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Cyclones and depressions in the Indian seas in 1978

V. SRINIVASAN, A. R. RAMAKRISHNAN and R. JAMBUNATHAN

Meteorological Office, Pune

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1. Chief Features

Although the number of cyclonic storms in the Bay of Bengal and the Arabian Sea was near normal during this year, the activity in the Bay of Bengal was less marked compared to the previous two years. There were only 2 severe storms in 1978 in the Bay.

At the height of the monsoon, in July and the first half of August, monsoon depressions were less than usual. Subsequently during the season their activity picked up. Extensive floods were caused by some of the depressions, the worst flood was in Gangetic West Bengal caused by a slow-moving depression which had an unusual southerly track.

2. Brief Summary

The first cyclonic disturbance of the year was a severe storm which developed in the Bay of Bengal in May and moved towards Burma coast.

During the monsoon season, one storm and five depressions developed in the Bay of Bengal and entered India while only one depression developed in the north Arabian Sea and moved away towards the Gulf of Oman. Three depressions formed over land of which two dissipated and the third one had an unusual southerly track and dissipated over northwest Bay of Bengal. The monsoon depression of 26 August to 2 September moved northwards to Western Himalayas. It was quickly followed by another (1 September to 5 September) which sharply recurved over east Uttar Pradesh. These changes in the track heralded the seasonal changes in the circulation features associated with the withdrawing phase of the southwest monsoon.

In the post-monsoon season there were four cyclonic storms — two in the Bay and two in the Arabian Sea which also had their genesis in the Bay. One of the storms in the Bay and one in the Arabian Sea became severe with a core of hurricane winds. Both of them were in November. Two depressions also formed in the Bay. Both the November storms had a life period of 10 to 12 days and had a long track of 3500 to 4000 km. The Bay hurricane formed and moved at an unusually low latitude of 7 to 8 deg. N. In the case of the Arabian Sea hurricane, a ship near its centre reported an estimated wind speed of the order of 150 kt which is a near record value for the Indian seas.

The tracks of the storms and depressions are shown in Fig. 1 and their listing 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 in the following section.

3. Detailed account

Bay of Bengal

1. *Severe cyclonic storm of 14-17 May*

A well marked low pressure area which lay over southeast Bay on 12 and 13 May concentrated into a deep depression on the morning of 14th, with its centre at 0300 GMT near 11.5 deg. N, 91.0 deg. E. Many ships in south Bay and south Andaman Sea in the latitudinal belt 5 deg. to 7 deg. N reported westerly winds of 30 kt, indicating the advance of the southwest monsoon current over these areas under the influence of the depression. The deep depression moved in a northerly direction and intensified into a cyclonic storm on the morning of 15th with its centre at

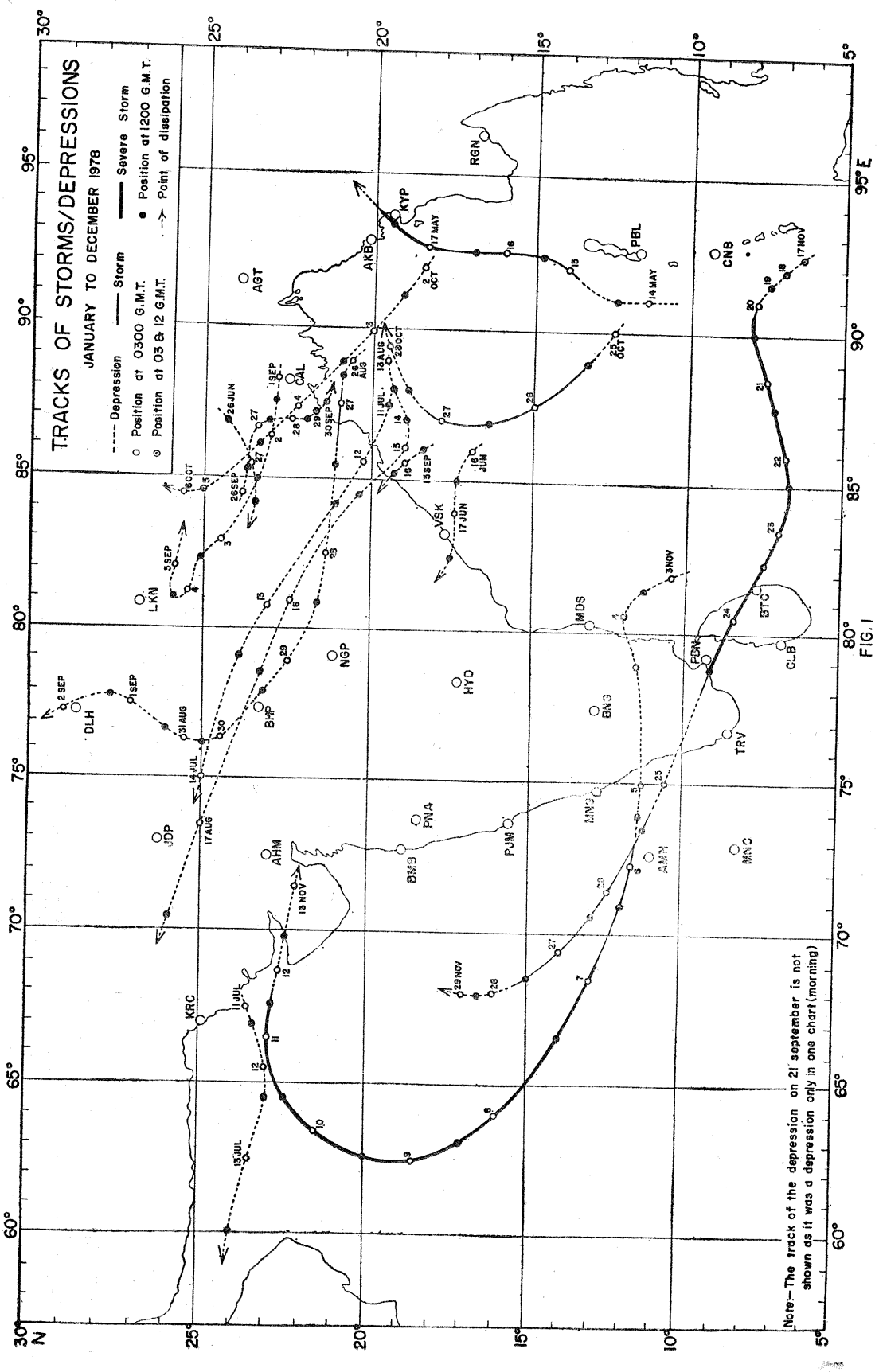

Fig. 1. Tracks of storms and depressions, in 1978

TABLE 1

Storms and depressions of 1978

S. No.	Type of disturbance	Life period	Location
1	Severe cyclonic storm	14-17 May	Bay of Bengal
2	Deep depression	16-17 Jun	Bay of Bengal
3	Depression	26-27 Jun	Land
4	Deep depression	11-14 Jul	Bay of Bengal
5	Depression	11-13 Jul	Arabian Sea
6	Deep depression	13-17 Aug	Bay of Bengal
7	Cyclonic storm	26 Aug-2 Sep	Bay of Bengal
8	Deep depression	1-5 Sep	Land
9	Depression	15-16 Sep	Bay of Bengal
10	Depression	21 Sep	Bay of Bengal
11	Deep depression	26-30 Sep	Land
12	Deep depression	2-6 Oct	Bay of Bengal
13	Cyclonic storm	25-28 Oct	Bay of Bengal
14	Severe cyclonic storm	3-13 Nov	Bay of Bengal and Arabian Sea
15	Severe cyclonic storm	17-29 Nov	Bay of Bengal and Arabian Sea

0300 GMT near 14.0 deg. N, 92.0 deg. E. Continuing its northward course, the cyclone became severe on the morning of 17th near 18.5 deg. N, 92.5 deg. E and probably developed a core of hurricane winds before crossing coast. It crossed Burma coast just north of Kyaukpyu the same evening and rapidly weakened into a low over north Burma.

In association with this system, generally widespread rain occurred in Andaman and Nicobar Islands from 13 to 17th with isolated heavy falls on 14 and 17th. The southwest monsoon also advanced into south Andaman Sea and the extreme southern parts of the Bay between 14 and 16th. A few stations in Burma reported very heavy rain between 16 and 18th. According to press reports heavy damage to property was caused in Kyaukpyu town and neighbouring places like Myebon in coastal Burma. Winds of 160 kmph were estimated to have been experienced in these areas.

As the storm came close to Burma coast, the surface wind at Kyaukpyu was E/53 kt at 0900 GMT and changed to S/59 kt at 1200 GMT on 17th. The lowest pressure of 974 mb was recorded at Kyaukpyu close to the storm centre at 6 P.M. (local time) on 17 May. The pressure fell 21 mb between 12 noon and 6 P.M. The pressure departure from normal was about *minus* 30 mb at this station. The available observations show that at the time of crossing the coast, gale force winds did not extend more than 100 km from the storm centre.

On the basis of satellite pictures, Joint Typhoon Warning Centre (JTWC) at Guam estimated the maximum winds in association with this storm as 35 kt on 15th, 40 kt on 16th, 50 kt on 17th morning and 60 kt at 0800 GMT on 17th indicating a rather slow development. These estimates were in general agreement with the low level winds recorded at nearby stations. The maximum wind speed associated with this cyclone was estimated to be about 80 kt, the lowest pressure at the storm centre worked out to be 965 mb.

2. *Deep depression of 16-17 June*

On the leading edge of the advancing monsoon current, a low pressure area developed off south Andhra coast on 11 June. Moving slowly north, it became well marked and lay off north Andhra coast on 15th and concentrated into a depression on 16th with its centre at 0300 GMT near 17.0 deg. N, 86.0 deg. E. Moving in a westerly direction it became deep on 17th morning and crossed coast, south of Visakhapatnam in the afternoon. It weakened into a low by that night over north coastal Andhra Pradesh and adjoining parts of southeast Madhya Pradesh and south Orissa.

In association with this system the southwest monsoon advanced into north Andhra Pradesh, interior Maharashtra, south Madhya Pradesh and south Orissa between 12th and 17th. Generally widespread rain with heavy to very heavy falls occurred in coastal Andhra Pradesh, Telangana and Vidarbha on 17th and 18th. Some of the notable amounts of rainfall in cm were: Narasapur (west Godavari district) 19 on 17th; Kaddam (Adilabad district) 23, Mudhole (Adilabad district) 22, Bodhan (Nizamabad district) 20, Banswara (Nizamabad district) 16, Amraoti, Warora (Chandrapur district) 14 on 18th. Marathwada also experienced widespread rain on 18th with Nander reporting 12 cm of rain.

Ship *ATFB* about 100 km to the southeast of the centre reported wind WSW/18 kt on 16th evening (1200 GMT). At the same time, the winds over Visakhapatnam upto 0.9 km asl were NE/20-35 kt. Visakhapatnam reported 20-25 kt wind at these levels on 17th morning also. On 17th evening, Gannavaram reported WNW/30-35 kt winds upto 0.9 km asl. The depression centre passed close to Visakhapatnam which reported a pressure departure of *minus* 10 mb from normal around noon on 17 June.

3. *Deep depression of 11-14 July*

A low pressure area which lay over west central and adjoining northwest Bay on 10 and 11 July concentrated into a depression on the evening of 11th with its centre near 19.5 deg. N, 87.5 deg. E, under the influence of another low

TABLE 2

Maximum wind and minimum pressure in cyclones

Cyclonic disturbance	Surface wind (kt)		Pressure (mb)	
	Maximum estimated from satellite pictures or other sources	Maximum reported from nearest land station or ship	Estimated lowest MSL pressure at the centre	Lowest MSL pressure reported from nearest observation
1. Severe cyclonic storm (14-17 May)	80	59 (At Kyaukpyu on Burma coast)	965	974 (At Kyaukpyu)
2. Cyclonic storm (26 August-2 September)	45	35 (At Sandheads)	986	985.4 (At Balasore)
3. Cyclonic storm (25-28 October)	45	—	996	—
4. Severe cyclonic storm (5-13 November)	115	100 kt (Ship *GZJD* within 50 km from storm centre)	940	959 (Ship *HONN* at the storm centre)
5. Severe cyclonic storm (17-24 November)	120	78 (At Batticoloa 100 km from storm centre)	938	—
6. Cyclonic storm (25-29 November)	45	36 (Ship *JKPL* about 250 km from storm centre)	998	—

pressure system moving westwards across Burma coast into the Bay. The depression became deep at 0000 GMT on 12th when it was centred close to Orissa coast near 20 deg. N. It crossed Orissa coast the same morning, a little later and moving northwestwards rather fast across Madhya Pradesh, weakened into a low over west Rajasthan on the evening of 14th.

Simultaneous with this depression, there was another depression in northeast Arabian Sea and the axis of the monsoon trough connecting these two depressions was south of its normal position, leading to a spell of active monsoon in central parts of the country and north Peninsula. Generally widespread rain with some heavy falls occurred in Orissa and east Madhya Pradesh from 12th to 14th, in Vidarbha and Telangana on 12th and 13th, in west Madhya Pradesh on 13th and 14th and in east Rajasthan and Gujarat State on 14th and 15th. The following stations recorded very heavy rain: Adilabad 22 cm, Cuttack 13 cm on 12th ; Gadchiroli (Chandrapur district) 21 cm ; Sirpur (Adilabad district) 15 cm on 13th ; Petlabad (Madhya Pradesh) 14 cm on 14 July.

At 1200 GMT on 12th, Bhubaneswar reported upper winds S/25-35 kt up to 0.9 km asl. The easterlies in the lower troposphere about 300 to 500 km to the north and northeast of the depression centre were 35 to 45 kt from 13th morning to 14th morning with one or two stations reporting 50/55 kt. The westerlies to the south of the depression and over the Peninsula during this period were relatively weak and were generally less than 20 kt. The maximum pressure departure from normal near the depression centre was about *minus* 6 mb.

4. *Deep depression of 13-17 August*

A cyclonic circulation was initially seen over north Bay in the middle tropospheric levels on the evening of 11 August. As it descended downwards, a low pressure area formed over north Bay on 12th. It concentrated into a depression on the morning of 13th with its centre near 19.5 deg. N, 89.0 deg. E under the influence of the remnants of tropical storm *Bonnie* from south China Sea which weakened over Cambodia on 12th and moved westwards as an isallobaric low across Burma. The depression moved westwards rather slowly and deepened and crossed south Orissa coast between, Gopalpur and Puri on the afternoon of 15th. Thereafter, it moved northwestwards rather fast during the next two days

across Madhya Pradesh, extreme north Gujarat State and south Rajasthan without much weakening and apparently merged with the seasonal low over south Pakistan on 18th. Satellite observations suggested the persistence of the vortex for another 24 hours or so.

This system caused active to vigorous monsoon in Orissa, coastal Andhra Pradesh and Telangana from 13th to 16th, in Madhya Pradesh from 15th to 17th in Vidarbha on 16th, in Madhya Maharashtra on 17th, in Rajasthan on 16th and 17th and in Gujarat State on 17th and 18th. Fairly widespread rain also occurred in Bihar Plateau on 15th and 16th. Very heavy rain occurred at a few places in Orissa, Madhya Pradesh, Andhra Pradesh, Gujarat region and east Rajasthan on one or two days.

Floods in rivers *Mahanadi* and *Indravathi* were reported to have disrupted road communications between Jagdalpur and Raipur and between Jagdalpur and Koraput. Floods in river *Narmada* inundated low lying areas of Broach town in Gujarat.

The principal amounts of rainfall in cm were : Bhawanipatna 19 on 13th; Mahbubnagar 25, Hakimpet 17, Tandur (Andhra Pradesh) 15, Shadnagar (Andhra Pradesh), Khammam, Devarkonda (Andhra Pradesh), Gariyaband (Madhya Pradesh) 14, Rentachintala 13 on 15th; Balod (Madhya Pradesh), Pachmarthi 24, Bhanupratappur (Madhya Pradesh) 16, Sonapur (Madhya Pradesh) 14, Badnawar (Madhya Pradesh), Antagarh (Madhya Pradesh), Dhamtari (Madhya Pradesh), Khindhi (Vidarbha) 13 each on 16th; Baroda 22, Dungarpur 17, Banswara 16, Broach 13 on 17 August.

The maximum pressure departure from normal near the centre of the depression was about *minus* 14 mb on 15th.

5. *Cyclonic storm of 26 August-2 September*

An isallobaric low moving westwards across Cambodia and Burma reached northeast Bay by the evening of 24 August and a low pressure area formed over north Bay the next morning. It concentrated into a deep depression by the morning of 26th, with its centre near 20.5 deg. N, 89.0 deg. E, and further intensified into a cyclonic storm by midnight of 26th near 21 deg. N, 88 deg. E. The cyclonic storm crossed north Orissa coast between Chandbali and Balasore by about noon on 27th and lay as a deep depression over interior parts of north Orissa on that evening. Subsequently, it moved westnorthwestwards across Madhya Pradesh and weakened into a depression on 30th morning over northwest Madhya Pradesh and adjoining southeast Rajasthan. Later it recurved northeastwards and again became deep on 1 September. Thereafter it moved northwards and dissipated over Haryana and neighbourhood by 3 September. The recurvature of the depression after 30 August and its deepening seem to be associated with the eastward movement of an upper level trough in the westerlies across extreme north of the country between 30 August and 2 September.

This system caused active to vigorous monsoon conditions in Orissa on 27th and 28th, in east Madhya Pradesh on 28th and 29th, in Vidarbha on 29th, in west Madhya Pradesh from 29th to 31st, in north Madhya Maharashtra on 30th, in Gujarat State from 29th to 31st, in east Rajasthan from 31 August to 2 September, in Haryana and west Uttar Pradesh from 1 to 3 September and in Himachal Pradesh on 3 September. Heavy to very heavy rain occurred over the above areas on some days. According to press reports, some trees were uprooted in Balasore district due to gales associated with the cyclone. A fishing boat capsized near Digha killing one of the fishermen. Low lying paddy fields in Contai were submerged and many huts collapsed. Floods affected the eastern districts of Gujarat extending from Sabarkantha to Bulsar. Floods in rivers *Narmada, Tapti* and *Indravathi* affected Madhya Pradesh disrupting road communications. Some parts of Haryana were also affected by floods. Delhi and neighbourhood experienced unprecedented floods and army was called to evacuate about 2 lakhs people.

The principal amounts of rainfall in cm were: Paradip 19 on 27th, Akhuapada (Orissa) 20, Talcher (Orissa) 18, Phulbani 14 on 28th ; Makrai (Madhya Pradesh) 23, Umrer (Vidarbha) 22, Khandwa 21, Brahmapuri 20, Pachmarhi, Wardha, Ahwa (Gujarat) 17 each, Depalpur (Madhya Pradesh), Mohoa (Vidarbha) & Saoner (Vidarbha) 16 each, Ramtek, Khindsi, Chooki & Sironcha (all in Vidarbha) 15 each, Nagpur 13 on 29th ; Indore 17, Dhar 16, Dharmpur (Gujarat) 15 on 30th; Ahwa (Gujarat) 22, Kota 18, Jawahar Sagar Dam (Rajasthan) 17, Rawat Bhata (Rajasthan) 16, Dhrangadhra (Gujarat), Viramgam (Gujarat) 15 each on 31st; Alwar 15 on 1 September ; Sonepat (Haryana) 20, Muzaffarnagar (Uttar Pradesh) 18, Najibabad 17, Hindon (Haryana), New Delhi 16 each, Nainital, Roorkee 15 each on 2nd.

This system was declared as a cyclonic storm on the midnight of 26th based on the wind observations of Sandheads, Bhubaneswar and Calcutta. Sandheads reported surface wind NE/35 kt at 1800 GMT of 26th. At the same time the upper winds at 0.6 and 0.9 km asl were E/35-40 kt over Calcutta and NW/30 kt at Bhubneswar. Calcutta Cyclone Warning Radar estimated the centre of this storm near 21.0 deg. N, 87.6 deg. E at 0200 and 0300 GMT and 21.0 deg. N, 87.2 deg. E at 0400 GMT on 27 August.

The lowest pressure of 985.4 mb was reported by Balasore at 0400 GMT on 27th near the storm centre. This corresponds to a pressure departure of *minus* 18 mb from normal. This system was classified as T 3/3 in Dvorak's scale from satellite pictures (Dvorak 1975). This would give the maximum wind associated with the storm as 45 kt. For this maximum wind, the estimated pressure at the centre of the storm would be 986 mb which agrees well with the pressure reported by Balasore.

6. *Depression of 15-16 September*

A low pressure area moving westwards across central Burma on 8 September reached central Bay and neighbourhood by 11th where it persisted for the next few days. Moving slightly northwestwards, it concentrated into a depression over northwest and adjoining west central Bay off south Orissa coast on the evening of 15th with its centre near 18.5 deg. N, 86 deg. E. It moved northwest, crossed coast between Gopalpur and Puri on 16th night and weakened into a low over interior Orissa by 17th morning.

Under the influence of this depression, the monsoon was active in Gangetic West Bengal on 16th in Orissa on 16th and 17th and in east Madhya Pradesh on 17th. Isolated heavy rain occurred in Orissa on 16 and 17 September.

Gopalpur reported NE/25 kt and Vizag N/30 kt at 0.9 km asl on 15th evening. At 0000 GMT on 16th, Gopalpur reported surface wind NE/15 kt. At Bhubaneswar the upper winds up to 0.9 km asl were SE/25-30 kt at 1200 GMT that day.

7. *Depression of 21 September*

A low pressure area moved westwards across Tenasserim coast into north Andaman Sea on 19 September. It subsequently moved northwest Bay and concentrated into a depression on the morning of 21st with its centre at 0000 GMT about 50 km southeast of Balasore. The depression crossed coast, weakened and lay over interior parts of north Orissa that evening as a low. The low moved further northwest and persisted over northeast Madhya Pradesh and adjoining parts of Bihar and south Uttar Pradesh from 22nd to 25th.

In association with this depression active to vigorous monsoon conditions prevailed in Orissa and Gangetic West Bengal on 21st and in east Madhya Pradesh and Bihar State on 22nd. The principal amounts of rainfall were : Sandheads 16 cm, Chandbali 8 cm, Rajghat (Orissa) and Uluberia 7 cm each on 21 ; Swampatna (Orissa) 9 cm on 22nd.

8. *Deep depression of 2-6 October*

The remnants of tropical storm *'KIT'* moved westwards across Cambodia and Burma and reached north Andaman Sea and adjoining east central Bay as a well marked low pressure area on 1 October. It moved northwestwards to east central Bay and concentrated into a depression on the morning of 2nd with its centre near 18.5 deg. N, 92.0 deg. E. Continuing to move northwestwards, it became deep on the morning of 3rd after merging with a low (the remnant of an earlier depression) which lay over northwest Bay on 1st and 2nd. The deep depression crossed West Bengal coast near Contai on the early morning of 4th and moved to Bihar plains by 5th morning. It persisted there for a day and weakened into a low by the evening of 6th.

This system caused generally widespread rain in West Bengal and Orissa between 3rd and 6th in Bihar Plateau on 4th and 5th and in Bihar plains from 5th to 7th, with heavy to very heavy falls over these areas on one or two days. The principal amounts of rainfall in cm were : Cuttack, Bagati 14 each, Sandheads 13, Chandbali, Jenapur (Orissa) 11 each, Rajghat (Orissa), Akhuapada (Orissa), Midnapore 9 each on 4th; Chapra 23, Samastipur (Bihar) 16, Darbhanga, Sabour, Bhagalpur 11 each, Patna Airport 10 on 5th; Maheshi (Bihar) 20, Supaul 12, Chapra 11 on 6th; Motihari 10 on 7th.

The pressure departure from normal was *minus* 12 to 13 mb near the centre of the depression. 4 closed isobars at 2 mb interval covered the depression field on 4th and 5th. This system was classified as T 2/2 in Dvorak's scale based on satellite pictures.

9. *Cyclonic storm of 25-28 October*

A low pressure area moved from the Gulf of Siam into south Andaman Sea on 23rd evening. Later moving northwestwards, it concentrated into a depression on the morning of 25th over southeast and adjoining east central Bay with its centre near 12.5 deg. N, 90.0 deg. E. It intensified further into a cyclonic storm the same evening and moved northwestwards to 16.5 deg. N, 87.0 deg. E by 26th evening. Later it recurved northeastwards and dissipated over north Bay by 28th evening.

This storm did not affect the Indian coast. There was generally widespread rainfall in Andaman and Nicobar Islands on 25th and 26th and in coastal Orissa on 28th and 29th with isolated heavy falls in Andaman Islands on 25th. Port Blair recorded 9 cm of rain on 25th.

No ship's reports were available close to the storm field. The maximum wind estimated from the satellite pictures was about 45 kt and the estimated pressure at the centre worked out to be 996 mb.

The storm was under the surveillance of the radar at Paradip from morning till night of 27th and of the radar at Calcutta from 270900 GMT to 280300 GMT. The radar pictures of both the stations did not show any spiral bands at any time and also any features of an intense storm. This would suggest that the system was not a severe cyclonic storm. However, Washington had classified this system as T3.5/3.5 in Dvorak's scale on 26th evening based on satellite pictures, which would correspond to a maximum wind of 55 kt which was perhaps an overestimate. JTWC at Guam, however, estimated the maximum sustained wind as only 35-45 kt on the basis of satellite pictures. A satellite view of this storm is reproduced in Fig. 2.

This storm was steered along the western periphery of an upper tropospheric anticyclone over Burma and Thailand.

10. *Deep depression of 3-4 November*

The seasonal low over southwest Bay became well marked on 2 November and a depression formed off Sri Lanka-Tamil Nadu coasts on the morning of 3rd with its centre near 10.5 deg. N, 82.0 deg. E at 0300 GMT. Moving northnorthwest, the depression became deep and crossed Tamil Nadu coast around noon of 4th near Cuddalore. It weakened into a depression over land, moved westwards and emerged into the Arabian Sea off north Kerala coast on 5th morning.

This system caused torrential rains in Tamil Nadu and Kerala. There was generally widespread rain in Tamil Nadu between 3rd and 6th, in Kerala and Lakshadweep between 3rd and 5th, in south interior Karnataka on 4th and 5th and in south coastal Andhra Pradesh and Rayalaseema on 5th and 6th. Very heavy rain occurred in Kerala and Tamil Nadu during the above period. Isolated heavy rain also occurred in south coastal Andhra Pradesh, Rayalaseema and south interior Karnataka. Cuddalore and Pondicherry had record rainfall of 38 cm and 32 cm respectively on 4th and Ootacamund 33 cm on 5 November. When the depression was located off north Sri Lanka coast, Trincomalle recorded 27 cm of rain and Jaffna 26 cm on 3rd.

The other notable amounts of heavy rainfall in cm were: Quilon, Trivandrum 18 each, Kovalam 17, Thumba 13, Kanniyakumari 12 on 3rd; Mayuram 29, Kumbhakonam 26, Nagapattinam 23, Karaikal 22, Thanjavur, Tiruchirappalli, Trivandrum 19 each, Mannargudi, Quilon 18 each, Kanniyakumari 17, Kovalam, Thumba 14 each on 4th ; Satyamangalam 25, Mannarghat 19, Peermedu 18, Kozhikode 17, Coonoor 16, Quilon 15, Namakkal 13 on 5th ; Coonoor 13 on 6th.

According to press reports, floods and landslides due to heavy rain took a toll of about 120 human lives in Tamil Nadu. About 90 persons died in Nilgiris district alone (Ootacamund and neighbourhood) where the floods and landslides were reported to be unprecedented. About 50 persons died in Kerala due to floods and house collapse. Low lying areas in Trivandrum city remained submerged for 3 days due to heavy rain and floods. Considerable damage to houses and crops was reported from Tamil Nadu and Kerala.

The maximum pressure departure from normal near the centre of the depression was about *minus* 10 mb.

11. *Severe cyclonic storm of 17-24 November*

Under the influence of a low pressure area moving westwards across Malaya Peninsula and south Andaman Sea, a low which lay over southeast Bay concentrated into a depression on the morning of 17th with its centre near 6.5 deg. N, 92.5 deg. E. Moving slowly northwestwards, it intensified into a cyclonic storm near 8 deg. N, 91 deg. E on the morning of 20th as identified by the satellite pictures. A dim 'eye' was also noticed by the satellite. It developed a core of hurricane winds by the morning of 21st when it was centred near 7.5 deg. N, 88.5 deg. E. The storm progresssively intensified further and took a westsouthwesterly and later a northwesterly course and crossed Sri Lanka coast on 23rd night near Batticoloa. According to satellite pictures the storm reached its peak intensity on 23rd morning when the estimated maximum winds were 120 kt. The storm retained the hurricane intensity even over land, till it emerged into Gulf of Mannar. It moved south of Pamban and crossed Tamil Nadu coast between Kilakkarai and Roche Mary Nagar in Ramanathapuram district on 24th evening as a severe storm and emerged into the Arabian Sea off Kerala coast as a deep depression on 25th morning.

In association with this system, Andaman and Nicobar Islands had fairly widespread rain from 19th to 21st. Generally widespread rain with heavy to very heavy falls occurred in Tamil Nadu from 24th to 26th and in Kerala on 25th. Rayalaseema had fairly widespread rain on 25th.

The principal amounts of rainfall in cm were : Karaikal 22, Nagapattinam 14, Nannilam 13, Mannargudi 11 on 24th ; Kodaikanal 17, Tuticorin 16, Coonoor 12, Thanjavur 11, Papanasam, Peermedu 10 each on 25th, Coonoor 25, Ootacamund 8 on 26th.

Tidal waves of 3-5 metres affected the Rameswaram Island and the coastal areas of Ramanathapuram district between Tondi and Devipattinam. According to press reports and information obtained from State Govt., the coastal taluks, namely Ramanathapuram, Tiruvadanai, Mudukalatur and Rameswaram of Ramanathapurm district were worst affected by the cyclone. About 5,000 huts were damaged in these taluks. A large number of trees were uprooted. About 1,000

TABLE 3

Severe Cyclonic Storm of 17-24 November

Date	Time (GMT)	Ship/station	Location		Approx. distance from storm centre (km)	Wind		Pressure (mb)
			Lat. (°N)	Long. (°E)		Dir.	Speed (kt)	
17	1200	S6GT	5.7	92.0	100	W	25	—
	1200	JKGG	6.2	93.6	125	S	20	1005.2
19	0900	S6EH	7.3	91.2	50	NW	40 (8-9 B.F.)	999.0
	1200	S6EH	7.1	91.7	50	WSW	24 (6 B.F.)	1003.0
21	1200	5MBH	5.6	86.6	200	W	28	1004.2
	1200	JHCK	5.8	86.2	200	WNW	30	1005.0
22	1200	S6GZ	5.1	83.9	225	WNW	30	1008.0
	1200	GZHY	5.7	85.7	125	SSW	30	1002.9
	1800	GXHY	5.7	84.8	100	SSW	40	1003.7
23	0000	GXHY	5.6	84.3	175	SSW	29	1003.5
	0600	Batticoloa	—	—	—	NW	55	1006.2
	0600	Trincomalee	—	—	—	N	28	1008.0
	1200	Batticoloa	—	—	—	N	78	997.9
	1200	Trincomalee	—	—	—	N	30	1004.8
	1300	ATJJ	8.6	81.4	150	NNE	40	1002.8
	1700	ATJJ	9.3	82.1	175	ENE	40	1005.4
	1800	Trincomalee	—	—	—	N	40	1002.9
	1900	ATJJ	9.5	82.5	200	E	40	1006.4
24	0000	Negombo	—	—	—	NW	50	1006.9
	0000	Hambantota	—	—	—	WSW	35	1005.9
	0100	VWJN	10.0	82.5	250	ESE	30	1005.7
	0600	Trincomalee	—	—	—	SSE	31	1006.7
	0600	Karaikal	—	—	—	ENE (at 0.6 & 0.9 km a.s. l)	35–45	
	0900	Pamban	—	—	—	NE	30	996.6
	1200	Pamban	—	—	—	SE	30	998.4
	1200	Karaikal	—	—	—	E	40	1007.5
	1300	Tuticorin	—	—	—	WSW	36	1002.2
	1800	Tuticorin	—	—	—	SSW	28	1008.7

country boats and mechanised fishing vessels were damaged in Rameswaram, Pamban Kilakkarai, Mandapam, Vedalai and Morepannai areas. Boat building yards at Mandapam and Morepannai were also damaged. Materials and machinery stored for construction of the road bridge near Pamban were washed away. There was also extensive damage to roads in Ramanathapuram district due to heavy rain. Crops of sugarcane, chillies, betel vines and plantain were also damaged in the interior taluks of Ramanathapuram district, *viz.*, Sattur, Paramakudi, Aruppukottai, Srivilliputtur, Rajapalayam and Virudunagar. The total damage to property was estimated to be about 5 crores of rupees. Thanjavur and Tirunelveli districts also suffered some damage to roads. Road and rail communications were disrupted in south Tamil Nadu.

On account of timely warnings, the Tamil Nadu Government took prompt and effective precautionary measures including evacuation of people from coastal areas. These helped to prevent loss of life and reduce damage to property to the minimum. As reported in the press, this storm was the worst to hit Sri Lanka in the last half a century. The toll of human lives in Sri Lanka was estimated to be about one thousand.

Serious loss to property was also reported from Sri Lanka.

On 17th two ships within 100 km of the centre of the disturbance reported surface winds of 20 to 25 kt which indicated that the disturbance was a depression on that day. This system was assessed to be of hurricane intensity from 21st to 24th on the basis of satellite pictures in which an 'eye' was seen on these days. Satellite views of this storm on 22nd and 23rd are reproduced in Figs. 3 and 4. As the storm approached close to Sri Lanka coast, Batticoloa reported northerly wind of 78 kt at 1200 GMT of 23rd. Important observations in the field of this storm are given in Table 3.

In the Satellite Tropical Disturbance Summary from Washington, this system was classified as T5/5 on 22nd and T6/6 on 23rd, the latter corresponding to a maximum wind of 115 kt. JTWC Guam estimated the highest maximum wind associated with this system as 125 kt (T6.5/6.5) on 23rd on the basis of satellite pictures. Assuming the maximum wind as 120 kt, the pressure at the centre of the storm could be estimated as 938 mb which is about 70 mb below normal.

As the storm was crossing Tamil Nadu coast on 24th evening it had weakened. The storm passed within 50 km of Pamban observatory on 24th afternoon and the winds recorded by that station were only 25 to 30 kt between 0600 and 1300 GMT on 24th. Tuticorin observatory recorded generally southwesterly surface winds of 30 to 35 kt between 1200 and 1800 GMT that day. The peak wind speed in gusts at Tuticorin observatory was 49 kt at 1342 GMT. Assuming the maximum wind in circulation as 50 kt on 24th evening, the central pressure of the storm works out to be 993 mb which agrees well with the lowest pressure of 993.4 mb reported by Pamban observatory at 1015 GMT on 24th very close to the storm centre.

Arabian Sea

1. *Depression of 11-13 July*

Under the influence of a middle latitude westerly system moving across Russian Turkistan, Afghanistan and north Pakistan, a low pressure area formed over southwest Rajasthan and adjoining Gujarat on 9th. It moved westwards into northeast Arabian Sea and concentrated into a depression on the morning of 11th with its centre at 0300 GMT near 23.5 deg. N, 67.5 deg. E. Moving practically westwards, it dissipated over the Gulf of Oman by the morning of 14th.

In association with this depression, fairly widespread rain occurred in Gujarat State on 11th and 12th with isolated heavy falls on 11th. Rainfall was also fairly widespread in south Rajasthan on these two days. The pressure departure from normal near the centre of depression was about *minus* 8 mb.

2. *Severe cyclonic storm of 5-13 November*

The Bay depression which moved across south Peninsula and emerged into the Arabian Sea off north Kerala coast on 5th morning, intensified into a cyclonic storm on the morning of 6th with its centre about 50 km northwest of Amini Divi. Then moving in a westnorthwesterly direction, the storm became severe on 7th morning when it was centred near 13.0 deg. N, 68.5 deg. E. Satellite picture showed that by this time an 'eye' had developed. The cyclonic storm developed a core of hurricane winds that evening, moved northwestwards till 9th and then recurved northeastwards to northeast Arabian Sea by 11th morning when it started weakening. Thereafter it moved eastwards and weakened into a cyclonic storm by 11th night and into a deep depression by 12th morning. The deep depression crossed north Gujarat coast near Okha on the forenoon of 12th and dissipated over the eastern parts of Gujarat by 13th evening.

In association with this system generally widespread rain occurred in Kerala and Lakshadweep on 6th and 7th with heavy to very heavy falls over these areas on 6th. Agathi had a record rainfall of 31 cm on 6th. On the same day Amini and Peeramedu (Kerala) recorded 18 cm, Trichur 13 cm, Punalur, Trivandrum and Minicoy 12 cm each. Fairly widespread rain also occurred in Karnataka on 7th and in western parts of Maharashtra on 8th and scattered to fairly widespread in Saurashtra-Kutch and south Rajasthan on 12th and 13th. Kothara and Jakhau (in Kutch) were reported to have recorded very heavy rain of 20 cm and 30 cm respectively on 12th. Naliya observatory recorded 10 cm the same day.

According to press reports, damage to coconut trees and houses was reported from the northern islands in Lakshadweep. As the storm moved towards Gujarat State, it caused some damage in Bhuj district and the adjoining parts of Saurashtra. According to the report of officer who visited the storm affected areas in Gujarat State, three out of the crew of six of a fishing trawler *'Krishna Prasad'* which was in distress between Rupen (Dwarka) and Veraval lost their lives and a sailing vessel *'Dolatpasa'* sank near Okha Madh on 11 November. Asbestos sheets of the roof of the transmitter station at Bhuj airport were blown off. Almost all electric poles in the vicinity of the aerodrome near Naliya were bent under the impact of strong winds. More than 60 kutcha houses were damaged in Jakhau village located about 10 km westsouthwest of Naliya, which was the worst affected village due to torrential rain and gale force winds. Huge stocks of salt belonging to the salt house at Jakhau port were also washed away.

TABLE 4

Severe cyclonic storm of 5-13 November

Date	Time (GMT)	Ship/Station	Location		Approx. distance from storm centre (km)	Wind		Pressure (mb)
			Lat. (°N)	Long. (°E)		Dir.	Speed (kt)	
5	0000	Trivandrum	—	—	—	W (at 0.6 & 0.9 km asl)	30–35	—
	0600	Amini	—	—	—	NW	25	1005.1
	1200	Androth	—	—	—	W	25	1001.6
	1200	ATJW	10.6	75.6	200	S	25	1002.0
	1200	Minicoy	—	—	—	W (upto 0.9 km asl)	30–35	—
6	0000	Amini	—	—	—	S	36	987.8
	0300	Amini	—	—	—	SW	39	994.6
	0600	GZHR	10.7	71.5	150	NW	40	1003.1
	0600	Mangalore	—	—	—	SE (at 0.6 & 0.9 km asl)	30–35	—
	1200	Mangalore	—	—	—	SSE (at 0·6 & 0·9 km asl)	35–40	—
	1200	Minicoy	—	—	—	SW (up to 0.9 km asl)	35–40	—
	1800	9KFE	14.5	72.4	400	ESE	37	1006.2
7	0000	9KFE	13.9	73.6	500	SSE	28	1008.6
	0600	ATJX	14 9	71.4	400	ESE	27	1009.2
	1200	JBOW	14.4	70.1	400	SSE	34	1006.0
	1200	ESSO Cambria	16.9	65.1	350	N	35	1004.7
	1800	,,	15.8	65.2	100	NNE	47	992.1
	1950	,,	15.3	65.3	50	WSW	100 (in gusts)	985.9
	2200	,,	14.8	65.3	100	SW	60	995.5
8	0000	,,	14.8	65.7	175	S	45	998.6
	1200	GQUC	19.3	63.2	250	E	40	1006.0
9	0000	HOYL	18.6	60.7	300	N	30	—
	0000	GQUC	18.0	63.6	100	ESE	58	—
	0600	MFPO	16.5	61.5	300	NW	30	—
11	0000 & 1200	Jamnagar	—	—	—	S (up to 0.9 km asl)	30–35	—
	1130	Nalya IAF	—	—	—	SE	35 (50 kt in gusts)	—
	1200	Naliya	—	—	—	SE	30	1001.8
	1200	Bhuj	—	—	—	SE	25	1002.2
	1400	Kutch Mandvi	—	—	—	S	44	1010.0
	1415	New Kandla	—	—	—	SSE	40 (48 kt in gusts)	
	1900 & 2000	Porbandar	—	—	—	SSW	40	1005.2
12	0600	Rajkot	—	—	—	SE	30	1007.1
	0900	Okha	—	—	—	NNW	25	1004.6

A few glass panes of the lighthouse tower and of residential quarters at Dwarka were broken. Uprooting of trees was also reported at Bhuj, Kothara, Kutch Mandvi, Gandhidham and Jamnagar.

Agathi in Lakshadweep reported on the morning of 6th stormy winds and waves of 3 to 4 metres height. Amini Divi reported surface winds of 30 to 40 kt and the lowest pressure of about 983 mb on the early morning of 6th as the storm centre moved close to the station. The pressure departure from normal at Amini at this time was about *minus* 26 mb. Available ships observations in the Arabian Sea showed that gale force winds extended as far as 400 km from the storm centre on 7th. Two ships reported valuable observations from close to centre of the storm. One ship *GZJD* (*ESSO CAMBRIA*) reported winds of more than 100 kt from north by west at 1900 GMT and westsouthwest at 2000 GMT of 7th. A composite chart showing the surface winds reported by this ship at different hours from the storm centre on 7th and 8th as it moved across the storm field from north to south is given in Fig. 7. Another ship *Eastern Express* (HONN) passed through the centre of the storm and reported the location of the centre at 0300 GMT of 8th as 16.2 deg. N, 64.2 deg. E and the central pressure as 959 mb. Winds around the centre were more than 150 kt; the radius of the centre (eye) was reported as 40 km. Important observations in the field of this storm are given in Table 4. As the system approached Saurashtra

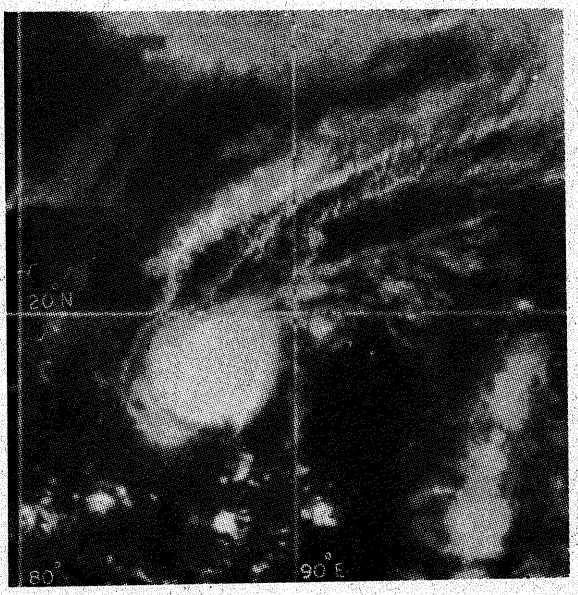

Fig. 2. Satellite view of Bay storm at 2003 GMT on 26 October 1978

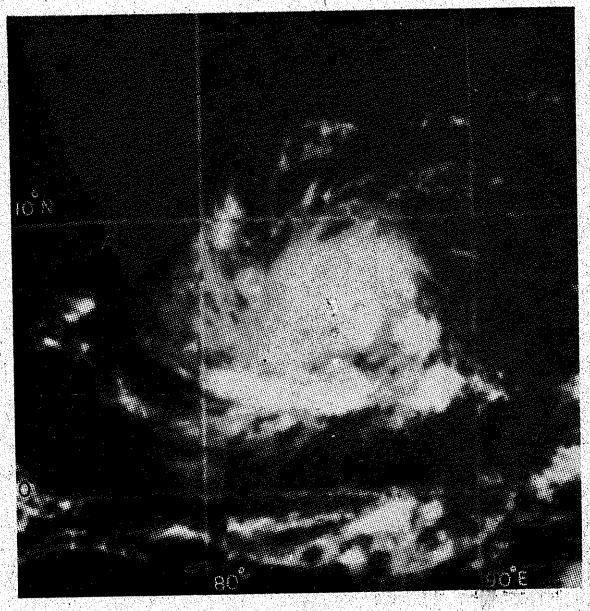

Fig. 3. Satellite view of Pamban cyclone at 1010 GMT on 22 November 1978 showing a clear 'eye'

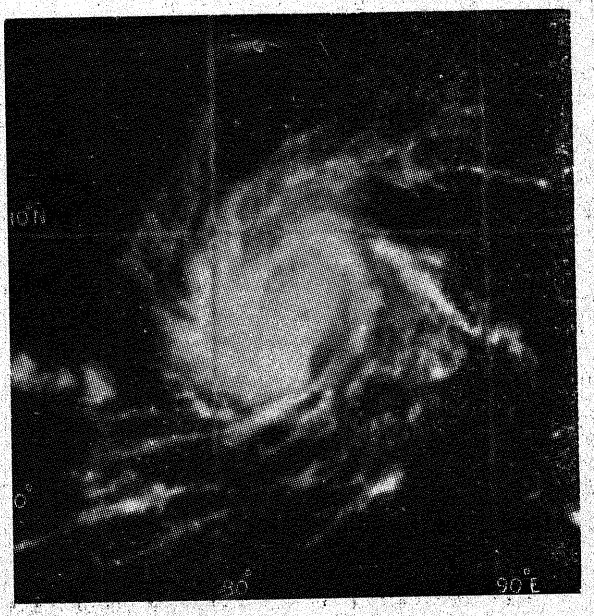

Fig. 4. Pamban cyclone as viewed by satellite at 0952 GMT on 23 Noevmber 1978. The 'eye' of the cyclone can be seen dimly

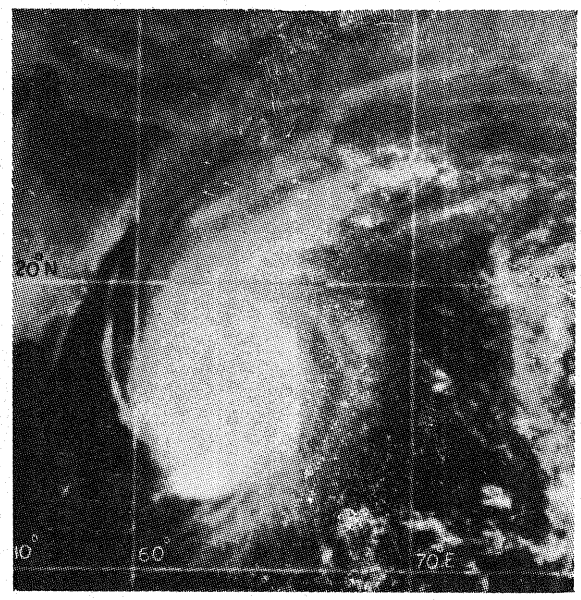

Fig. 5. Satellite view of Arabian Sea cyclone in its peak intensity at 0916 GMT on 8 November 1978, showing a dim 'eye'

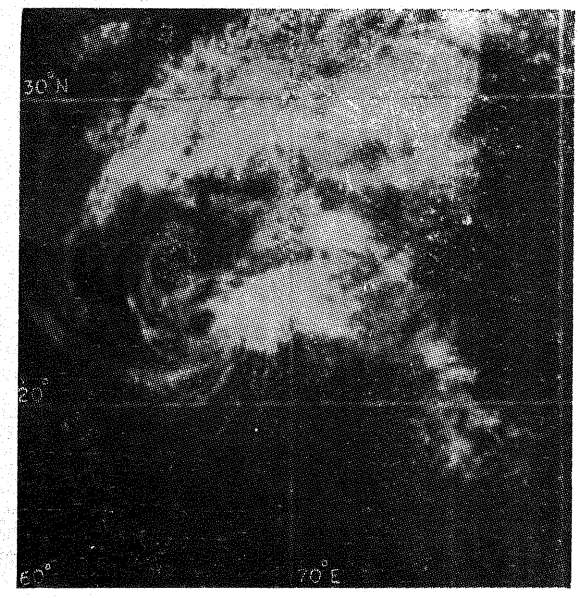

Fig. 6. Arabian Sea cyclone in its weakening phase as seen by satellite at 1004 GMT on 11 November 1978

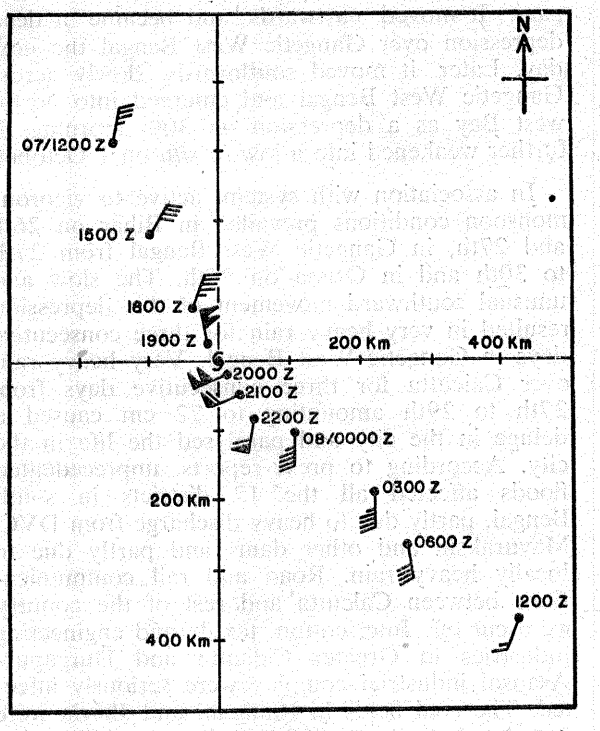

Fig. 7. Wind reports from ship ESSO CAMBRIA (GZJD) on 7 and 8 November 1978

coast the coastal observatories reported southerly surface winds of 30 to 40 kt on the night of 11th, when the storm centre was 100-150 km away from the coast. On the morning of 12th when the system lay as a deep depression close to Saurashtra-Kutch coast, the pressure departure from normal was about *minus* 12 mb near the depression centre.

In the Satellite Tropical Disturbance Summary bulletin from Washington this system during its peak intensity was classified as T5.5/5.5 on Dvorak's scale, which corresponds to a maximum wind of about 100 kt. JTWC, Guam also estimated the maximum sustained winds in this storm as 115 kt (T 6.0/6.0) on 8th afternoon based on satellite pictures. The 'eye' of the storm was seen in the satellite pictures on 8th and 9th. Assuming the maximum wind associated with this storm as 115 kt, the pressure at the centre of the storm works out to be about 940 mb. If the estimate of the winds by the ship *Eastern Express* (HONN) as 150 kt is correct, then this will be one of the most severe storms on record in the Indian Sea areas. The corresponding pressure at the storm centre will be 895 mb. Satellite views of this storm are shown in Figs. 5 and 6.

The cyclonic storm was apparently steered around the periphery of the upper anticyclone over north Peninsula. By the 11th, the storm had moved to the north of the ridge line and it came under the influence of the strong upper level westerlies. The strong vertical wind shear over this area caused the weakening of the storm over the sea itself; the shearing of the top of the storm was noticed well in the satellite pictures.

3. *Cyclonic storm of 25-29 November*

The deep depression which emerged into the Arabian Sea off north Kerala coast on 25th morning reintensified into a cyclonic storm the same evening with its centre about 100 km east of Amini Divi. Moving northwestwards, it weakened into a depression on 28th. Then moving northwards, it weakened further into a low over the central parts of east Arabian Sea by 29th evening. Moving slowly northeastwards, the low pressure area dissipated over Saurashtra and Kutch by 2 December.

This system caused generally widespread rain with isolated heavy falls in Kerala and Lakshadweep on 26th. Rainfall was scattered in coastal Karnataka on 26th, in Konkan and Madhya Maharashtra on 28th and 29th and in Gujarat region on 29th. Trichur and Androth recorded 7 cm of rain each on 26th.

The maximum sustained wind in association with this storm was estimated as 45 kt from satellite pictures. This would give the minimum pressure at the storm centre as 998 mb.

Land Depressions

1. *Depression of 26-27 June*

A low pressure area which was over Bihar and adjoining West Bengal on 25th, concentrated into a depression on the evening of 26th, with its centre close to Dumka. The formation of the depression appears to have taken place under the influence of a trough in the middle tropospheric westerlies moving eastwards across Tibet and Nepal. The depression moved westsouthwestwards and weakened into a low over northeast Madhya Pradesh by the morning of 28th.

In association with this depression, generally widespread rain occurred in West Bengal on 26th and 27th, in Bihar State from 26th to 28th, in east Uttar Pradesh on 26th, in east Madhya Pradesh on 27th and 28th and in west Madhya Pradesh on 28th. A few stations in West Bengal, Bihar, east Uttar Pradesh and east Madhya Pradesh reported heavy to very heavy rainfall during this period. The notable amounts in cm were: Varanasi Airport 25, Daltonganj 18, Bankura & Sriniketan 16 each, Dhanbad 13, Purulia 12 and Patna 11 on 26th; Jamshedpur 12, Gaya 10, Purulia 9 on 27th; Pendra 17, Jabalpur 8 on 28th.

2. *Deep depression of 1-5 September*

The cyclonic storm over northwest Bay which crossed Orissa coast on 27 August was followed by the arrival of another low pressure system from the east into northeast Bay and

neighbourhood on 31st. This low was the remnant of typhoon *Elaine* which crossed the southern coast of China near Lat. 21.5 deg. N on 27 August. The low pressure area concentrated into a depression over Gangetic West Bengal on the morning of 1 September with its centre about 50 km north of Calcutta. The depression became deep on the morning of 2nd and moved west-northwestwards to east Uttar Pradesh by 4th where it weakened into a depression during the course of the day. Thereafter, it sharply changed its course, moved eastwards and weakened further into a low over east Uttar Pradesh by 5th evening and was located over east Uttar Pradesh and adjoining Bihar plains by 6th morning.

In association with this system, the monsoon was active or vigorous in Gangetic West Bengal, Orissa and Bihar Plateau from 1st to 3rd, in Madhya Pradesh on 3rd and 4th, in east Uttar Pradesh from 3rd to 6th and in west Uttar Pradesh on 5th. Heavy to very heavy rain occurred over these areas on one or two days. According to press reports, floods affected Midnapore, Bankura, Hooghly, Malda and Murshidabad districts in West Bengal. Floods in the *Subarnarekha* river affected some parts of Balasore district in Orissa. Some parts of Bihar were also affected by floods.

The principal amounts of rainfall in cm were: Bankura 21, Sandheads 18, Bagati 16, Dhanbad 15 on 1st; Midnapore 25, Jamshedpur city 23, Jamshedpur Airport, Deogarh (Orissa) 19 each, Purulia 14 on 2nd; Satna 18, Jatara (Madhya Pradesh) 16, Rewa 15, Sidhi 14 on 3rd; Panna, Nowgong 38 each, Satna 27, Ajaigarh (Madhya Pradesh) 23, Sohawal (Madhya Pradesh) 21, Pawai (Madhya Pradesh) 15, Sidhi, Jatara (Madhya Pradesh) 13 each on 4th; Tikamgarh 17, Jhansi 13 on 5th.

The maximum pressure departure from normal reported near the centre of the depression was *minus* 11 mb on the morning of 2nd when it was over Gangetic West Bengal and adjoining Bihar Plateau. The winds in the field of this depression up to about 1.5 km asl were generally 25 to 35 kt on 2nd and 3rd.

3. *Deep depression of 26-30 September*

The remnants of the depression which crossed coast near Balasore on 21st evening lay as a low pressure area over northeast Madhya Pradesh and adjoining parts of south Uttar Pradesh and Bihar from 23rd to 25th and concentrated again into a depression on the morning of 26th over Bihar with its centre about 50 km east of Daltonganj. It moved eastwards and became a deep depression over Gangetic West Bengal the next day. Later it moved southwards slowly across Gangetic West Bengal and emerged into northwest Bay as a depression on 30th morning. It further weakened into a low *in situ* on 1 October.

In association with system, active to vigorous monsoon conditions prevailed in Bihar on 26th and 27th, in Gangetic West Bengal from 27th to 30th and in Orissa on 27th. The slow and unusual southward movement of this depression resulted in very heavy rain for three consecutive days in Gangetic West Bengal. Very heavy rain over Calcutta for three consecutive days from 27th to 29th amounting to 72 cm caused a deluge in the city and paralysed the life in the city. According to press reports, unprecedented floods affected all the 12 districts in south Bengal, partly due to heavy discharge from DVC, Mayurakshi and other dams and partly due to locally heavy rain. Road and rail communications between Calcutta and rest of the country were cut off. Jute, cotton, textile and engineering industries in Greater Calcutta and Durgapur-Asansol industrial complex were seriously affected. The coal fields in Raniganj and Jharia were inundated. About 1,000 people were killed due to floods and house-collapses in West Bengal. Heavy damage was caused to crops, houses and other property.

Sriniketan and Panagarh had record rainfall of 34 and 33 cm respectively on 27th and Calcutta (Alipore) 37 cm on 28th. The other principal amounts of rainfall in cm were : Hazaribagh 12 on 26th; Dumka 30, Dhanbad 23, Calcutta 22, Bankura 18, Uluberia 16, Magra, Khishnanagar 14 each, Balasore, Midnapore 13 each on 27th; Dum Dum 33, Magra 28, Sriniketan 17, Diamond Harbour 15 on 28th; Krishnanagar 15, Calcutta 13 on 29th.

During the last 100 years there has not been such a southerly track of any depression over Gangetic West Bengal. The initial eastward movement of this depression from Bihar to West Bengal was under the influence of the upper tropospheric westerly steering flow. On 27th and 28th, the depression was located below the eastern periphery of the upper tropospheric anticyclone over the central parts of the country and came under the influence of the upper northerly winds which apparently resulted in a southerly track of the depression on these two days.

Reference

Dvorak, V. F., 1975, *Mon. Weath. Rev.*, **103**, 5, pp. 420-430.