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Cyclones and depressions over the Indian seas in 1979

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1. Chief features

During 1979, cyclonic disturbance activity was below normal in the Bay of Bengal, especially between September and December when only one cyclonic storm and one depression developed.

Five cyclonic storms and six depressions developed during the year. Only one cyclonic storm formed in the pre-monsoon season in May in the Bay, and it attained hurricane intensity. It formed at an unusually low latitude (6 to 7 deg. N) and had a rather long life of 8 days, before it hit the south Andhra coast resulting in heavy loss of life and property. No serious damage to life or property was caused by the other storms.

During the monsoon season (June to September) one severe cyclone and four depressions developed in the Bay. Two severe cyclones also developed in the Arabian Sea but they moved away westwards to Arabia coast.

During the post-monsoon season (October to December), one cyclonic storm and one depression formed in the Bay and one depression in the Arabian Sea.

The tracks of these systems are shown in Fig. 1 and the details are tabulated in Table 1. The maximum wind and lowest mean sea level pressure associated with the cyclones are given in Table 2. The salient features of the disturbances are discussed below:

2. Bay of Bengal

2.1. *Severe cyclonic storm of 5-13 May*

The first cyclonic storm of the year had its genesis as a low over southeast Bay, which concentrated into a depression on the evening of 5 May with its centre near 7 deg. N, 90 deg. E. Moving slowly westwards and intensifying at the same time, the depression attained storm intensity by the morning of 7th near 7 deg. N, 88 deg. E. Ship *VWMG* (*Betwa*) reported NNW/36 kt surface winds at 0000 GMT and WSW/32 kt at 0600 GMT on 7th within 100 km from the storm centre. The storm took a westsouthwesterly track upto the 8th morning. It attained hurricane intensity as indicated by satellite pictures and executed a cyclonic loop near 6 deg. N, 86 deg. E during the period 080000 to 081800 GMT. Joint Typhoon Warning Centre (JTWC) at Guam classified this system as T4.0/4.0 in Dvorak's scale at 0528 GMT on 8th, which suggests a maximum wind of 65 kt. Satellite Tropical Disturbance Summary (STDS) from Washington classified this system as T 4.5/4.5 in Dvorak's scale at 0852 GMT on 8th, which corresponds to a maximum wind of 77 kt.

After 081800 GMT, the storm took a north-northwesterly course up to the 11th morning and later moved northwest towards south Andhra coast attaining its peak intensity on 11th and 12th as revealed by satellite pictures. It came close to Nellore (within about 100 km) by 0600 GMT of 12th. Then it took a more northerly course and crossed coast about 50 km south of Ongole by the evening of 12th and gradually dissipated by the morning of 14th over the eastern parts of Telangana.

This is the first time during the last 100 years that in the month of May a cyclonic storm of hurricane intensity formed at such a low latitude. Another noteworthy feature of this storm was the very heavy rain along and to the left of its track over south coastal Andhra Pradesh and Telangana. Many stations in Prakasam district recorded more than 20 cm rainfall on 13th. The notable amounts of very heavy rainfall (cm) were : Kanigiri (Prakasam district) 43, Markapur (Prakasam district) 40, Srisailam (Kurnool district) 34, Srisailam (Mahbubnagar district) 34, Kavali (Nellore district), Tumadu (Prakasam district) 30 each, Juvvigunta 29, Pakala 25, Kondapi 24, Kandukuru, Podilli 23 each

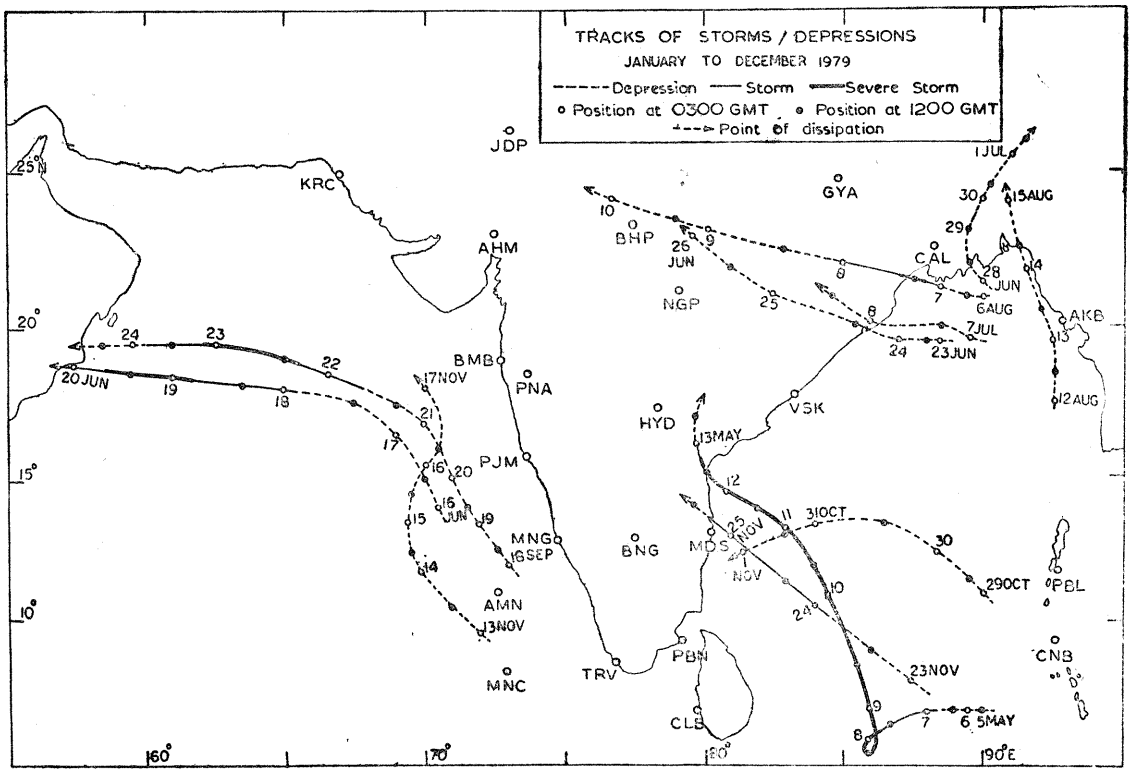


Fig. 1. Tracks of storms and depressions

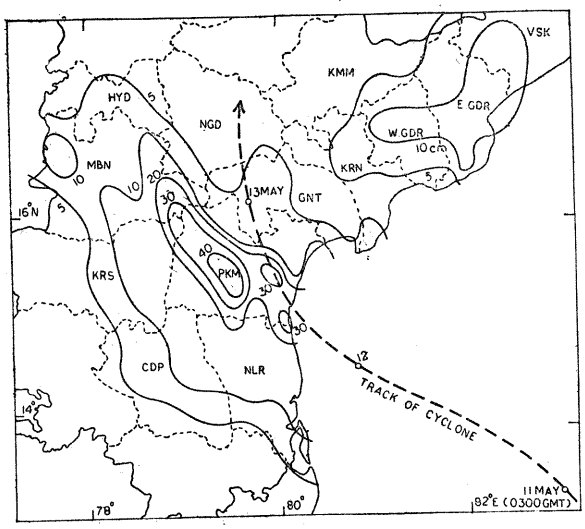


Fig. 2. Rainfall (cm) for 24 hr ending at 0830 1ST on 13 May

(all in Prakasam district), Achampet (Mahbubnagar district) 22 on 13th; Atmakur, Kollapur (Mahbubnagar district) 20 each, Mahbubnagar, Kodangal (Mahbubnagar district), Pargi, Laknapur (Ranga Reddy district) 17 each, Wanaparthi (Mahbubnagar district), Vikarabad (Ranga Reddy district) 16 each on 14th.

An isohyetal map showing the distribution of rainfall during the 24 hour period ending 0300 GMT of 13th is presented in Fig. 2.

TABLE 1

Storms and depressions of 1979

S. No.	Type of disturbance	Life period	Location
1	Severe cyclonic storm	5-13 May	Bay of Bengal
2	Do.	16-20 Jun	Arabian Sea
3	Deep depression	23-26 Jun	Bay of Bengal
4	Do.	28 Jun-1 Jul	Do.
5	Depression	7-8 Jul	Do.
6	Severe cyclonic storm	6-10 Aug	Do.
7	Depression	12-15 Aug	Do.
8	Severe cyclonic storm	18-24 Sep	Arabian Sea
9	Deep depression	29 Oct-1 Nov	Bay of Bengal
10	Do.	13-17 Nov	Arabian Sea
11	Cyclonic storm	23-25 Nov	Bay of Bengal

Gales with speed reaching 100 to 160 kmph were reported in Nellore and Prakasam districts almost continuously from the morning till midnight of 12th. According to the report of the touring officer, total sea level elevation which affected the coastal areas of Prakasam, Guntur and Krishna districts was 3 to 4 metres near Woolapalam and Pedaganjam, 3 metres near Suryalanka and 2 to 3 metres along the coast extending from Nizampatnam to Hamsaladivi. However, normal tide at the time of landfall was insignificant.

TABLE 2

Maximum wind and minimum pressure in cyclones

Cyclonic disturbance	Wind (kt)		Pressure (mb)	
	Max. estimated from sat. pictures or other sources	Max. reported from nearest observation	Estimated lowest MSL pressure at the centre	Lowest MSL pressure reported from nearest obsn.
1. Severe Cyclonic Storm (5-13 May)	110	70 (at Nellore)	936	963 (at Ongole)
2. Severe Cyclonic Storm (16-20 Jun)	55	44 (Ship PJKJ 150 km to the north of storm centre)	981	989.1 (Ship PJKJ 150 km to the north of storm centre)
3. Severe Cyclonic Storm (6-10 Aug)	55	45 (at Balasore)	971	970 (at Balasore)
4. Severe Cyclonic Storm (18-24 Sep)	70	70 (Ship ATJZ 50 km from storm centre)	980	986 (Ship ELWT 50 km from storm centre)
5. Cyclonic Storm (23-25 Nov)	45	40 (Ship ATKK 150 km from storm centre)	996	1001.1 (Ship ATKK 150 km from storm centre)

Ship *ATGW* reported ESE/45 kt surface wind and mean sea level pressure of 993.0 at 1000 GMT on 8th about 100 km from the storm centre. At 1200 GMT it reported surface wind NE/30 kt and pressure 994.4 near about the same position. This wind shift suggests the shift of the storm centre eastwards and supports the possible cyclonic loop in the track of the storm. A few other ships also reported some useful observations in the storm field but more than 100 km away from the storm centre. Important observations from ships and observatories in the storm field are given in Table 3. Nellore recorded the lowest pressure of about 980 mb between 0600 and 1800 GMT on 12th. It reported surface winds of 50 kt or more from morning to midnight of 12th and 70 kt from 0200 GMT to 0900 GMT that day. At Ongole surface wind of more than 50 kt commenced from 0900 GMT of 12th. At about 1100 GMT the roof of the observatory fell down and the windvane was blown off. No observations were recorded subsequently. The barograph at Ongole functioned till 1430 GMT and became unserviceable subsequently. The lowest pressure recorded by the barograph at 1430 GMT was 963 mb and the barogram showed a falling tendency even at that time. According to the report of the officer who visited Ongole, a lull was experienced at Ongole between 1500 and 1700 GMT on 12th. Hence the storm centre must have passed very close to Ongole between 1500 and 1700 GMT and the pressure at that time at Ongole (*i.e.*, close to the storm centre) should have been less than 963 mb. The maximum wind speed estimated at Ongole was 150 to 160 kmph (80 to 90 kt) between 1230 and 1430 GMT.

This storm was tracked continuously by the radar at Madras from 0900 GMT of 10th to 0500 GMT of 12th. Most of the eye-wall could be seen in the radar picture from 2300 GMT of 10th to 2000 GMT of 11th. A radar picture of the storm at 0604 GMT on 11th is reproduced in Fig. 3. The diameter of the eye as seen in the radar picture is about 20 km.

The eye of the storm was seen in the satellite pictures also between 9th and 12th morning. The storm was in its peak intensity on 11th and 12th as indicated by the satellite pictures. In the STDS from Washington the system was classified as T 5.5/5.5 and JTWC Guam classified the system as T 6.0/6.0 on 11th and 12th, the corresponding maximum sustained winds being 102 and 115 kt. A satellite view of the storm is shown in Fig. 4. Assuming the maximum sustained wind associated with this storm as 110 kt, the lowest pressure at the storm centre works out to be 936 mb based on the formula $V_{max} = 14.2\sqrt{(P_n - P_o)}$ developed for the Indian sea area by Mishra and Gupta (1976), where P_n is the peripheral pressure and P_0 is the pressure at the centre of the storm.

According to press reports and reports of the officer who toured the cyclone affected areas, many trees were uprooted and electric poles were bent and twisted in Nellore and Prakasam districts leading to disruption of road transport and telecommunications and extensive damage to power lines. Enormous damage was caused to railway property in these districts by the swollen rivers and heavy rain. Two bridges near Tanguturu (Prakasam district) were washed away. According to "Weekly Flood News Letter" of Central Water Commission, 40 lakhs of people were affected by the cyclone in Andhra Pradesh, crops in 0.7 lakh hectares and about 7 lakh houses were damaged; about 700 human beings and 3 lakh heads of cattle lost their lives and the total damage to crops, houses and public utilities was about 170 crores of rupees.

TABLE 3

Severe cyclonic storm of 5-13 May

Date	Time (GMT)	Ship/Station	Location		Approximate distance from storm centre (km)	Wind		Pressure (mb)
			Lat. (°N)	Long. (°E)		Direction	Speed (kt)	
6	0600	ATJJ	7.6	89.5	50	E	24	1003.6
7	0000	VWMG (Betwa)	6.8	87.4	75	NNW	36	1000.4
	0600	VWMG (Betwa)	6.2	87.2	75	WSW	32	997.4
								(Remarks : Passing through Severe Storm force 10 BF Minimum pressure 994 mb)
8	1000	ATGW	6.2	86.3	75	ESE	45	993.0
	1200	ATGW	6.3	86.0	100	NE	30	994.4
	1200	VWMG	5.6	88.4	250	S	28	998.6
								(Remarks : Sea state Very High; Swell 7 metres at 13 GMT)
9	1000	ATJN	5.8	86.4	300	W	37 (BF 8)	1002.0
10	0300	VWYJ	14.1	84.8	350	ENE	30	999.6
	0600	ATPT	13.7	84.0	250	NE	30	995.7
	1200	FNTG	14.0	85.0	250	E	33	999.5
11	0300	FNTG	13.5	82.0	100	N	40	994.5
	0900	FNTG	12.5	81.4	150	WNW	48	991.5
12	1200	Gannavaram	—	—	—	NNE	40	990.9
13	0300	Gannavaram	—	—	—	SE	30	994.0

Heavy rains and strong winds of 80 to 100 kmph also affected Madras city and Chingleput district uprooting a large number of trees and twisting advertisement boards. Roofs of some houses were also blown off. Gale force winds and high seas caused erosion at several places along and near Madras coast affecting a number of fishing villages. Pulicat area (Chingleput district) was isolated by the rise in the back waters. Power supply was disrupted in many areas in Madras city on 11th and 12th. Photographs of damage caused by this cyclone in Andhra Pradesh are reproduced in Figs. 5 & 6.

2.2. *Deep depression of 23-26 June*

Under the influence of an isallobaric low moving westwards across north Burma, a low pressure area over north Bay concentrated into a depression on the morning of 23 June with its centre near 19.5 deg. N, 88.5 deg. E. The depression became deep on 24th and moving westnorthwestwards across Orissa and east Madhya Pradesh, it weakened into a low over northwest Madhya Pradesh by the evening of 26th. E/35 kt at Calcutta and N/35 kt at Bhubaneswar at 0.6 km asl on 24th morning and SW/30 kt at the surface at Puri on 24th evening were the strong winds associated with this system. The pressure departure from normal near the centre of the depression was about *minus* 10 mb.

Under the influence of this system, the monsoon moved into Gangetic West Bengal, Orissa, Bihar, Madhya Pradesh, Vidarbha, north Gujarat State and southeast Rajasthan between 23rd and 26th. The monsoon was active to vigorous in Orissa, Madhya Pradesh and Vidarbha where heavy to very heavy rain occurred during the above period. Generally widespread rain with isolated heavy falls also occurred in Marathwada, Telangana and north coastal Andhra Pradesh between 23rd and 26th. According to press reports heavy rain in Madhya Pradesh caused floods in the *Narmada* and *Tapti*. Some rivers in Orissa also rose in spate.

The principal amounts of heavy rainfall (cm) were: Dhamtari (Madhya Pradesh) 16, Jagdalpur, Gopalpur 15, Chandrapur (Vidarbha), Asifabad (Andhra Pradesh), Titlagarh, Bhawanipatna 11 on 25th; Khargone 14, Wardha, Alirajpur 13, Kanker 12, Khandwa, Balod 11, Yeotmal 10 on 26th.

2.3. *Deep depression of 28 June-1 July*

A cyclonic circulation developed in the middle troposphere over north Bay of Bengal

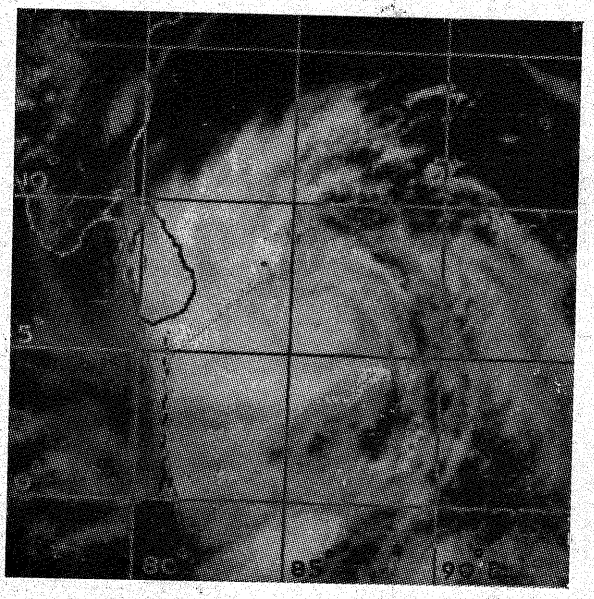


Fig. 4. Satellite view of Bay of Bengal cyclone at about 0900 GMT on 8 May showing 'eye' of the cyclone

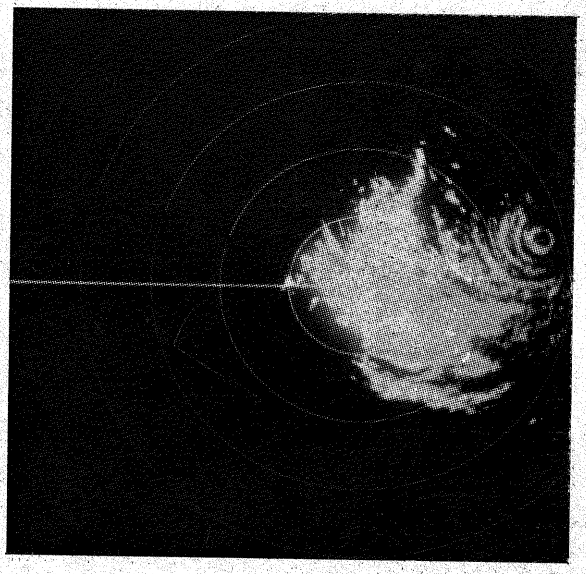


Fig. 3. Bay of Bengal cyclone as viewed by Madras radar at 0604 GMT on 11 May

Fig. 5. Tettu railway station in Prakasam district damaged by May cyclone

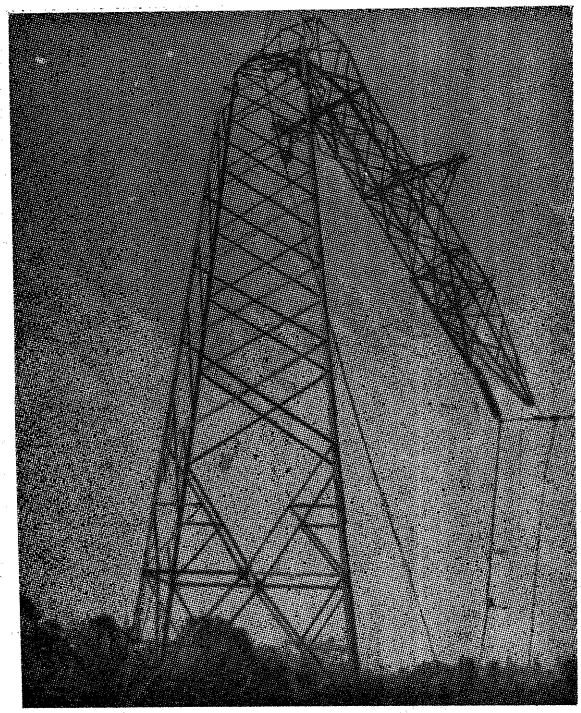


Fig. 6. Electrical tower bent by cyclone in Prakasam district

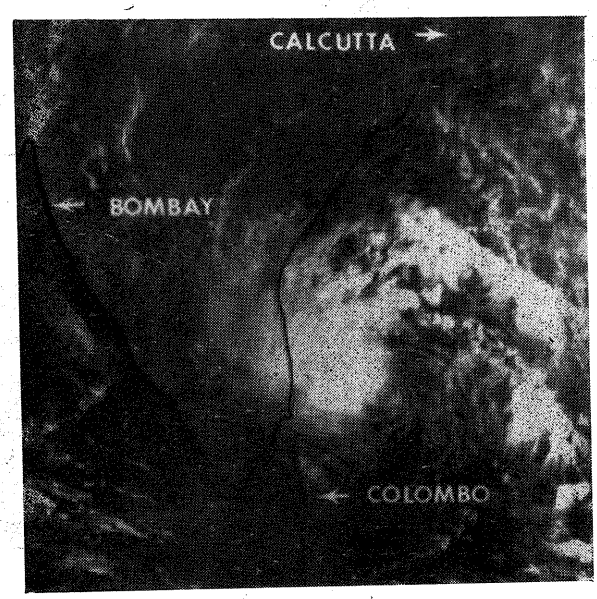


Fig. 7. Satellite view of Bay cyclone at 0455 GMT on 24 November with an exposed low level circulation

on 27 June. Under the influence of an isallobaric low moving westwards across Arakan coast, the circulation over north Bay built downwards to the surface on 28th morning and a depression formed at 0300 GMT that day with its centre near 21.5 deg. N, 90.0 deg. E. Moving in a northerly direction, it became deep the next morning over Bangla Desh. Subsequently the deep depression moved slowly in a northnortheasterly direction being steered by the southwesterly winds ahead of a trough in the upper tropospheric westerlies which moved into east Tibet on 30th. The deep depression weakened into a depression by the evening of 1 July and into a low over the western parts of Assam by the morning of 2 July.

This system caused generally widespread rain in Gangetic West Bengal and Orissa from 29 June to 1 July, in Sub-Himalayan West Bengal, Assam and adjacent States from 30 June to 2 July and in Bihar State on 30 June and 1 July. Heavy to very heavy rain occurred in Gangetic West Bengal on 29 and 30 June and in Assam and adjacent States on 1 and 2 July. According to press reports, floods in the *Brahmaputra* and its tributories inundated many areas in the Brahmaputra valley. The northward movement of this depression resulted in weak monsoon conditions in the central parts of the country in the first week of July although there was good rainfall in northeast India.

The principal amounts of heavy rainfall (cm) were : Sandheads 15 on 28th; Sandheads 29 on 29th ; Sandheads 24, Midnapore 21, Contai 18, Rajghat (Orissa) 14, Bagati (Magra) 12, Dum Dum 11, Jamshedpur, Balasore 10 on 30th; Cherrapunji 35, Agartala 17, Raxaul 13, Shillong 12, Muzaffarpur 11 on 1 July; Cherrapunji 41, Gauhati, Rangiya, Cooch Behar 14, Goalpara, Haflong 12, Majbat 11, Chapar-mukh 10 on 2nd.

Agartala reported E/SE 25-30 kt winds at 0.6 and 0.9 km asl and Dacca E/30-40 kt at 0.3 and 0.6 km asl on 29th morning. On 30th morning the cyclonic circulation associated with this system extended to 250 mb. The pressure departure from normal near the centre of the depression was about *minus* 15 mb.

2.4. *Depression of 7-8 July*

A low pressure area with associated cyclonic circulation extending to the middle troposphere moved westwards from north coastal Burma into northeast Bay on 6th and concentrated into a depression on the morning of 7th with its centre at 0300 GMT near 19.5 deg. N, 89.5 deg. E. Moving westwards, it crossed Orissa coast in the early morning of 8th and weakened into a low over central parts of Madhya Pradesh on 9th morning. The system was probably a deep depression on the morning of 8th. Bhubaneswar reported upper winds N/NE 30-40 kt upto 0.9 km asl on 8th morning. From the dropsonde reports of the research aircrafts of the Monex, which flew over the depression field on 7th, it is seen that the depression sloped southwestwards with height by about 3 degrees of latitude between surface and 500 mb.

In association with this system, generally widespread rain occurred in Orissa and east Madhya Pradesh from 7th to 9th, in north coastal Andhra Pradesh on 8th and in Marathwada, Vidarbha and west Madhya Pradesh on 9th with some heavy falls in Orissa, Vidarbha and Madhya Pradesh. According to the "Weekly Flood News Letter" of the Central Water Commission, river *Indravathi* rose in spate on 9 July and submerged the road bridge on Raipur-Visakhapatnam highway disrupting road communications.

The principal amounts of heavy rainfall (cm) were : Angul 13, Raipur, Khairagarh 10, Gopalpur, Puri, Talcher, Seoni 7 each on 8th; Khandwa 18, Chandrapur 11, Betul 10, Chhindwara 9, Phulbani, Bolangir 7 each on 9th.

2.5. *Severe cyclonic storm of 6-10 August*

A low formed over north Bay and adjoining parts of Bangla Desh on the morning of 5th August. Under the influence of a low pressure wave (remnants of typhoon *Hope*) moving westwards across Arakan coast, the low over north Bay concentrated into a deep depression on the morning of 6th with its centre at 0300 GMT near 21.0 deg. N, 90.0 deg. E. Moving slowly in a westerly direction, and progressively intensifying, it became a cyclonic storm by the morning of 7th and a severe cyclonic storm the same afternoon. The severe storm crossed Orissa coast early that night (about 1500 GMT) near Balasore. The system retained storm intensity over land till next morning when it was located over northwest Orissa. Later moving westnorthwest across east Madhya Pradesh as a deep depression and west Madhya Pradesh as a depression the system weakened into a well marked low over southeast Rajasthan by the evening of 10th. This well marked low moved further westwards and lay over southwest Rajasthan and adjoining north Gujarat State on 11th and 12th. It weakened on 13th and merged with the seasonal low over Pakistan on 14th.

Sandheads reported surface wind W/30 kt at 0000 GMT of 6th, NW/35 kt at 0600 GMT and N/30 kt at 1200 GMT the same day indicating that the low over north Bay had become a deep depression on 6th. On 7th morning at 0000 GMT the upper winds at Calcutta at 0.6 and 0.9 km asl were NE/E 40-45 kt and the surface wind at Sandheads at 0300 GMT strengthened to N/40 kt showing that the system had intensified into a cyclonic storm. The pressure departure from normal at Sandheads and Sagar

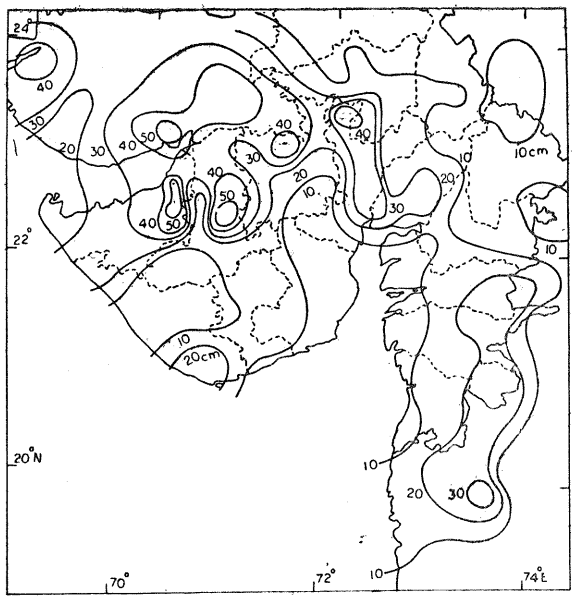


Fig. 8. Rainfall (cm) for 48 hrs from 0830 IST of 10th to 0830 IST of 12 August

Island was about *minus* 19-20 mb at that time. The strengthening of the upper winds at 0.6 km asl at Calcutta to ENE/60 kt at 0600 GMT on 7th and the surface wind at Balasore to NW/45 kt at 1500 GMT suggested the further intensification of the system into a severe cyclonic storm after 7th noon. Balasore continued to report surface winds of 30 to 45 kt from south during 7th night and till early morning of 8th. Balasore which recorded only 3-hourly observations reported the lowest pressure of 970.9 mb at 1500 GMT of 7th. It is seen from the barogram of Balasore that the lowest MSL pressure of 970 mb was reached at 1530 GMT that day. The corresponding pressure departure from normal was *minus* 30 mb.

This storm was tracked by the radar at Calcutta and centre was estimated every hour from 0500 to 2000 GMT of 7th. The radar at Paradip also tracked the cyclone and the centre of the cyclone was estimated every hour from spiral bands from 1000 GMT to 2100 GMT of 7th.

This storm could not be classified in Dvorak's scale based on satellite pictures as the cloud features associated with the storm were masked by the general monsoon cloudiness.

Assuming the maximum wind associated with this storm as 55 kt the pressure at the centre of the storm works out to be 971 mb which agrees well with the lowest pressure of 970 mb reported by Balasore when the storm centre was passing over that station.

Generally widespread rain occurred in Orissa, Gangetic West Bengal and Bihar Plateau from 7th to 9th with heavy to very heavy falls in Orissa and Gangetic West Bengal. Rainfall was also generally widespread in Madhya Pradesh and Vidarbha from 7th to 10th, in north Madhya Maharashtra and Marathwada on 9th and 10th and in Gujarat State and southeast Rajasthan from 10th to 13th. Many stations reported heavy to very heavy rain in Madhya Pradesh and Gujarat State and a few stations in Interior Maharashtra and southeast Rajasthan. According to press reports, some damage was caused to houses and crops in the coastal areas of Orissa and West Bengal mainly due to heavy rain. Road and rail communications were disrupted over these areas due to flooding. Telephone and electricity lines were also damaged over these areas and some trees were uprooted in north coastal Orissa. Some parts of West Bengal coast experienced saline inundation although there was no storm surge associated with this cyclone. Very heavy rain in Madhya Pradesh between 8th and 10th caused floods in the *Narmada* and the *Tapti*. Road bridges at Mandla and Tilwara Ghat were submerged. Road communication between Nagpur and Jabalpur was disrupted. Low lying areas in Broach were submerged by the flooded *Narmada*. Very heavy and incessant rain in Gujarat State, particularly in Rajkot district, caused the collapse of the Machhu dam-II near Morvi and the consequent flash floods submerged the Morvi town and nearby areas in Morvi and Malia taluqs. According to the 'Weekly Flood News Letter' of Central Water Commission, about 1500 human lives and 12800 live-stock were lost in Gujarat. 180000 houses including about 73000 huts were damaged. Many minor irrigation tanks in Gajarat State breached and damage was caused to some minor irrigation works. In Vidarbha floods and heavy rain affected over 600 villages in 8 districts in the second week of August resulting in

damage to 13,000 houses and loss of 35 human lives and 1500 heads of cattle.

The following observatories in Gujarat had record 24-hour rainfall for the month. Rajkot 35 cm on 11th, New Kandla 51 cm and Bhuj 24 cm on 12th. Rainfall ranging from 20 to 40 cm was reported from more than 20 stations on 11th and more than 12 stations on 12th in Gujarat State. The other notable amounts of very heavy rainfall (cm) were : Sandheads 15 on 7th; Chandbali 29, Tihidi (Orissa) 21, Akhuapada (Orissa) 20, Phulbani 17, Keonjhargarh, Kuchinda (Orissa) 16, Khajuripada (Orissa), Sonepur Raj (Orissa), Shimola (Orissa), Kawardha (Madhya Pradesh) 15, Champa, Kamakhyanagar (Orissa), Pallahara (Orissa), Anandpur (Orissa) 14, Bhubaneswar, Paradip, Balasore 13 on 8th; Seoni 26, Malanjkhand (Madhya Pradesh) 21, Balaghat (Madhya Pradesh) 18, Katangi (Madhya Pradesh) 16, Gondia 13 on 9th; Depalpur (Madhya Pradesh), Makrai (Madhya Pradesh) 24, Punasa (Madhya Pradesh), Sardarpur (Madhya Pradesh) 21, Khandwa, Betul 18, Dhar 16, Harda (Madhya Pradesh), Peint (Maharashtra), Bagti (Madhya Pradesh) 15, Ujjain 14, Indore, Akola 13 on 10th; Dungarpur (Rajasthan) 14 on 11th; Abu 20 on 13th.

An isohyetal map showing the total rainfall for 11th and 12th, *i.e.,* for the 48-hour period from 0830 IST of 10th to 0830 IST of 12th over Gujarat and neighbouring States is presented in Fig. 8.

2.6. *Depression of 12-15 August*

A depression which lay over Vietnam on 9 August moved slowly westwards as a low across north Burma and emerged into east central and adjoining northeast Bay off Arakan coast on the evening of 10 August. It persisted there on 11th and concentrated into a depression on the morning of 12th with its centre at 0300 GMT near 17.5 deg. N, 92.5 deg. E. The depression moved northwards skirting Arakan-Chittagong coasts and weakened into a low over north Bangla Desh and adjoining Assam by the evening of 15th. The pressure departure from normal at Chittagong and Akyab was about *minus* 10 mb. The AVRO aircraft of Monex which flew over the western sector of the depression at 850 and 700 mb on 12th and 13th reported winds of 20 to 30 kt at these levels and supported the centre of the depression fixed with the help of conventional data.

No trough in the middle and upper-tropospheric westerlies was present over Tibet or northeast India during the period of the depression to influence its movement northwards. The wind flow in the upper troposphere over and near the depression field was mainly easterly during the above period. The direction of movement of this depression appears to practically coincide with the direction along which the 24-hour pressure fall was maximum.

In association with this depression, scattered to fairly widespread rain occurred in Assam and adjacent States and Sub-Himalayan West Bengal from 14th to 16th. The northward movement of this depression into northeast India resulted in the shift of the monsoon trough to the foot of the Himalayas and a *'break'* in the monsoon in the subsequent week.

2.7. *Deep depression of 29 Oct-1 Nov*

A low pressure area moved from south Andaman Sea into southeast Bay on 28 October and concentrated into a depression on the morning of 29th with its centre at 0300 GMT near 11 deg. N, 90 deg. E. Moving northwest the depression became probably deep the next day as revealed by satellite pictures. The location of the centre of this depression and its intensity were assessed on 29th and 30th only on the basis of satellite pictures as there were no ships' reports in or near the depression field on those two days. However on 30th evening ships *YTBE* and *VWXB* reported surface wind E/NE 20 to 30 kt about 300 km to the northwest of the depression centre. Later this system moved in a westerly direction and weakened into a depression on the morning of 1 November and into a low over the sea off north Tamil Nadu coast by the same evening. The low moved into north Tamil Nadu by 2nd noon.

According to STDS, this system was classified as T 2.5/2.5 on 30th and T 3.0/3.0 on 31st which give the maximum wind as 35 to 45 kt. The JTWC at Guam also estimated the maximum winds in association with this system as 25 to 35 kt on 30th and 30 to 45 kt on 31st based on satellite pictures. Although the estimated maximum wind based on satellite pictures ranged from 30 to 45 kt which would justify classifying the system as a cyclonic storm, the system has been classified as a deep depression as the available ships' reports in the field of this system did not support estimating the wind in circulation to be more than 30 kt strong.

This system caused widespread rain with an isolated heavy fall on 29th and scattered rainfall on 30th and 31st over Andaman and Nicobar Islands. Kondul recorded 9 cm of rain on 29th. As a depression this system caused only isolated rainfall in coastal Tamil Nadu on 1 November. On 2nd also the rainfall in Tamil Nadu was isolated but Madras city had a very heavy rainfall of 15 cm and Madras airport a heavy fall of 9 cm on that day. However, the rainfall over Tamil Nadu increased after the low moved inland. On 2nd Rayalaseema and coastal Andhra Pradesh had scattered rainfall.

TABLE 4

Cyclonic storm of 23-25 November

Date	Time (GMT)	Ship/Station	Location		Approximate distance from storm centre (km)	Wind		Pressure (mb)
			Lat. (°N)	Long. (°E)		irection	Speed (kt)	
23	0000	ATJJ	10.2	86.2	350	NE	24	1006.9
	1200	ATMS	9.4	82.3	400	NNW	25	1008.2
24	0000	ATKK	10.8	82.5	200	N	34	1004.0
	0300	ATMS	12.1	82.8	250	N	33	1005.9
	0900	ATKK	12.4	82.7	150	NNW	40	1001.1
	1200	ATKK	12.7	82.8	125	ENE	33	1001.8
	1200	ATKE	11.5	81.9	125	NNW	34	—
	1200	ATMS	13.6	82.8	225	NNE	35	1005.0
	1200	Madras & Karaikal	—	—	—	N (at 0.9 km asl)	40	
25	0000	ATKE	11.1	81.0	200	W	30	1007.5
	0000	ATKK	14.1	83.5	300	SE	31	1008.4
	1200	Gannavaram	—	—	—	NE/E (Upto 0.9 km asl)	35	

2.8. *Cyclonic storm of 23-25 November*

A low pressure area moved westwards from south Andaman Sea to southeast Bay on 22nd and concentrated into a depression on the morning of 23rd with its centre at 0300 GMT near 8 deg. N, 87.5 deg. E. Moving in a northwesterly direction, the depression intensified into a cyclonic storm on the morning of 24th with its centre near 10.5 deg. N, 84 deg. E. This intensification was inferred from satellite pictures and confirmed by a few ships in the storm field reporting winds 30 to 40 kt strong. Continuing to move northwest, the system retained storm intensity on 25th also as a marginal case with winds of 30 to 35 kt in circulation till it crossed north Tamil Nadu, south Andhra coast near Sriharikota by about 0900 GMT on 25th. Important observations from ships and coastal observatories in the storm field are given in Table 4.

After crossing coast, the storm weakened into a depression on 25th evening over south coastal Andhra Pradesh and into a low over Rayalaseema and adjoining Telangana by 26th morning.

The observatory at Sriharikota (SHAR) reported calm at 0900 GMT on 25th indicating that the storm centre passed through that station at that time. The winds at Sriharikota changed to a northeasterly direction from a general NW/N direction by about 0500 GMT on 25th. By 0930 GMT the wind became SW after the *'calm'* at 0900 GMT. The maximum speed recorded in gusts was 30 to 35 kt. The lowest m.s.l. pressure recorded at that station was 1001.2 mb at 0900 GMT on 25th and the corresponding pressure departure from normal was *minus* 9.5 mb. The lowest pressure reported in the storm field was 1001.1 by ship *ATKK* at 0900 GMT on 24th about 100 km from the storm centre.

In the STDS received from Washington, this system was classified as T 1.5/1.5 at 0800 GMT on 23rd equivalent to maximum wind speed of 25 kt. JTWC at Guam classified it as T 2.5/2.5 on 24th morning which corresponds to maximum wind speed of 35 kt. A satellite view of this storm on 24th is given in Fig. 7 which shows an exposed low level circulation with the main convective cloudmass to the north and west of the circulation centre. Guam JTWC also estimates the maximum wind speed in gust as 45kt. The maximum wind reported by ships in the storm field was 40 kt. Hence assuming the maximum wind speed associated with this storm as 45 kt, the lowest pressure at the storm centre works out to be 996 mb.

This storm was well within the range of the S-band radar at Madras and C-band radar at Sriharikota but at no stage was any clear spiral band seen in the cloud echoes. Hence no centre could be estimated from the radar.

In association with this system, fairly widespread rain occurred in Andaman and Nicobar Islands on 23rd and 24th, in Tamil Nadu on 25th, in coastal Andhra Pradesh on 25th and 26th and in Rayalaseema and Telangana on 26th with isolated heavy to very heavy falls in coastal

TABLE 5

Severe cyclonic storm of 16-20 June

Date	Time (GMT)	Ship/Station	Location		Approximate distance from storm centre (km)	Wind		Pressure (mb)
			Lat. (°N)	Long. (°E)		Direction	Speed (kt)	
16	0600	ATKE	15.4	71.1	200	ESE	20	1002.0
	1200	ATNN	14.9	68.0	200	NNW	30	996.8
17	0000	VWVJ	18.5	70.5	300	ESE	28	998.8
18	0000	VWVJ	16.1	68.1	350	S	25	996.1
	1200	JJSU	19.1	62.4	175	NNE	38	993.2
19	1000	PJKJ	19.8	59.2	150	NE	44	989.1
	1200	PFND	20.5	59.3	200	ENE	31	989.9

Andhra Pradesh and Rayalaseema. No damage was reported in association with this system, except for some damage to harvested paddy crops in Krishna and Guntur districts due to heavy rain.

The principal amounts of heavy rainfall (cm) were: Kakinada, Visakhapatnam 9 cm each, Sriharikota, Koderu 8 each, Narasapur 7 on 25th, Kakinada 25, Chintapalli 13, Visakhapatnam 12, Dhone (Kurnool district) 11, Nellore, Jammalamadugu 10 each, Kalingapatnam 9 on 26th.

3. Arabian Sea

3.1. *Severe cyclonic storm of 16-20 June*

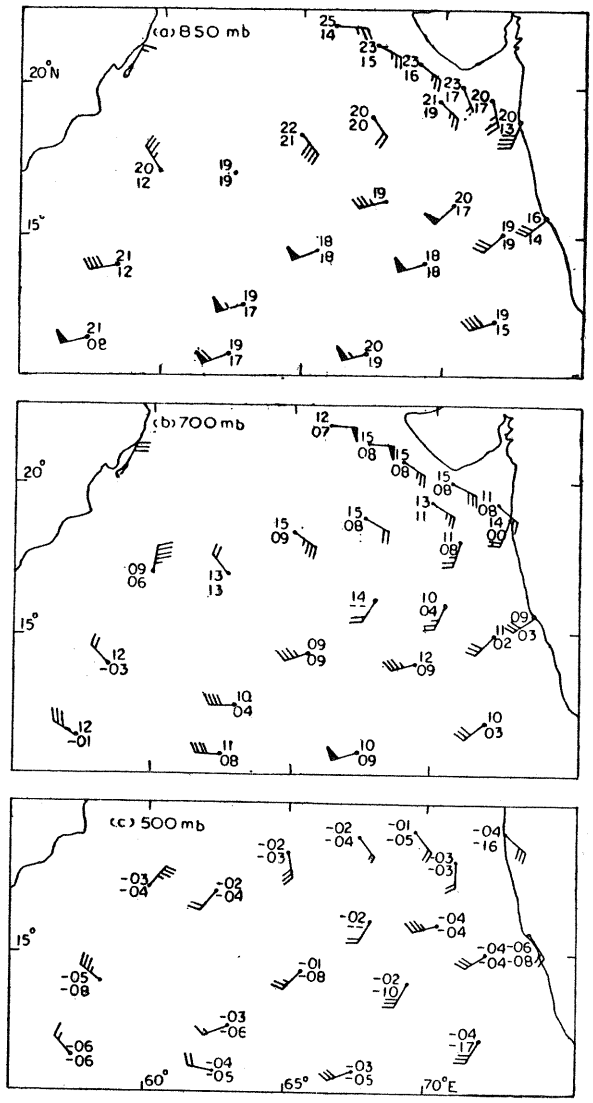
A low pressure area which was over north Lakshadweep and adjoining east central Arabian Sea off north Kerala, Karnataka coasts on 14 June moved slowly northwestwards and concentrated into a depression on the morning of 16th with its centre at 0300 GMT near 14.0 deg. N, 70.5 deg. E. Ship *ATKE* about 200 km northeast of the depression centre reported ESE/20 kt at 0600 GMT on 16th showing the intensification of the low into a depression. The depression became deep the same evening and continuing its northwestward course upto 17th evening and later a more westward course, it intensified into a cyclonic storm on the morning of 18th with its centre at 0300 GMT near 18 deg. N, 65 deg. E. The storm moved westwards to Kuria Muria coast by the morning of 20th and weakened after crossing coast. The storm was probably severe on 19th.

Important observations from ships and coastal observatories in the field of this system are given in Table 5. This system caused the Arabian Sea branch of the monsoon to strengthen considerably. Ships even 7 to 10 degrees of latitude away to the south of the system reported SW/W surface winds of 30 to 40 kt from 17th to 20th. On 19th evening ship *PGLB* near 13 deg. N, 59 deg. E reported surface winds WSW/64 kt and ship *DMEB* near 12.5 deg. N, 63 deg. E reported WSW/52 kt in the monsoon field. Ship *PJKJ* reported surface wind NE/44 kt at 1000 GMT on 19th near 20 deg. N, 59 deg. E about 150 km from storm centre. It reported the lowest pressure of 989.1 mb in the storm field at that time.

The research aircrafts engaged in the Monsoon Experiment (Monex) 1979, flew into this system on 16th, 17th and 18th and took dropsonde observations. The observations of wind, dry bulb and dew point temperatures recorded in the storm field at the standard isobaric levels 850, 700 and 500 mb on 18th are shown in Figs. 9 (a-c).

In the STDS from Washington this system was classified as T 3.5/3.5 at 2200 GMT on 19th which gives the maximum wind as 55 kt. JTWC, Guam estimated the maximum sustained winds associated with this system as 50 kt gusting to 65 kt based on satellite pictures on 19th. Assuming the maximum wind associated with this storm as 55 kt, the lowest pressure at the centre of the storm works out to be 981 mb.

This system caused the advance of the southwest monsoon into Lakshadweep and north Kerala on 14th, coastal and south Interior Karnataka on 16th, Goa on 17th and south Konkan



Figs. 9 (a-c). Wind (kt), temp. (°C) and dew point (°C) recorded by P3, CV990 and AVRO aircraft between 0600 and 1200 GMT on 18 June at (a) 850, (b) 700 and (c) 500 mb levels

on 18th. The monsoon was active to vigorous in Kerala from 14th to 17th, and active in coastal Karnataka on 17th and 18th and in south Konkan and Goa on 18th and 19th. The notable amounts of heavy rainfall (cm) were : Cochin 15, Punalur 11, Quilon, Kayamkulam, Tiruvalla 10 each on Cochin 11 on 16th ; Karwar, Mangalore 15 each Coondapur, Kozhikode 14 each, Cochin 13, Shirali, Mavelikara, Alleppey 12 each, Trichur 11, Quilon, Kayamkulam. Tiruvalla 10 each on 17th ; Karwar 13, Mangalore, Beltangadi 10 each on 18th ; Vengurla 12 on 19th.

3.2. *Severe cyclonic storm of 18-24 Sep*

A low pressure area which was over southwest Bay on 16 September moved westwards across south Peninsula and emerged into north Lakshadweep by 17th evening. It concentrated into a depression on the morning of 18th with its centre at 0300 GMT near 12 deg. N, 73 deg. E. Moving in a northwesterly direction, the depression intensified into a cyclonic storm by midnight of 21st and was centred at 0300 GMT on 22nd near 18.5 deg. N, 66.5 deg. E. Moving westnorthwest, the cyclone became severe with a core of hurricane winds on 22nd evening. Subsequently moving westwards the system weakened gradually into a deep depression on 24th morning and into a depression on 24th evening close to Oman coast. Later it moved inland and dissipated.

In association with this system generally widespread rain occurred in Kerala, Lakshadweep and coastal and south Interior Karnataka from 18th to 20th and in Konkan and Goa and Madhya Maharashtra from 19th to 21st. Amini recorded

TABLE 6

Severe cyclonic storm of 18-24 September

Date	Time (GMT)	Ship/Station	Location		Approximate distance from storm centre (km)	Wind		Pressure (mb)
			Lat. (°N)	Long. (°E)		Direction	Speed (kt)	
18	1200	Amini	—	—	—	WSW	25	1003.5
	1200	Amini	—	—	—	W (at 0.9 km asl)	30	
	1200	Mangalore	—	—	—	S (at 0.9 km asl)	30	
19	0600	ATJY	15.2	71.6	200	E	25	1005.7
	0900	ATJY	14.6	72.3	125	E	28	1001.5
	1300	ATJY	14.1	72.9	150	SSE	25	999.5
20	0000	Panjim	—	—	—	SSE (at 0.6 & 0.9 km asl)	25-35	
21	0600	ATDE	17.3	69.0	100	N	25	1001.7
	1500	ATDE	16.7	68.3	125	NW	25	999.2
22	0930	ELWT	18.6	65.0	50	WNW	75 (in gusts)	986.0
	0950	5LXS	19.3	65.6	75	E	54	1002.5
	1130	5LXS	19.1	65.7	75	SE	52 (10 BF)	1001.5
	1500	ATJZ	19.4	64.1	75	NE	40	1000.8
	1800	ATJZ	19.0	63.8	50	N	70	993.5
	2100	ATJZ	18.4	63.7	100	WNW	45	999.0
23	1200	PHDO	18.3	61.8	200	SW	27	1001.7

very heavy rainfall of 14 cm on 18th. Isolated heavy rain also occurred in Kerala on 18th.

On 18th evening (1200 GMT) Amini reported surface wind WSW/25 kt and upper winds of 25 to 30 kt from W upto 0.9 km asl. At the same time the winds at Mangalore were S/25-30 kt upto 0.9 km asl. These observations showed that the system was a depression on 18th. On 19th, report from ship *ATJY* was very useful in fixing the centre of the depression and assessing its intensity. The ship reported E/28 kt at 0900 GMT and SSE/25 kt at 1300 GMT within 100 to 150 km from the centre of the system. The system was declared a cyclonic storm on 22nd morning based mainly on the satellite cloud picture. On that evening and night reports of surface wind reaching 50 to 75 kt from ships *5LXS, ATJZ* and *ELWT* within 100 km from the storm centre showed that the storm had become severe with a core of hurricane winds. Important observations from ships and observatories in the storm field are given in Table 6.

In STDS bulletin from Washington, this storm was classified as T 3.5/3.5 on the early morning of 23rd. This corresponds to a maximum wind of 55 kt. JTWC, Guam estimated the maximum sustained wind associated with this storm as 65 kt with gusts reaching 80 kt on 23rd morning based on satellite pictures. Ships had reported 70-75 kt as maximum wind associated with this storm. Assuming the maximum wind associated with this storm as 70 kt the lowest pressure at the centre of the storm works out to be 980 mb.

3.3. *Deep depression of 13-17 November*

A low pressure area with associated cyclonic circulation extending to the middle troposphere moved westwards across Sri Lanka and Comorin on 11 November and merged with a low that lay over south Lakshadweep and adjoining Maldive area on 12th. The combined system moved northwestwards and concentrated into a depression on the morning of 13th with its centre at 0300 GMT near 9.5 deg. N, 72 deg. E. Moving northwestwards initially and mainly northwards later as a deep depression, it weakened into a low off Saurashtra coast by the evening of 17th.

This system caused generally widespread rainfall in Kerala on 13th, in Lakshadweep from 13th to 15th, in coastal Karnataka on 14th, in Konkan

and Goa on 15th and 16th, in Gujarat State on 17th and 18th and in east Rajasthan on 18th with a few very heavy falls in Kerala and Gujarat State. A fishing trawler sank in Gulf of Cambay where strong winds were experienced. Otherwise no damage was caused by this system. The notable amounts of heavy rainfall (cm) were: Peermade (Kerala) 16 on 13th; Mahuva 14, Diu 12, Bhavnagar 11 on 17th ; Abu 12, New Kandla 9 on 18th.

This system was declared a depression on 13th on the basis of the reports from ships *FNLO* and *ATGO* which reported easterly winds of about 15 kt about 150 to 200 km from the centre of the system on the morning of 13th. The low level winds (upto 0.9 km asl) at Minicoy and Mangalore were 20 to 30 kt the same morning. Ship *FNLO* which was moving from southeast to northwest along with the depression about 150 to 200 km to the north of the depression centre on 13th & 14th reported surface winds not more than 20 kt strong from E/NE. Ship *PJKE* passed close to the depression centre in the early hours of 15th. It reported a wind shift from SW/15kt at 141800 GMT to N/15 kt at 15 0000 GMT while moving from 12.5 deg. N, 69.8 deg. E to 13.5 deg. N, 68.5 deg. E. Later during the day it reported northerly winds of 30-35 kt at 0600 and 1200 GMT in the northwest quadrant of the depression, more than 200 km from the centre. Ship *FNDN* about 4 to 5 degrees north of the depression centre reported E/30 kt at 0600 GMT on 15th. These suggest that the depression had become deep on 15th. The depression continued to remain deep on 16th morning as could be inferred from the strong low level winds along the west coast. Mangalore, Goa and Bombay reported S/SE 30-35 kt at 0.9 km asl at 0000 GMT on 16th. By the same evening the system had weakened into a depression as indicated by the weakening of the winds at the above stations to 20 to 25 kt and also by the reports for ship *FNCC* which passed through the depression field from northwest to southeast and close to its centre the same evening. This ship reported a wind shift from N/15 kt at 1200 GMT to S/15 kt at 1800 GMT in moving from 16 deg. N, 70 deg. E to 15.5 deg. N, 71 deg. E.

The radar at Bombay could not identify any well defined spiral bands on 16th or 17th when the system had come within the range of this radar. Thus the reports from radar and ships do not give any support or evidence to classify this system as a cyclonic storm although based on satellite pictures received at Bombay and Delhi, the system was estimated to be T 3.0/3.0 in Dvorak's scale with maximum sustained winds of 45 kt on 16th. On 15th evening it was classified as T 2.5/2.5 (maximum wind 35 kt). However JTWC at Guam had classified this system as T 1.5/1.5 on 16th morning and this was the highest classification given for this system. The corresponding maximum wind is 25 kt. In many of the bulletins from Guam, it was mentioned that centre was difficult to locate from satellite pictures. In their bulletin issued at 161400 GMT it was stated that "this system has an exposed low level surface circulation with the majority of the convective activity in the northern semi-circle. If the surface circulation continues to be separated from its convection the system may dissipate over water before reaching India".