.5 (35 kt) at 0530 GMT and 3.0 (45 kt) at 0900 and 1200 GMT. By 1200 GMT the coastal winds along Tamil Nadu coast were north to northwesterly of the order of 10 to 15 kt and ship *ATKE* (9.4 deg. N, 81.6 deg. E) reported wind 270 deg./20 kt. Wind at 0.9 km a.s.l. at Karaikal increased to N/35 kt. However, no significant pressure changes for the past 24 hrs along the Tamil Nadu coast were observed. The system appeared to be of small extent. Cyclone Detection Radars at Karaikal and Madras reported 'open eye' of the system at 1100 GMT of 11th. Though satellite classification did not conform, but the radar observations indicated the system as a severe cyclonic storm in the evening of 11th.

The severe cyclonic storm, hereafter, took northwest to northerly course. At 0300 GMT of 12th, the winds along north Tamil Nadu coast were 05-15 kt only though the system lay at about 100 km away from the coast. The pressure changes for past 24 hrs along north Tamil Nadu coast were —2 to —3 hPa and the departures were —3 to —5 hPa. The T-classification as judged from INSAT pictures was 3.5 (55 kt) at 11th, 2200 GMT and it was 5.0 (90 kt) at 12th, 0300 GMT, thus indicating a rapid intensification of the system.

The INSAT-1B imagery showed a clear 'eye' of the system at 0300 GMT of 12th. At 1200 GMT the surface wind at Madras was NNE/35 kt while that at Nellore was ENE/10 kt and at Cuddalore was WNW/05 kt. These observations showed that the extent of gale force wind associated with the hurricane was limited to a small radial extent. At this time the pressure change for past 24 hrs at Madras was —7.2 hPa and the departure was —9.4 hPa. CDRs at Madras, Karaikal and Machilipatnam tracked the system on this day and could see the 'eye' of the system throughout. In the morning of 13th the hurricane lay about 90 km NW of Madras and remained practically stationary upto 1200 GMT. Some significant observations of this day are given below :

Station/ ship	Time of obsn. (GMT)	Position			Wind direction and speed (°/kt)
		Lat. (°N)	Long. (°E)	PPP (hPa)	
A ship	0000	12.7	81·4	—	160/18
Ship ATCH	0000	12.7	80.5	1009.9	230/15
Nellore	0300	—	—	1007.9	NNE/15
Madras	0300	—	—	1006.2	WSW/25
Ship ATKD	0600	14.5	83.1	1009.4	100/20
SHAR	0230	—	—	997.9	Var/30 gusting to 57

On this day pressure changes for past 24 hrs along north Tamil Nadu-south Andhra coasts were only —1 hPa and the departures were —3 hPa to —6 hPa. The T-classification of the system was 5.5 (102 kt) at 0300 GMT and 6.0 (115 kt) at 1000 GMT which continued to be so upto 1800 GMT. The minimum pressure recorded at Sriharikota was 984.2 hPa at 0710 GMT of 13th with the inferred maximum wind of 102 kt (equivalent to T 5.5) at 13th, 0300 GMT. The estimated central pressure of the system, according to the formula of Mishra and Gupta would be 956 hPa and that at 1200 GMT corresponding to T 6.0 would be 940 hPa. With the above central pressure values, the average pressure gradient comes roughly 1 hPa per km in the inner core of the storm (about 1 deg. in diameter). Sriharikota experienced 30 kt wind at 13th, 0230 GMT which reached to 50 kt by 0600 GMT. It experienced strong winds for nearly 22 hours from 13th, 0600 GMT to 14th, 0400 GMT.

The hurricane started moving extremely slowly northwestwards after 1200 GMT of 13th and lay at 0300 GMT of 14th very close to south Andhra coast north of Sriharikota. Half of the storm was over the land. Sriharikota recorded lowest pressure 984.1 hPa at 0840 IST of 14th. At 0300 GMT Nellore wind was NNW/20 kt and that at Madras was WSW/10 kt. At this time SHAR recorded wind 270 deg./50 kt. The pressure change for past 24 hrs along north Tamil Nadu coast become positive. The satellite classification also indicated the weakening of the system. It was T 4.0 at 0300 GMT of the 14th.

As per the reports the winds of hurricane strength at Vakadu and Durgarajupatnam (about 25 km north of Sriharikota) were blowing from north and north-northeasterly direction respectively from 14th early morning, which changed to easterly at Vakadu from 0900 IST and that at Durgarajupatnam from 0800 IST. The veering of winds at these places showed that the storm had entered land in between Sriharikota and Durgarajupatnam between 0800 & 0900 IST.

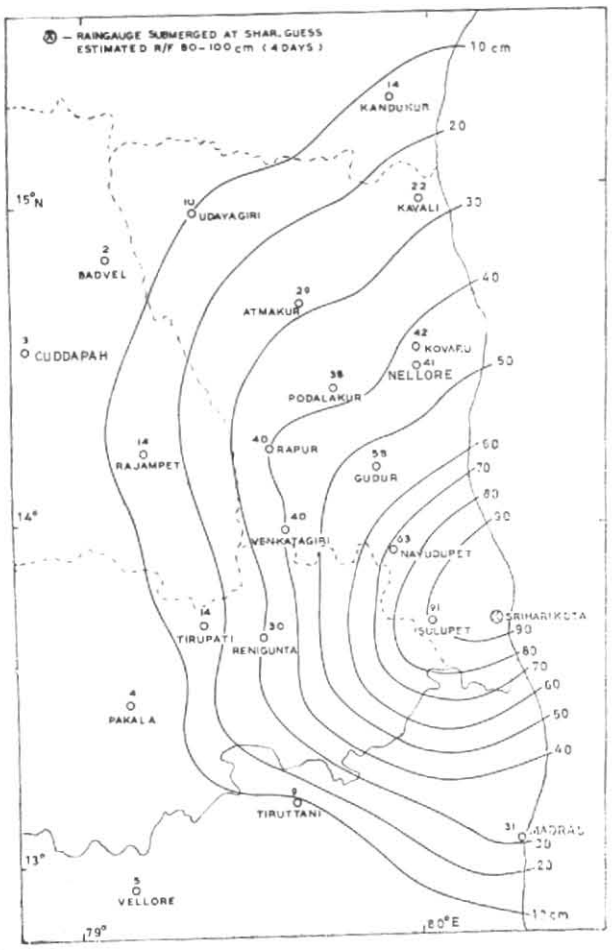

Fig. 4. Accumulated rainfall in south Andhra Pradesh from 13 to 15 Nov 1984

Thereafter, the storm started moving in southerly direction. Sulurpet experienced hurricane winds from westnorthwesterly direction, accompanied by heavy rain from early morning of 14th till 1130 IST of date. Then, suddenly the wind became 'calm', the rain stopped and the sky became clear. From 1400 IST, the hurricane winds from eastsoutheasterly direction accompanied by heavy rain again commenced. These features suggested that the 'eye' of the storm lay, over Sulurpet between 1100 IST and 1400 IST of 14th On its southward journey the system weakened to a deep depression and lay centred at 1200 GMT of 14th about 50 km northnorthwest of Madras. At this hour Madras radar located the system, near 13.5 deg. N, 79.9 deg. E. At 1200 GMT Madras surface wind was S/25 kt and that at Tirupati was N/40 kt. However a ship *ATSH* (13.1 deg. N, 80.3 deg. E) near to Madras reported at 1200 GMT wind S/25 kt. Hereafter, the system very rapidly weakened into a well marked low pressure area over north Tamil Nadu and adjoining Rayalaseema and neighbourhood by 15th morning. It become unimportant there by 16th morning.

It is very difficult to explain the southerly movement of the system on 14th. The system on this day was to the poleward side of the upper tropospheric ridge line. According to steering concept it should have moved in a northerly direction.

Sriharikota experienced hurricane strength winds in gustiness from 1100 IST of 13th to 1200 IST of 14th. Highest wind speed reached 174 kmph at 1230 IST of 13th in one gust.

Sea water of 2 ft height entered the village Durgarajupatnam on 14th and it reached 3 km inland from the coast.

Under the influence of this system heavy to very heavy rainfall occurred in Chingleput district of Tamil Nadu and Chittoor, Cuddapah, Nellore and Prakasam districts of Andhra Pradesh during 12th to 15th. The significant amounts (cm) of rainfall were : Madras AP 12 on 12th; Varadaiahpalam 28, Madras city 25, Satyavadu 15, Atmakur 13, Rapur 12, Gudur & Pedalakur 11 each, Sulurpet, Kavali, Rajampet & Srikalahasti 10 each on 13th. Sulurpet 42, Veradaiahpalam 34, Gudur 24, Satyavadu 18, Nellore & Srikalahasti 16 each, Kovur 13, Nayudupet & Rapur 12 each, Pedalakur 11 on 14th; Nayudupet 44, Sulurpet 38, Srikalahasti 36, Varadaiahpalam 24, Gudur & Venkatagiri 23 each, Govur 21, Nellore 19, Rapur & Pedalakur 16 each, Tirupati AP 15 on 15th.

Accumulated rainfall from 13th to 15th November 1984 has been given in Fig. 4.

Heavy rain caused floods in *Swarnamukhi* river. It breached its bank at several places on 14th morning. River *Kalinga* at Sulurpet was in spate from 14th morning to 15th evening. About one foot high water entered Sulurpet town due to breach in the river bank. Low lying areas of Gudur town were submerged. Two railway bridges between Sulurpet and Tada railway station were washed away disrupting rail services between Nellore and Madras. Large number of irrigation tanks in Nellore district to some extent in southern parts of Prakasam district of Andhra Pradesh breached causing local floods. Sriharikota island was cut-off from the mainland. According to reports heavy rain/floods claimed a toll of 604 lives in Nellore, Chittoor, Prakasam and Cuddapah districts of Andhra Pradesh and 54 lives in Tamil Nadu of which 17 in Madras, livestock perished were 90650 and number of buildings destroyed completely was 3,20,000 in the above districs of Andhra Pradesh. Damages to crops and property in Andhra Pradesh estimated at about Rs. 223.32 crores and that at Madras about Rs. 3 crores.

2.5. *Karaikal severe cyclonic storm, 27 November-2 December*

In the equatorial trough a well marked low pressure area developed over southwest Bay on 27th morning which concentrated into a depression by noon. Initially, it moved northwestwards rather slowly and intensified over southwest Bay into a cyclonic storm on 29th morning and into a severe cyclonic storm on 30th morning, thereafter, moving in a westnorthwesterly direction it crossed north Tamil Nadu coast north of Karaikal in the afternoon of 1st December. Then it moved in westerly direction and emerged in southeast and adjoining east central Arabian Sea on

2nd morning and weakened there into a well marked low pressure area by the same evening. On the basis of 0600 GMT INSAT imagery of the 27th the T-classification of the system was T 1.0. Ship *ATQO* (6.0 deg. N, 84.5 deg. E) at 0600 GMT reported wind 300 deg./20 kt. The same ship at 1200 GMT from 6.0 deg. N, 83.2 deg. E again reported wind 310 deg./25 kt. The system has been declared as depression centred at 1200 GMT of 27 November near 8.5 deg. N, 85.5 deg. E.

On 28th, 0300 GMT, the system lay centred near 9.0 deg. N, 85.0 deg. E with T-classification in the morning being T 1.5. Ship *ATPT* (11.3 deg. N, 86.4 deg. E) at 0300 GMT reported wind 100 deg./24 kt. INSAT pictures in the afternoon indicated intensification of the system. It was classified as T 2.0 on the basis of 0900 GMT INSAT imagery. At 0600 GMT ship *ATUD* (8.5 deg. N, 81.7 deg. E) reported wind 320 deg./30 kt and ship *ATPT* (11.5 deg. N, 85.8 deg. E) at this time reported wind 090 deg./25 kt. The system became a deep depression centred at 1200 GMT near 9.5 deg. N, 84.5 deg. E. At this time ship *ATPT* (12.2 deg. N, 84.8 deg. E) reported wind ENE/25 kt.

The system remained stationary from 28th, 1200 GMT to 30th, 0300 GMT at 9.5 deg. N, 84.5 deg. E. It intensified into a cyclonic storm by 28th night. The T-classification was 2.5 from 28th, 1500 GMT to 29th, 0900 GMT and it was 3.0 upto 30th, 0000 GMT and 3.5 thereafter till 0600 GMT of 1 December.

On 30th morning the system further intensified into a severe cyclonic storm. At 0000 GMT ship *GRHS* (9.0 deg. N, 86.1 deg. E) reported surface wind 190 deg./40 kt. The same ship at 0600 GMT from 7.0 deg. N, 86.1 deg. E continued to report wind 190 deg./40 kt. At 0600 GMT ship *ATUD* (6.4 deg. N, 83.0 deg. E) and ship *ATJX* (7.5 deg. N, 82.0 deg. E) reported winds 310 deg./31 kt and 320 deg./27 kt respectively. At 1200 GMT of 30th ship *VTPY* (7.8 deg. N, 82.5 deg. E), ship *ATJX* (8.8 deg. N, 81.7 deg. E) reported winds 300 deg./32 kt and 290 deg./28 kt respectively.

Afterwards the severe storm speeded up (average speed about 23 kmph) and lay at 0300 GMT of 1 December about 125 km east of Karaikal. At this time the winds were of the order of 10-25 kt along Tamil Nadu coast. Ship *ATJX* (9.7 deg. N, 81.2 deg. E) and ship *ATKB* (12.6 deg. N, 83.6 deg E) reported at 0300 GMT winds 300 deg./55 kt and 120 deg./40 kt respectively. The pressure changes for the past 24 hrs were —6 to —8 hPa along the coast and the departures were —5 to —9 hPa, Cyclone Detection Radars at Karaikal and Madras could detect the 'open eye' at 0300 GMT of 1st.

The system crossed north Tamil Nadu coast just north of Karaikal between 0900 & 0930 GMT of 1st and lay at 1200 GMT as a cyclonic storm about 40 km WNW of Karaikal. The following observations from Karaikal were of interest :

Time of observations (GMT)	Pressure (hPa)	Wind direction and speed (°/kt)
	1 December 1984	
0300	1003.2	WNW/23
0900	990.6	N/42
0930	990.3	—
0945	990.3	—
1000	990.4	WNW/06
1100	993.7	SSW/32
1400	1005.0	S/40

At 01st, 1200 GMT the pressure changes for past 24 hrs were between —5 hPa & —9 hPa and the departures were between —6 & —11 hPa in the storm field. The last T-classification by Sat. Met., New Delhi was 3.0 on the basis of 1st, 1000 GMT INSAT imagery. The T-classification does not satisfy the actual intensity as observed by C.D.Rs. It weakened into a deep depression by 1800 GMT about 150 km south of Bangalore.

Further weakening into a depression it emerged over southeast and adjoining east central Arabian Sea in the morning of 2nd centred at 0300 GMT near 11.5 deg. N, 74.0 deg. E. On this day at 0000 GMT ship *FLJT* (12.3 deg. N, 72.2 deg. E) and at 0600 GMT another ship *VWTR* (10.1 deg. N, 74.6 deg. E) reported winds 360 deg./24 kt and 270 deg./20 kt respectively. The system further weakened into a well marked low pressure area over southeast and adjoining east central Arabian Sea northwest of Amini Divi by the evening.

Under the influence of this system generally widespread rain or thundershowers occurred over Tamil Nadu, Kerala, Rayalaseema and Lakshadweep on one day each with heavy to very heavy falls over Tamil Nadu. The significant amounts (cm) of rainfall were : Nagapattinama & Vedaranyam 4 each on 1st, Kodaikanal & Uthagamandalam 15 each, Coonoor, Vedaranyam & Gudalur 9 each, Nagapattinam, K. Paramathi, Namakkal & Mannargudi 7 each, Satyamangalam, Dindigul, Tondi & Adirampatnam 6 each, Nellore & Chittoor 4 each on 2nd; Amini Divi 5, Coonoor & Kodaikanal 4 each on 3rd.

According to reports about 15000 persons in east Thanjavur district and 20,000 persons in south Arcot district were affected by the storm. Standing crops in about 50,000 acres in Mayiladuthurai and Nagapattinam Talukas of Thanjavur district were submerged due to heavy rains. Two villages were reported to have been marooned.

3. Arabian Sea

3.1. *Depression, 5-6 June*

A cyclonic circulation in the middle and upper tropospheric levels developed over Lakshadweep and adjoining areas on the last day of May. The circulation moved northnorthwestwards and developed into a well marked low pressure area over east central Arabian

Sea on 5th. It concentrated into a depression in the same evening. Moving northwards it became less marked over northeast Arabian Sea off north Gujarat coast on 7th.

At 0600 GMT of 5 June ship *VWUP* from Lat. 17.8 deg. N, Long. 68.6 deg. E reported wind 230 deg./22 kt. In the morning satellite imagery indicated intense convection in the northern parts of west central and adjoining east central Arabian Sea. At 1200 GMT of this day the system concentrated into a depression near 18.5 deg. N, 67.5 deg. E. At this time satellite imagery indicated a vortex defined by curved *Cu* lines to the south and east of the central overcast. Moving northwards, the depression lay at 0300 GMT of 6th near 20.0 deg. N, 67.5 deg. E. T-classification of the system, at this time, was T 1.5. Ship *ABGL* from about 350 km SSW of the depression centre reported wind 250 deg./18 kt at 0600 GMT and another ship *ATOU* (20.9 deg. N, 69.5 deg. E) reported at 0000 GMT NNE/light wind. From Saurashtra coast Porbandar reported wind southeast/15 kt at 0300 GMT. Pressure change for past 24 hrs due to the system was not significant along Gujarat-north Maharashtra coast. At 0600 GMT Sat. Met. classified the system as T 1.0. But at 1200 GMT Porbandar wind was SSW/20 kt and ship *PDSA* (20.0 deg. N, 66.0 deg. E) reported wind 270 deg./20 kt. Pressure changes for past 24 hrs along north Gujarat coast were about —4 hPa and the departures were —3 to —6 hPa. The depression at 1200 GMT lay off north Gujarat coast centred near 21.5 deg. N and 67.5 deg. E Thereafter the system weakened over northeast Arabian Sea off north Gujarat coast and became unimportant by next day. This system drew the monsoon current in the Arabian Sea northwards covering most parts of east central Arabian Sea and advanced it into west coast upto Goa by 6th. The significant amounts (cm) of rainfall were : Buldhana 7, Bidar 6 on 5th; Karwar 8 on 6th; Devgarh 17, Karwar 16, Vengurla 13, Panjim 9 on 7th.

3.2. *Deep depression, 3-5 December*

The remnant of Karaikal severe cyclonic storm reintensified over east central Arabian Sea into a deep depression on 3rd evening and was centred at 1200 GMT near 11.5 deg. N, 68.0 deg. E. At this time its assigned intensity was T 2.0. The system moved in a westsouthwesterly direction across south Arabian Sea and weakened over southwest Arabian Sea off Somalia coast by 6th morning. Its T-classification continued to be T 2.0 upto 0300 GMT of the 4th and as T 2.5 from 04th, 0600 GMT to 05th, 0300 GMT. Thereafter it rapidly weakened and could be classified as T 1.0 at 05th, 1500 GMT. By 1200 GMT of 6th the centre of the vortex of the cloud system over southwest Arabian Sea was not definable. Ship observations from the field of the system were absent during its life span.

The system did not cause any weather over India.