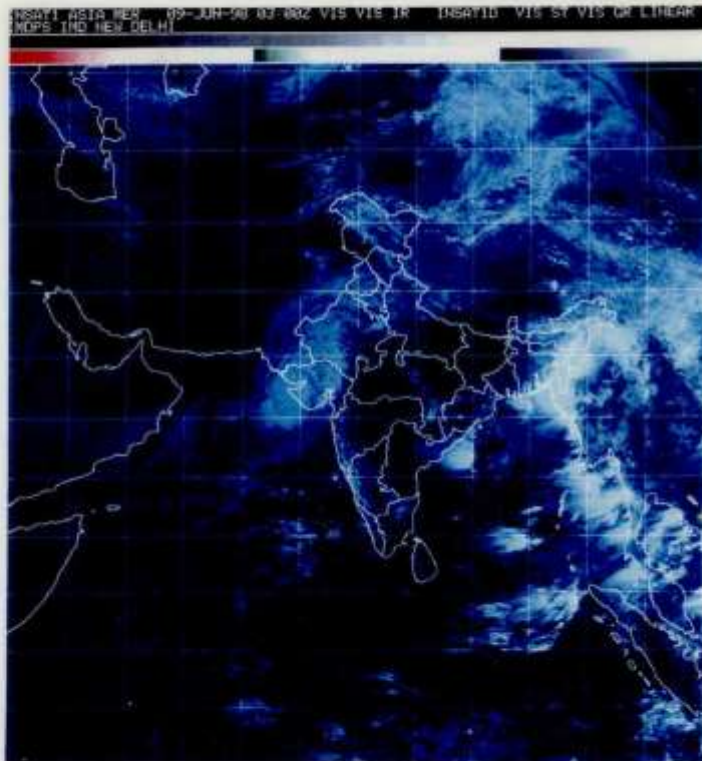




भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

**REPORT ON CYCLONIC DISTURBANCES OVER NORTH
INDIAN OCEAN DURING 1998**



**RSMC-TROPICAL CYCLONES NEW DELHI
FEBRUARY 1999**



भारत मौसम विज्ञान विभाग
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**REPORT ON
CYCLONIC DISTURBANCES
OVER NORTH INDIAN OCEAN**

*(ABRIDGED REPORT CIRCULATED DURING THE MEETING OF WMO/ESCAP
PANEL ON TROPICAL CYCLONES)*

1998

RSMC-TROPICAL CYCLONES, NEW DELHI
FEBRUARY 1999

**CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN
DURING 1998**

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INTRODUCTION

The North Indian Ocean witnessed increased number of cyclonic storms during 1998 (6 cyclones) as compared to 1997 (3 Cyclones). However, the number of depressions was same in both the years. One of the most significant features of the year was total absence of development of depressions in the Bay of Bengal during the period July to September of the southwest monsoon season. Yet another noticeable feature was increased cyclonic activity in the month of October when 4 disturbances developed over North Indian Ocean.

Four cyclonic disturbances developed over the Arabian sea during this year. Two out of them intensified into cyclonic storms. One of these acquired the intensity of very severe cyclonic storm and was the most intense system over the last 15 years.

The Regional Specialised Meteorological Centre (RSMC) -Tropical Cyclones New Delhi had mobilised all its resources, both technical and human, to track the tropical disturbances evolving in the North Indian Ocean and issued advisories for the whole region for the Member Countries of the ESCAP Panel region. The number of bulletins, advisories issued during the cyclone period given in a subsequent page are testimony to that.

This report consists of a review of the cyclonic disturbances and their associated features, that formed in the North Indian Ocean (the Bay of Bengal and the Arabian Sea) during the year 1998. RSMC- Tropical Cyclones New Delhi introduced a new nomenclature for description of cyclonic disturbances in the north Indian Ocean in 1998. This was intimated to all the Panel countries in July 1998. Based on this new nomenclature, the classification of cyclonic disturbances followed in the report is given below:

Weather System	Maximum sustained surface wind speed
1. Low (L)	Wind speed less than 17 kt. (31 kmph)
2. Depression (D)	Wind speed between 17 and 27 kt. (31 and 49 kmph)
3. Deep Depression (DD)	Wind speed between 28 and 33 kt. (50 and 60 kmph)
4. Cyclonic Storm (CS)	Wind speed between 34 and 47 kt. (62 and 88 kmph)
5. Severe Cyclonic Storm (SCS)	Wind speed between 48 and 63 kt. (89 and 117 kmph)
6. Very Severe Cyclonic Storm (VCSC)	Wind speed between 64 and 119 kt. (119 and 221 kmph)
7. Super Cyclone (SC)	Wind speed 120 kt and above. (222 kmph and above)

The term 'Cyclone' used in the text, is a generic term indicating all the four categories of cyclonic disturbances given above under S. No. (4) to (7).

List of cyclonic disturbances in chronological order

1. Severe Cyclonic Storm over the Bay of Bengal
(17-20 May 1998)
2. Very Severe Cyclonic Storm over the Arabian Sea
(4 – 10 June 1998)
3. Deep Depression over the Bay of Bengal
(13 – 15 June 1998)
4. Deep Depression over the Arabian Sea
(6 – 9 October 1998)
5. Cyclonic Storm over the Arabian Sea
(11 – 17 October 1998)
6. Deep Depression over the Bay of Bengal
(13 – 15 October 1998)
7. Deep Depression over the Bay of Bengal
(26-29 October 1998)
8. Very Severe Cyclonic Storm over the Bay of Bengal
(13 - 16 November 1998)
9. Very Severe Cyclonic Storm over the Bay of Bengal
(19-23 November 1998)
10. Severe Cyclonic Storm over the Arabian Sea
(13 – 17 December 1998)

**Statistical data relating to Cyclonic disturbances in the North Indian Ocean
During 1998**

1. Synoptic class distribution of Cyclonic Activity ($CI \geq 2.0$)

S.No.	Type	May	Jun	Jul	Aug	Sep	Oct.	Nov	Dec.	Life Time (days)
1.	SCS	↔								4
2.	VSCS		↔							7
3.	DD		↔							3
4.	DD						↔			4
5.	CS						↔			7
6.	DD						↔			3
7.	DD						↔			4
8.	VSCS							↔		4
9.	VSCS							↔		5
10.	SCS								↔	5

Average Lifetime=	4.6 (days)
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2. Frequency distribution of different intensity classes

CI	≥ 2.0	≥ 2.5	≥ 3.0	≥ 5.0	≥ 6.0	≥ 7.0
No. Of Disturbances	10	6	5	1		
No. of days with Cyclone Intensity(≥ 2.5)		20	13	2		

Note: CI=Current Intensity on Dvorak Scale

3. Basin-wise distribution of disturbances

Bay of Bengal	6
Arabian Sea	4

Activities of RSMC- Tropical Cyclones New Delhi

Tropical Weather Outlook

Tropical Weather Outlook was issued daily at 06 UTC for use by the Member countries of ESCAP Panel region. This contained description of synoptic systems over North Indian Ocean and sub-tropical ridge position at 200 hpa level. In addition , additional second weather outlook was also issued at 18 UTC in situations where a tropical depression was expected to attain cyclone intensity. These bulletins were transmitted through the Global Telecommunication System (GTS) . This year, seven second weather outlooks were issued.

Global Maritime Distress and Safety System (GMDSS)

In the GMDSS scheme, India has been designated as one of the 16 services in the world for issuing sea area bulletins for broadcast through GMDSS for METAREA VIII, which covers the entire North Indian Ocean and some parts of south Indian ocean. Preparation services for METAREAS VIII are : (i) India (ii) Kenya (iii) Mauritius and (iv) La Reunion. India has implemented the scheme of issuing the second GMDSS bulletins at 18 UTC with effect from October 1, 1998 .

Tropical Cyclone Advisories

These bulletins were issued at 6 hours interval at 03,09, 15 and 21 UTC based on the charts at 00 ,06,12 and 18 UTC for the benefit of the Members of Panel Countries . These bulletins contained the current position of the surface centre, the direction and speed of movement, estimated central pressure, distribution of winds and squally weather, description of the state of the sea in and around the system and its forecast. This year, 57 cyclone advisories were issued.

Satellite Bulletins

Satellite bulletins were produced every three hours based on the interpretation of INSAT cloud imagery. In the event of cyclonic storm , INSAT pictures are also taken at hourly interval . The bulletins contain information on central position, movement and intensity (T- number on Dvorak's scale) as well as a description of cloud organisation. Satellite derived information on tropical disturbances was included in RSMC bulletins cited above.

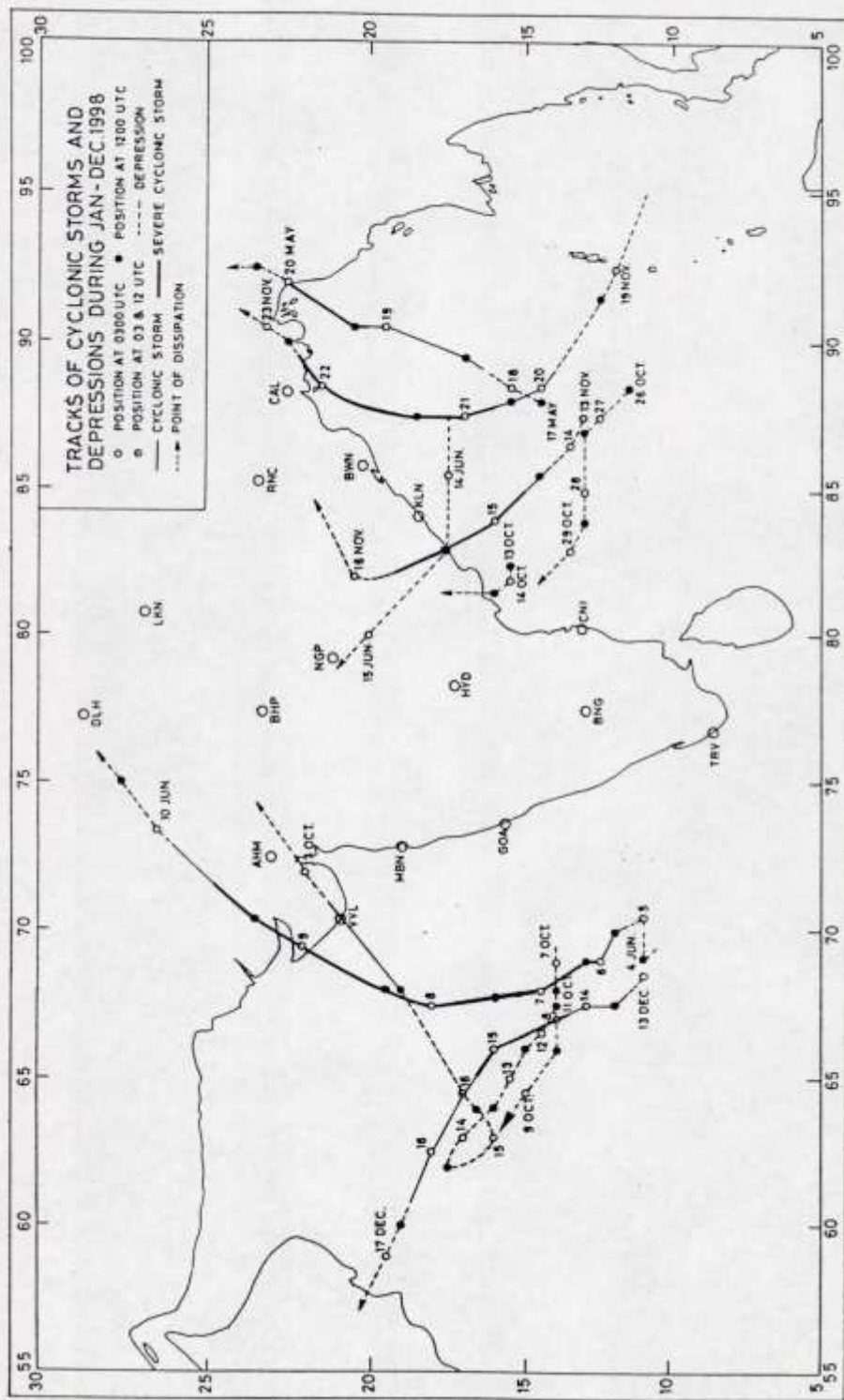


FIG. 1.1

CHAPTER 2

BRIEF DESCRIPTION OF THE SYSTEMS

2.1 Very Severe Cyclonic Storm over the Bay of Bengal (May 17- 20,1998) (BOB 98 01 05 17 20)

The first cyclonic disturbance of this year formed as a depression over the central Bay of Bengal. Moving northeastwards it intensified into a very severe cyclonic storm before crossing Bangladesh coast.

A pre-existing disturbance over the southern parts of central and adjoining south Bay of Bengal concentrated into a depression near Lat.14.5° N/ Long. 88.0° E in the evening of May 17, 1998. Moving northeastwards, it further concentrated into a deep depression near Lat. 16.0° N / Long. 88.5° E 06 UTC of May 18 when the satellite observed cloud pattern became more compact and organised. It further intensified into a cyclonic storm near Lat. 16.5° N /Long. 89.0° E by 12 UTC of the same day. Moving rapidly towards northeast the system further intensified into a severe cyclonic storm near Lat. 20.0° N/Long. 90.5° E by 06 UTC of May 19 when the spiral band in the satellite imagery tightened its grip further around the centre. The system was located near Lat. 20.5° N/Long. 90.5° E at 12 UTC of May 19. It crossed Bangladesh coast between Chittagong and Sitakundu around 02 UTC of May 20. After crossing coast, it rapidly weakened into a deep depression at 03 UTC over southeast Bangladesh and adjoining Mizoram with central region near Lat. 22.0° N/Long. 92.5° E. It further moved in a northnortheasterly direction and weakened into a depression at 12 UTC of May 20 near Aijwal in Mizoram.

Best track positions and other parameters are included in Table 2.1.1. The track of the system is given in Fig. 2.1.1. A few INSAT cloud images are shown in Fig. 2.1.2.

Weather realised

The storm affected the Bangladesh coast.

Damage report

Crops and Kutcha houses in the offshore island of Chittagong and Cox's Bazar were damaged. However, no deaths were reported.

The maximum surge of 3m (10 feet) occurred over the low lying areas and offshore islands of Chittagong and Cox's Bazar.

Table 2.1.1
Best track position and other parameters for the Bay of Bengal
severe cyclonic storm (May 17-20, 1998)

Date	Time (UTC)	Centre Lat. °N / Long. °E	C. I NO.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated Pressure drop at the centre	Grade
17.5.98	1200	14.5/88.0	1.5	998	25	4	D
	1800	15.0/88.5	1.5	998	25	4	D
18.5.98	0000	15.0/88.5	1.5	998	25	4	D
	0300	15.5/88.5	1.5	998	25	4	D
	0600	16.0/88.5	2.0	996	30	6	DD
	0900	16.5/89.0	2.5	992	35	8	CS
	1200	17.0/89.5	2.5	994	35	8	CS
	1800	18.0/89.5	2.5	994	35	8	CS
19.5.98	0000	19.0/90.0	3.0	990	35	10	CS
	0300	19.5/90.5	3.0	990	35	10	CS
	0600	20.0/90.5	3.5	986	55	14	SCS
	1200	20.5/90.5	3.5	976	55	14	SCS
	1800	21.0/91.0	3.5	974	60	18	SCS
20.5.98	0000	21.5 /91.5	3.5	972	60	18	SCS
Crossed Bangladesh coast around 0200 UTC between Chittangong and Sitakundu							
20.5.98	0300	22.0/92.5	Over land				DD
	1200	23.5/92.5	Over land				D

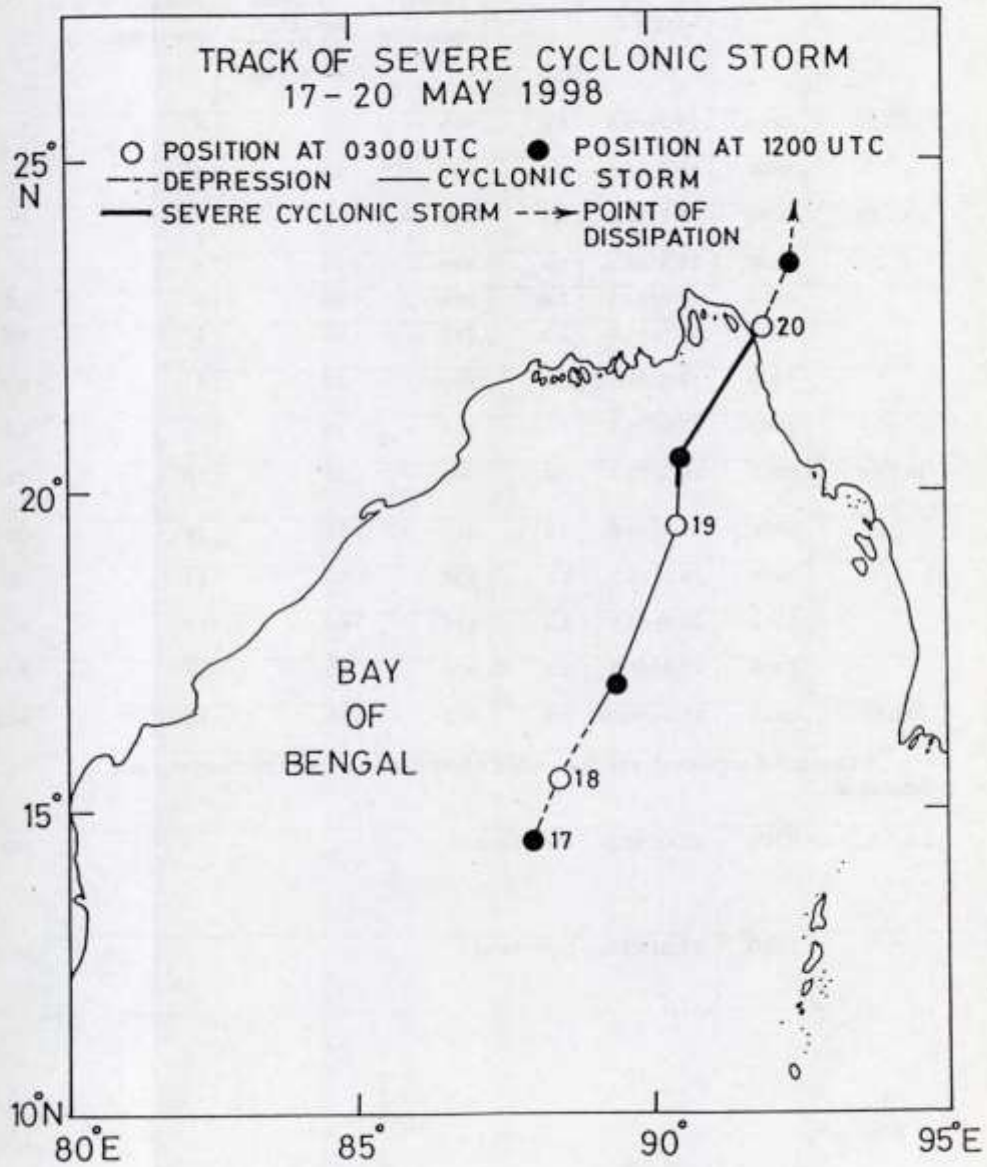


FIG. 2.1.1

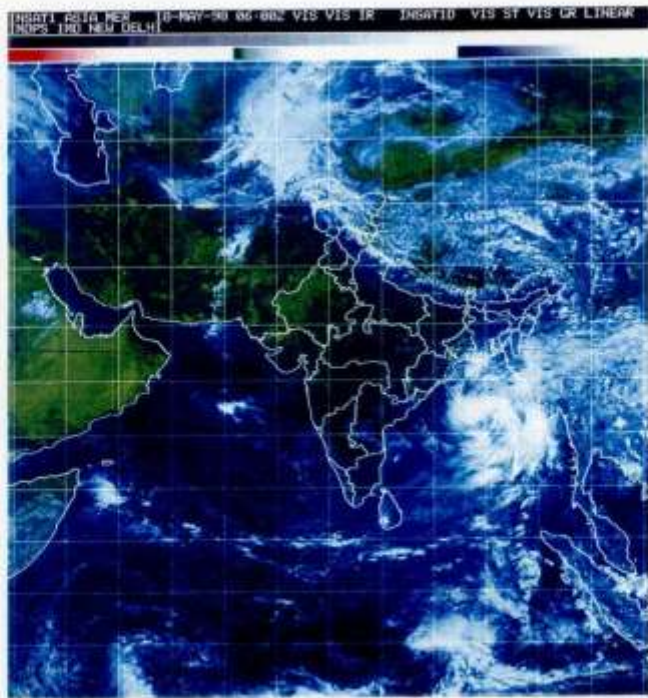


FIG. 2.1.2

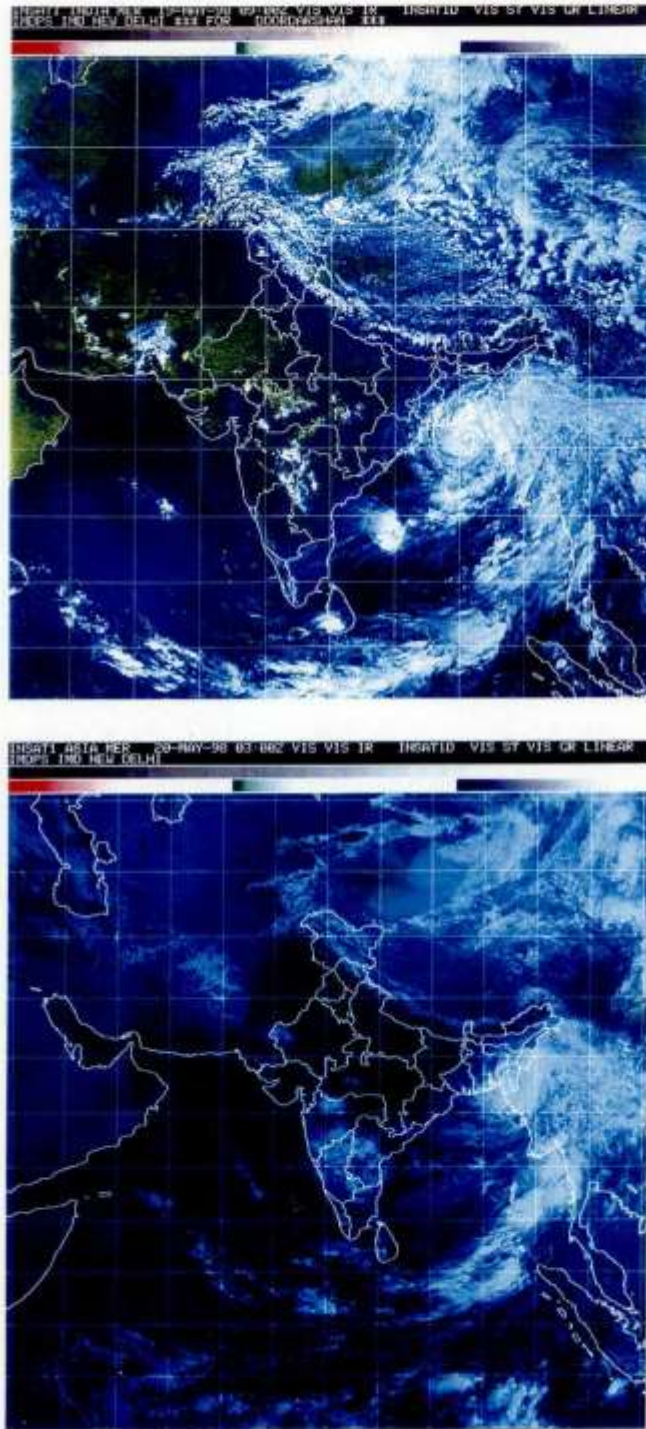


FIG. 2-1.2 contd.

2.2. Very Severe Cyclonic Storm over the Arabian Sea (June 4- 10,1998) (ARB 98 01 06 04 10)

This system acquired the stage of a very severe cyclonic storm in the Arabian Sea in which the maximum sustained surface wind speed reached 100 kts. It crossed Gujarat Coast near Porbandar in the morning of June 9. This very severe cyclone is the most intense system in the Arabian Sea for the last 15 years since the cyclone of 5-8 November 1982.

Tracing back its origin the initial disturbance was detected at the leading edge of monsoon current as a depression over the southeast Arabian Sea near Lat. 10.5° N/ Long. 69.5° E at 06 UTC of June 4. Moving northwestwards it intensified into a deep depression near Lat. 11.0° N/ Long. 70.5° E by 12 UTC of the same day. The environment was characterised by strong vertical wind shear as seen in the satellite imagery which showed low level circulation centre east of the dense overcast. The depression meandered over Lakshadweep and neighbourhood for next 12 hours and then intensified into a cyclonic storm at 09 UTC of June 5 when it was spotted near Lat. 11.5° N/ Long. 70.0° E. Under the influence of a weak steering flow it moved somewhat slowly northwestwards initially and intensified further into a severe cyclonic storm on 6th evening when it was located about 580 km southwest of Goa. Moving northwards, it intensified into a very severe cyclonic storm on 7th afternoon and was located about 700 km southwest of Mumbai. It continued to move northwards and was located about 500 km westsouthwest of Mumbai at 06 UTC of June 8. The very severe cyclonic storm was located about 350 Kms southwest of Porbandar in the evening of June 8. The estimated wind speed was of the order of 100 kts before landfall. Though the eye was revealed in the visible satellite imagery, there was no eye seen in the infrared imagery and also in radar imagery of Cyclone Detection Radar (CDR) Bhuj which showed only 4 to 5 spirals. After crossing the upper tropospheric ridge line the system recurved and accelerated northeastwards. It crossed Gujarat coast near Porbandar between 01 hrs and 02 hrs UTC of June 9 and lay centred at 03 hrs UTC about 50 km north of Porbandar. The system maintained its intensity as a very severe cyclonic storm even after crossing coast till noon when it lay over the Gulf of Kutch, about 50 km southwest of Kandla Port. It was located around Kandla at 09 hrs UTC of June 9. Thereafter, it continued to move northeastwards and weakened into a severe cyclonic storm about 50 km northeast of Kandla. Moving in the same direction the system further weakened into a cyclonic storm about 100 Km south of Barmer in southwest Rajasthan by the midnight of the same day. Under the influence of a westerly trough it gave heavy rains over southwest Rajasthan. The system weakened into a deep depression near Jodhpur on the morning of June 10 and dissipated later east Rajasthan.

Weather realised

The significant amounts of rainfall recorded during the movement of the system over Gujarat and Rajasthan are as below:

Gujarat State

Place	date	Amount in cm
Kheda	10.6.98	11
Bhuj	10.6.98	12

Rajasthan

Nagaur	10.6.98	11
Jodhpur	10.6.98	12
Siwasca(Barmer)	10.6.98	19

Damage report (Source: Government of Gujarat)

Total No. of lives lost : 1173

No.of persons missing : 1774

**Losses incurred due to storm are as follows:
(Rupees in Crores.)**

i. Energy & Petrochemical Department	: 476.65
ii. Agriculture & Animal husbandry	: 347.06
iii. Revenue Department	: 285.50
iv. Ports & Fisheries Department	: 282.50
v. Industry and Mine Department	: 275.19
vi. Roads & building Department	: 85.22
vii Co-operation Department	: 81.42
viii. Water supply Department	: 31.84

The lowest msl pressure recorded at Jamnagar was 961 hPa . Maximum wind of 98 kts was also reported from Jamnagar at 02 UTC on June 9 when the wind instrument became unserviceable.

Storm surge height was of the order of 2 to 3 meters over and above the astronomical tide of 6.6 meters. The astronomical tide coupled with storm surge and very strong winds resulted in a phenomenal fury of the cyclone at Kandla Port which has never been experienced by the community of that area in the span of their living memory.

Best track positions and other parameters are included in Table 2.2.1 .The track of the system is given in Fig.2.2.1. The speed of movement of the system is given in Fig.2.2.2 A few INSAT cloud images are shown in Fig. 2.2.3 . A few radar images of CDR Bhuj are shown in Fig.2.2.4 . A few photographs showing damages caused due to the cyclone are included in Fig. 2.2.5.

Table 2.2.1

Best track and other parameters for the Arabian sea
Very Severe Cyclonic storm (June 4-10, 1998.)

Date	Time (UTC)	Centre Lat. °N / Long. °E	.C.I. No.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
4.6.98	0600	10.5/69.5	1.5	1004	25	4	D
4.6.98	1200	11.0/69.0	2.0	1004	30	6	DD
5.6.98	0300	11.0/70.0	2.0	1004	30	6	DD
	0600	11.5/70.5	2.0	1000	30	6	DD
	0900	12.5/70.0	2.5	998	35	8	CS
	1200	12.0/70.0	2.5	998	35	8	CS
	1800	12.0/69.5	2.5	996	35	8	CS
6.6.98	0000	12.5/69.0	2.5	996	35	8	CS
	0300	12.5/69.0	3.0	996	45	10	CS
	0600	12.5/69.0	3.5	989	55	15	SCS
	1200	13.0/69.0	3.5	987	55	15	SCS
	1800	13.5/68.5	3.5	991	55	15	SCS
7.6.98	0000	14.0/68.0	3.5	989	55	15	SCS
	0300	14.5/68.0	3.5	989	55	15	SCS
	0600	15.0/68.0	3.5	989	55	15	SCS
	0900	15.5/68.0	4.0	979	65	21	SCS
	1200	16.0/68.0	4.5	970	80	30	VSCS
	1800	16.5/68.0	4.5	970	80	30	VSCS
8.6.98	0000	17.5/68.0	4.5	970	80	30	VSCS
	0300	18.0/67.5	4.5	970	80	30	VSCS
	0600	18.5/68.0	5.0	970	90	40	VSCS
	1200	19.5/68.0	5.0	958	90	40	VSCS

Table 2.2.1 (continued)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I. No..	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated Pressure drop at the centre	Grade
8.6.98	1800	20.5/68.5	5.0	960	80	40	VSCS
9.6.98	0000	21.5/69.0	5.0	958	80	40	VSCS
Crossed coast near Porbandar between 01 and 02 UTC							
	0300 Over	22.0/69.5 Land					VSCS
	0600	22.5/69.5					VSCS
	1200	23.5/70.5					SCS
	1800	24.5/71.5					CS
10.6.98	0000	26.0/73.0					DD
	0300	26.5/73.5					DD
	0600	27.0/74.0					DD
	0900	27.5/75.0					D

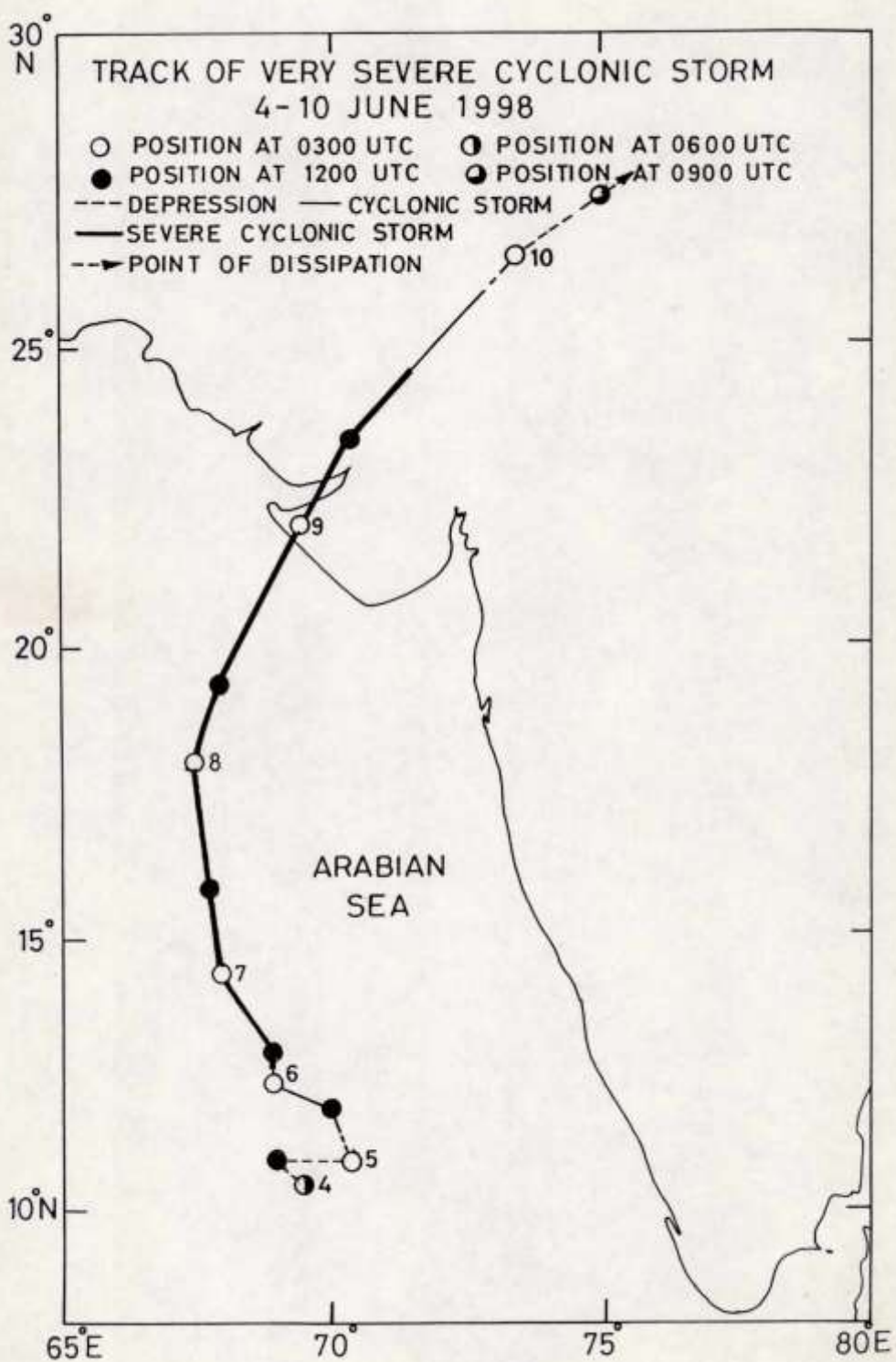


FIG. 2.2.1

Speed of the movement of the VSCS over Arabian Sea (June 4-9 1998)

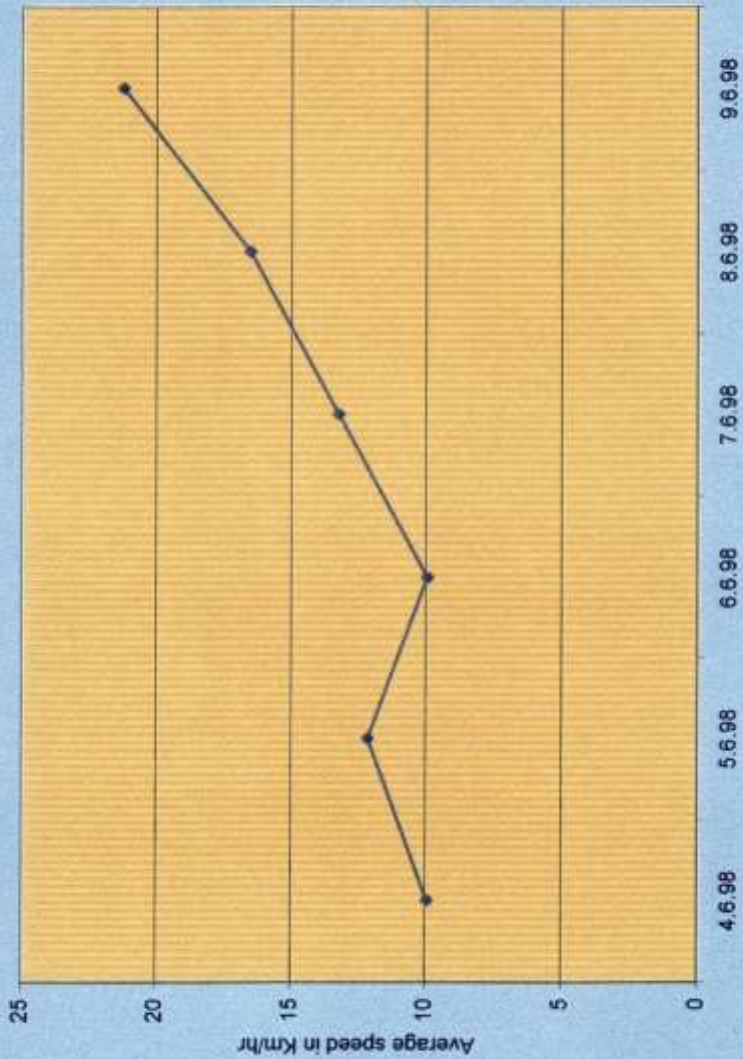


Fig. 2.2.2

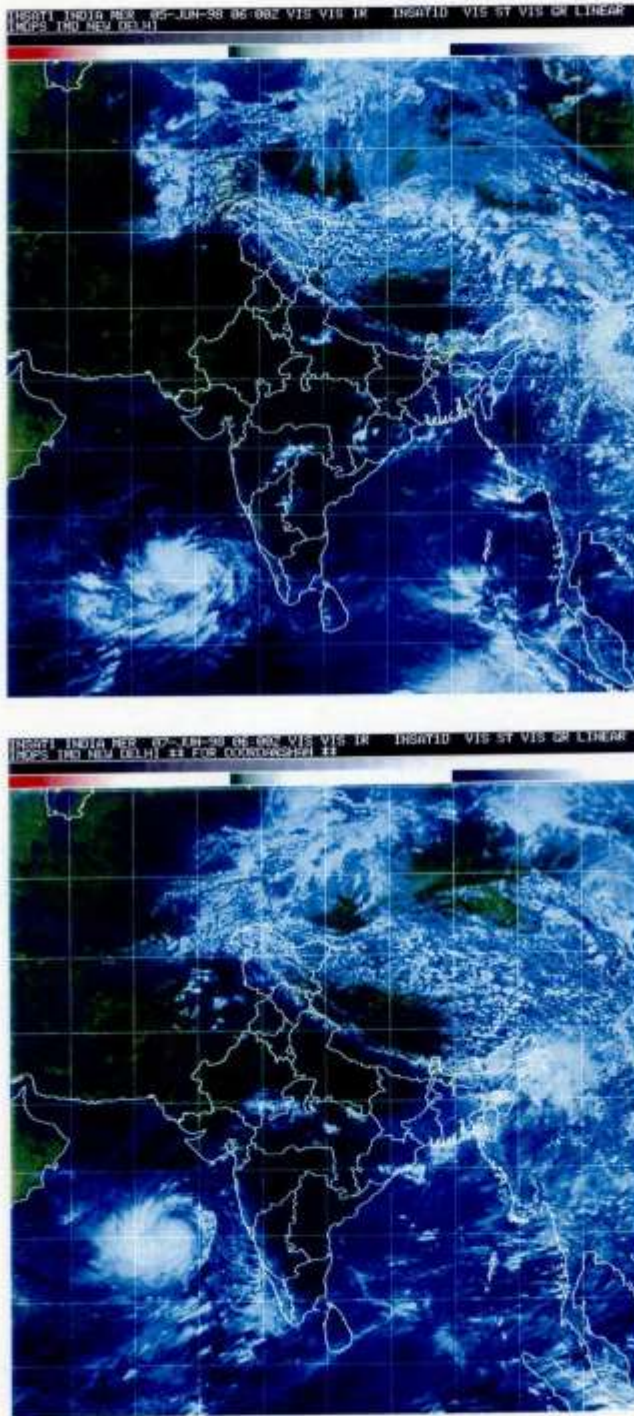


FIG. 2.2.3

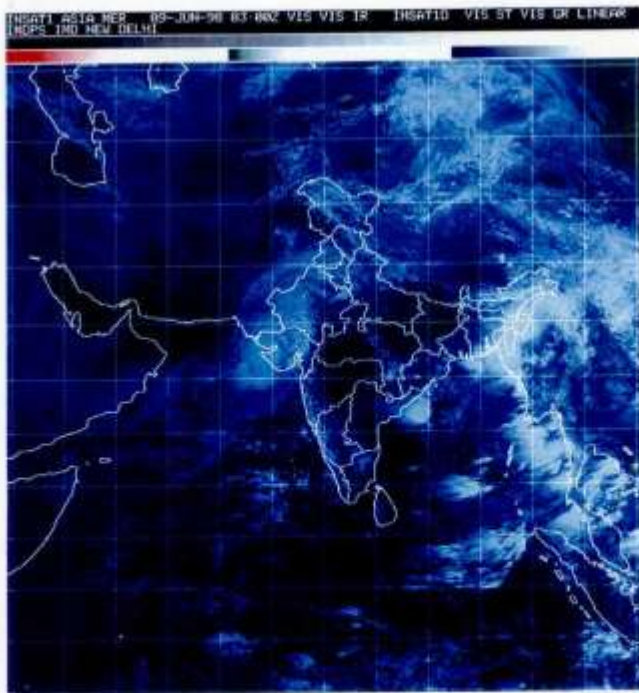
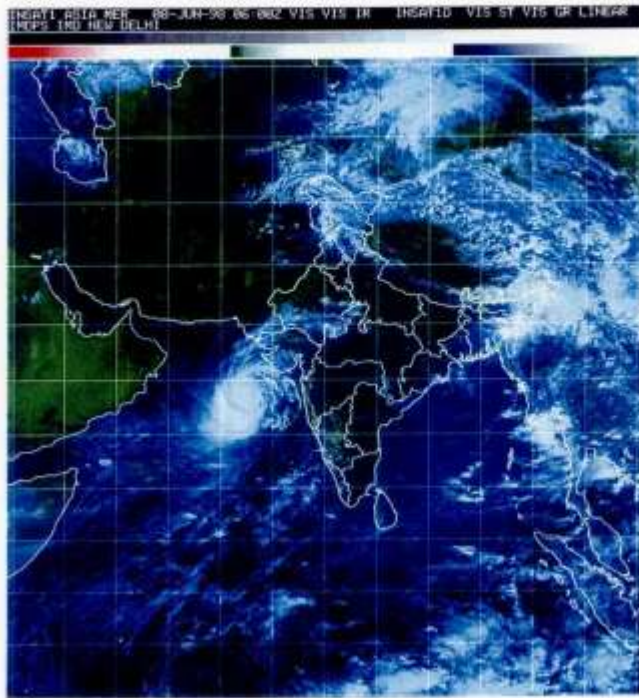
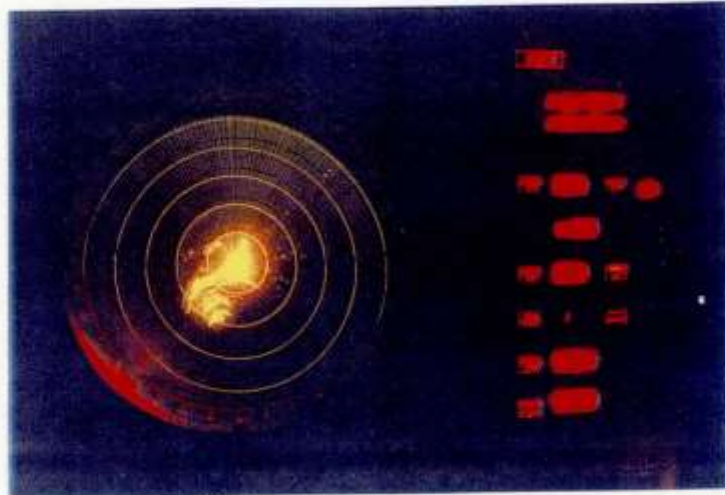
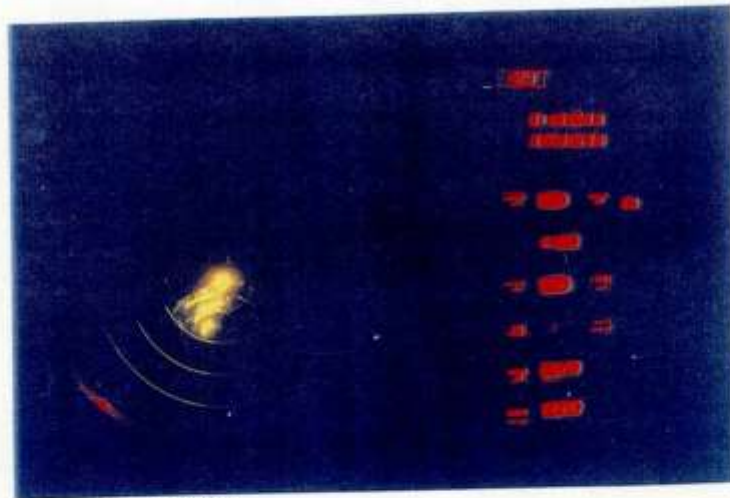


FIG. 2.2.3 contd.

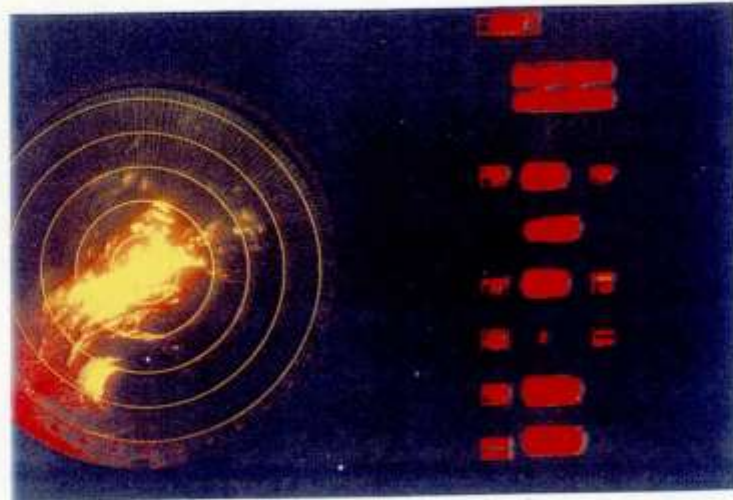


9-6-98 / 0000 UTC

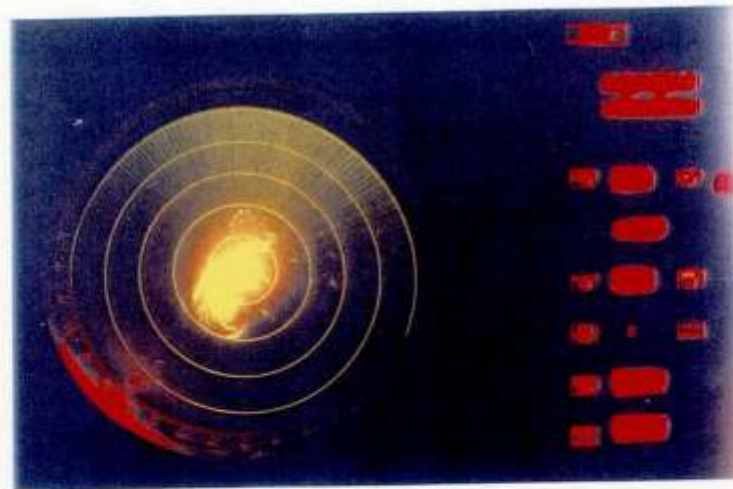


9-6-98 / 0100 UTC

FIG. 2-2-4



9-6-98 / 0200 UTC



9-6-98 / 0300 UTC

FIG. 2-2-4 contd.



DAMAGED MICROWAVE TOWER PORBANDAR



DAMAGED WIND MILLS

FIG. 2.2-5

2.3 BAY OF BENGAL DEEP DEPRESSION (June 13-15, 1998)

The third system developed as a deep depression over the central Bay of Bengal and crossed Andhra Pradesh coast near Visakhapatnam in the evening of June 15.

Towards the end of the second week of June, monsoon current got strengthened over the central Bay of Bengal. A well marked low pressure area formed there on the morning of June 13 and concentrated into a depression by the same day evening with its centre near lat. 17.5° N/long. 87.0° E at 15 UTC. It moved in a westerly direction and intensified into a deep depression near lat. 17.5° N/long. 86.0° E about 250 km east-southeast of Kalingapatnam (43105) by 18 UTC of the same day. Subsequently, without any change in its intensity, it continued to move westwards and lay centred near lat. 17.5° N/ long. 84.5° E on the morning of June 14. Spiralling low level cloud line centre became more marked in the satellite imagery which revealed shear band pattern associated with active monsoon conditions. Thereafter, while moving slowly in the same direction with its centre close to Visakapatnam (43149) in the evening of June 14, the deep depression crossed coast south of Visakapatnam between 15 and 16 UTC and changed its westward course to northwesterly. It weakened gradually into a depression near Jagdalpur (43041) by 21 UTC of the same day. The depression further moved northwestward and lay with its centre about 150 km southeast of Nagpur (42867) on the morning of June 15. While moving in the same direction, the system weakened further into a well marked low pressure area over west Madhya Pradesh by the evening of June 15, 1998.

Best track positions and other parameters are included in Table 2.3.1. The track of the system is given in Fig.2.3.1. A few INSAT cloud images are shown in Fig. 2.3.2.

Weather realised

This depression coupled with a middle latitude westerly trough helped in advancement of the southwest monsoon into Maharashtra, Madhya Pradesh, Bihar, most parts of Uttar Pradesh, southern parts of Gujarat, parts of east Rajasthan and parts of Haryana including Delhi by June 16. The system caused widespread rainfall with scattered heavy to very heavy fall over south Andhra Pradesh and its vicinity. Some of the significant amounts are given below:

Yelamanchili	17cm
Narsipatnam	13cm
Chodavaram	12cm
Anakapalli	12cm
Paderu	11cm

Damage report

No casualties were reported. Low lying areas in Anakapalli and Yellamanchili inundated and in Visakhapatnam trees uprooted and hoardings collapsed in some areas.

Table 2.3.1

Best track position and other parameters for Bay of Bengal
Deep Depression (June 13 - 15, 1998)

Date	Time (UTC)	Centre Lat. ° N /Long. ° E	C.I. NO.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
13.6.98	1500	17.5/87.5	1.5	994	25	4	D
	1800	17.5/86.0	2.0	995	30	5	DD
14.6.98	0000	17.5/85.0	2.0	995	30	5	DD
	0300	17.5/84.5	2.0	995	30	5	DD
	0600	17.5/83.5	2.0	995	30	5	DD
	1200	17.5/83.0	2.0	992	30	6	DD
Crossed Andhra Pradesh Coast near Visakhapatnam between 1500 and 1600 UTC							
14.6.98	1800	18.5/81.5	Over land				D
15.6.98	0000	19.5/80.5	Over Land				D
	0300	20.0./80.0	Over Land				D

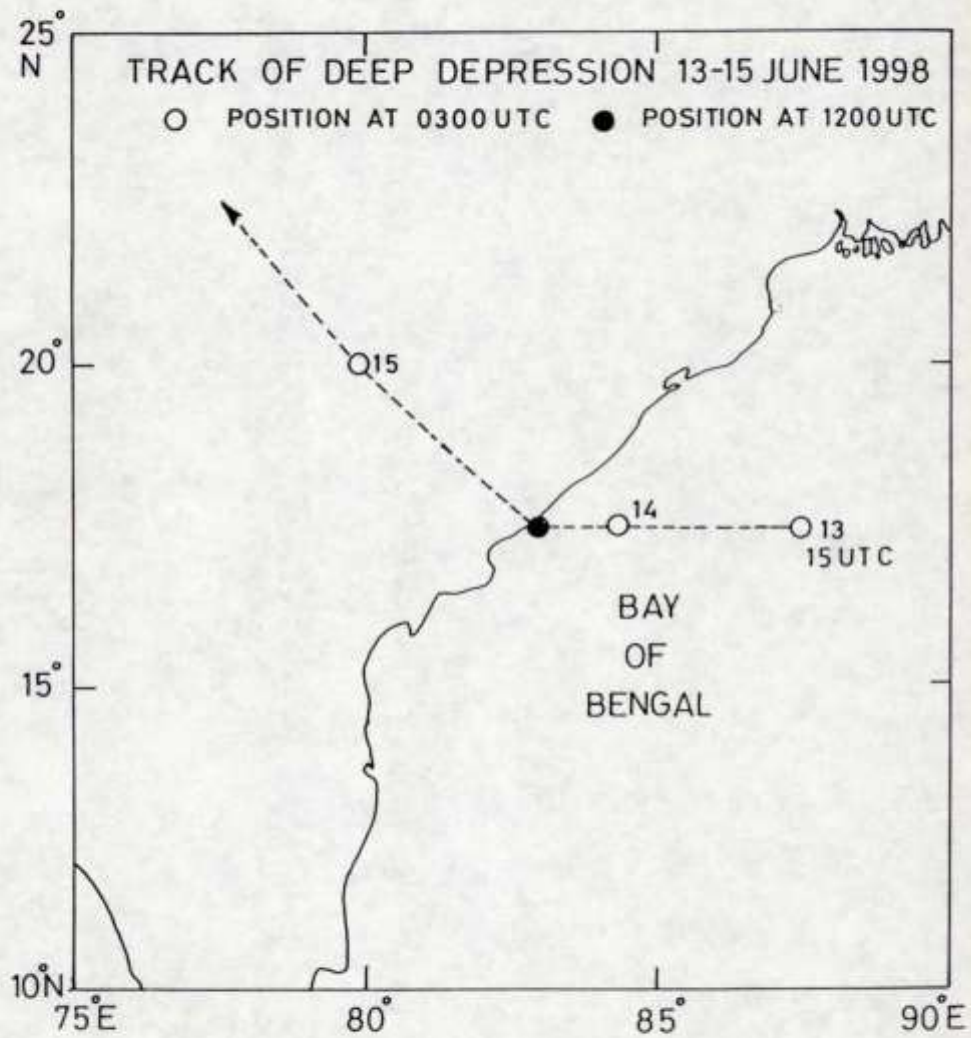


FIG. 2.3.1

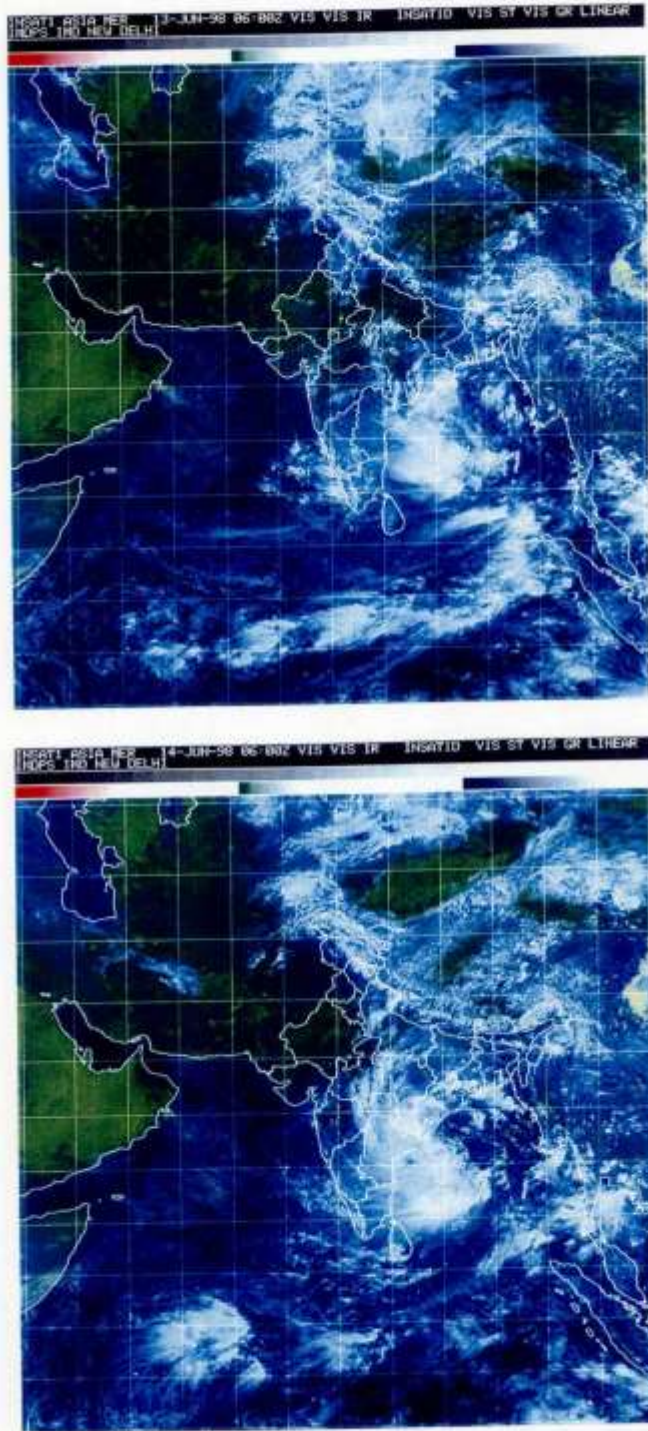


FIG. 2.3.2

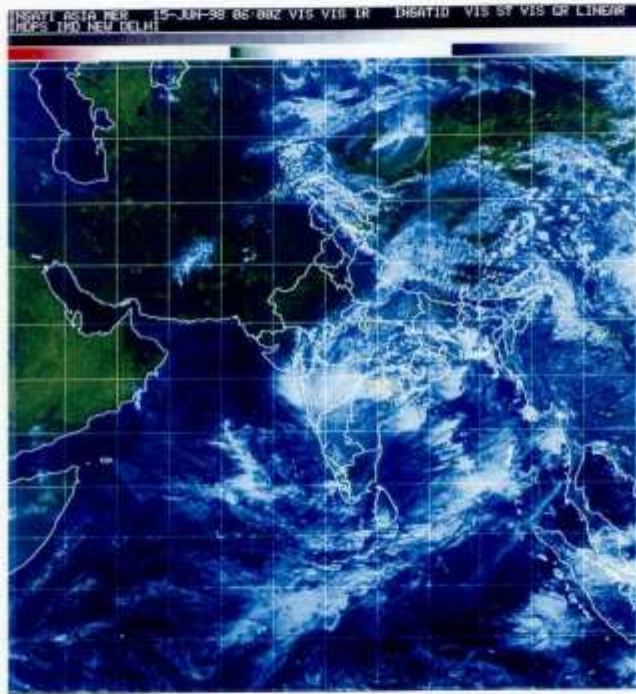


FIG. 2.3.2 contd.

2.4 Deep depression over the Arabian Sea (October 6-9, 1998)

This system developed as a deep depression in the southeast Arabian Sea and weakened over the west central Arabian Sea.

Organised convection was spotted around Lat 14.0°N / Long 69.0°E where a depression was declared at 12 UTC on October 6. Under the steering influence of upper air easterlies south of the ridge at about Lat. 20°N , the depression moved westwards and was upgraded to a deep depression at 03 UTC of October 8 near Lat. 14.0°N / Long 67.0°E when the system showed further signs of organisation. It took a west northwesterly course and was located near Lat 15.0°N / Long 64.5°E at 03 UTC of 9th. The clouds associated with this system started becoming disorganised at this time. It weakened into a depression at 12 UTC near Lat 15.0°N / Long 63.5°E and dissipated over the same area later.

Best track positions and other parameters are included in Table 2.4.1. The track of the system is given in Fig. 2.4.1. A few INSAT cloud images are shown in Fig. 2.4.2.

Weather realised

The system dissipated over sea.

Damage report

The system did not cause any damage to life and property.

Table 2.4.1
Best track position and other parameters for the Arabian Sea
Deep Depression (October 6-9, 1998)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
6.10.98	1200	14.0/69.0	1.5	1002	25	4	D
	1800	14.0/69.0	1.5	1002	25	4	D
7.10.98	0000	14.0/69.0	1.5	1002	25	4	D
	0300	14.0/69.0	1.5	1004	25	4	D
	0600	14.0/68.0	1.5	1002	25	4	D
	1200	14.0/68.0	1.5	1000	25	4	D
8.10.98	1800	14.0/67.5	1.5	1002	25	4	D
	0000	14.0/67.0	2.0	1000	30	6	D
	0300	14.0/67.0	2.0	1002	30	6	DD
	0600	14.0/67.0	2.0	1002	30	6	DD
	1200	14.0/66.0	2.0	998	30	6	DD
	1800	15.0/65.5	2.0	1002	30	6	DD
9.10.98	0000	15.0/64.5	2.0	1000	30	6	DD
	0300	15.0/64.5	2.0	1002	30	6	DD
	0600	15.0/64.0	2.0	1002	30	6	DD
	1200	15.0/63.5	1.5	1004	25	4	D

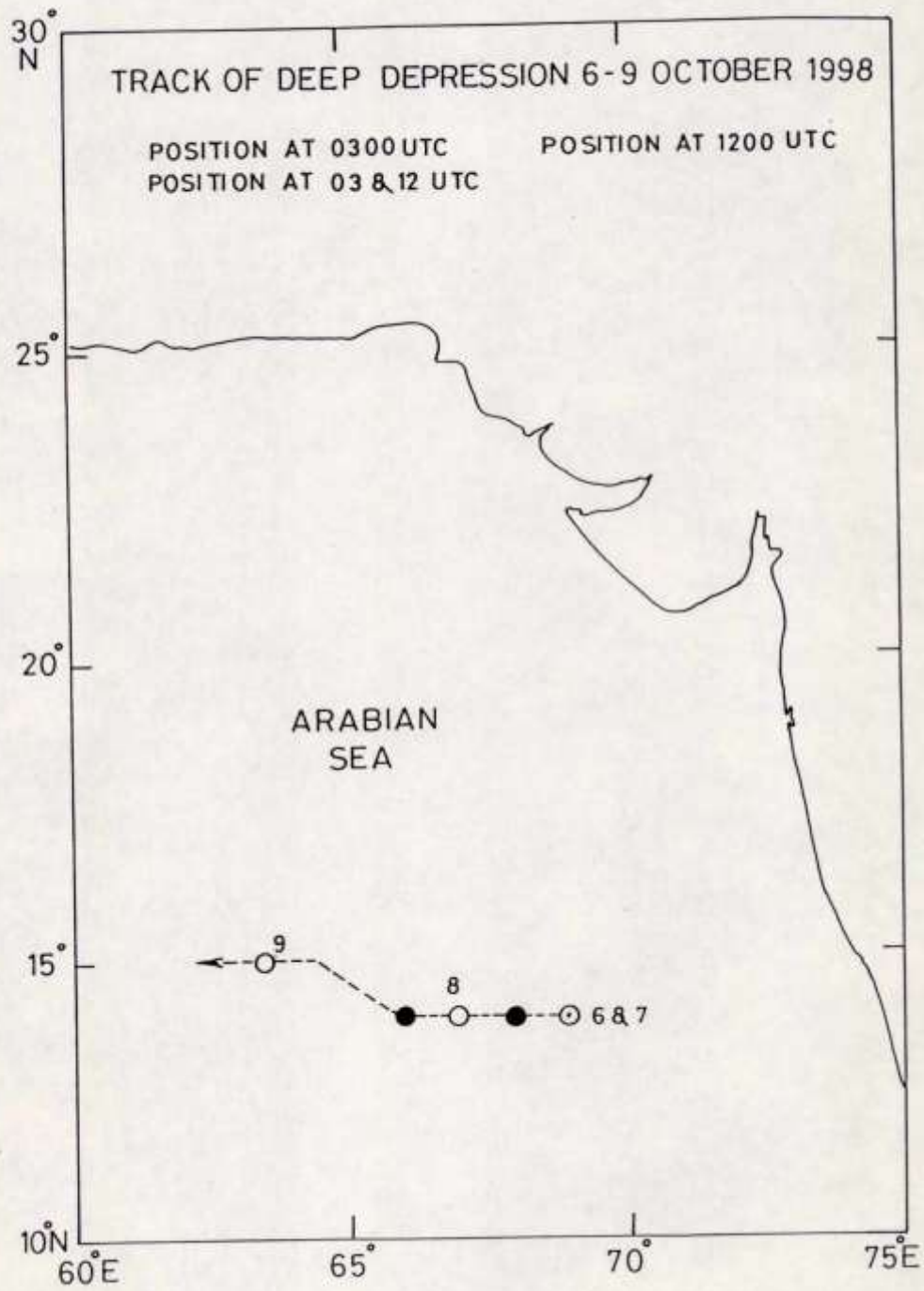


FIG. 2.4.1

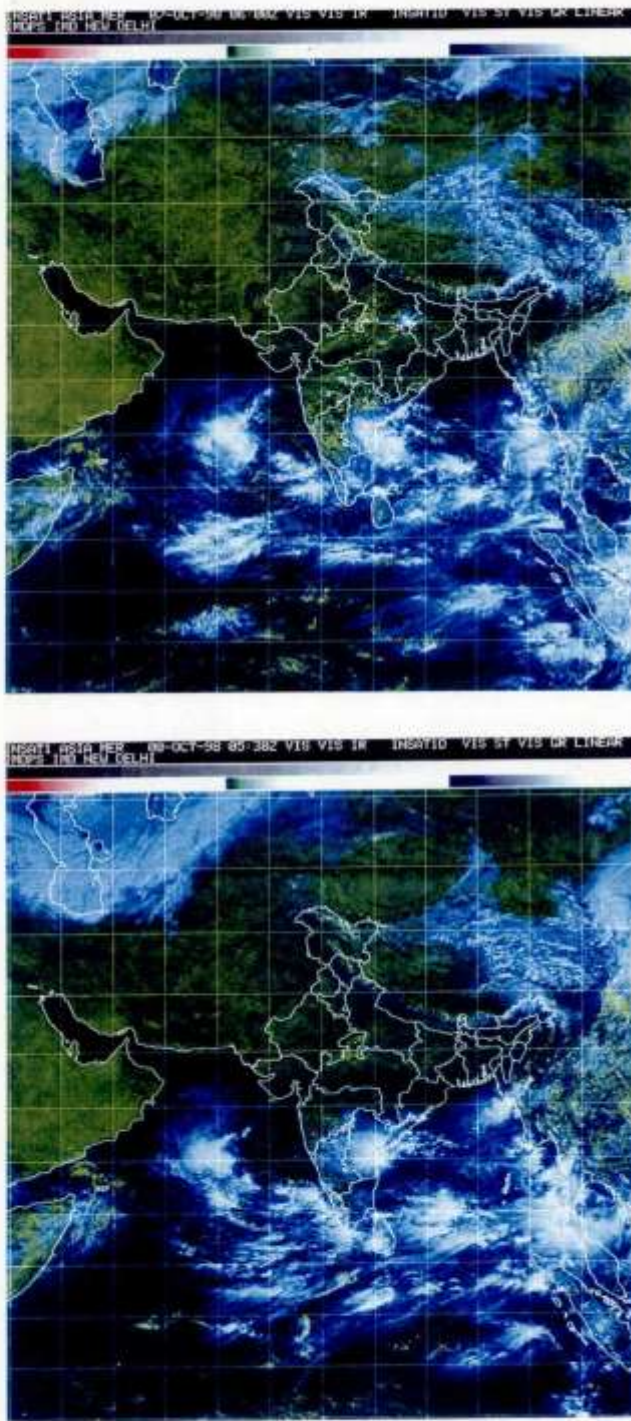


FIG. 2.4.2

2.5 Cyclonic Storm over the Arabian Sea (October 11 –17, 1998) (ARB 98 02 10 11 17)

It was a case of development under the influence of mid –latitude westerly trough. Monsoon was quite active over the southeast Arabian Sea and neighbourhood from the beginning of October. In this region a depression developed at 12 UTC on 11th near Lat. 14.0° N/Long 67.5° E Moving northwestwards it concentrated into a deep depression at 09 UTC of 12th near Lat. 14.5^{or} N/ Long. 66.5° E . It however weakened into a depression at 12 UTC of 13th when it lay near Lat. 16.0^{or} N/ Long. 64.0° E as the environment was characterised by strong vertical wind shear which hampered development. There were occasional surges of intensification which could help locate centre of this system which was tracked mainly with the help of satellite imagery. It continued to move northwestward and lay near Lat. 17.5^{or} N/ Long. 62.0° E at 12 UTC of 14th . A careful analysis of the visible imagery indicates that the depression executed a loop in which it was located near Lat. 16.0^{or} N/ Long. 63.0° E . It again concentrated into a deep depression at 12 UTC of 15th near Lat. 16.5^{or} N/ Long. 64.0° E . Thereafter it took a fast course towards northeast under the influence of westerly trough and intensified further to the stage of a cyclonic storm at 12 UTC of 16th when it lay near Lat. 19.0^{or} N/ Long. 69.0° E . While continuing to move northeast it crossed the coast near Veraval at 02 UTC of October 17. It weakened and dissipated over eastern parts of Gujarat State on the evening of October 17.

Best track positions and other parameters are included in Table 2.5.1 .The track of the system is given in Fig.2.5.1. A few INSAT cloud images are shown in Fig. 2.5.2.

Weather realised :

Under the influence of this system Gujarat State recorded significant amounts of rainfall from 16.10.98 to 17.10.98. Some of the chief amounts are given below.

Stations	Date	Amount of R/F in cm
Palanpur	16.10.98	11
	17.10.98	11
Banta	17.10.98	16
Dantiwada	17.10.98	10
Bhakudar	17.10.98	15
Khamba	17.10.98	10
Savarkundla	17.10.98	15
Okha	16.10.98	10
Bhuj	16.10.98	19
Naliya	16.10.98	15
Kutch Mandvi	16.10.98	14
Khavda	16.10.98	10

Damage report

The system did not cause any damage to life and property .

Table 2.5.1

Best track position and other parameters for the Arabian sea
Cyclonic Storm (October 11-17, 1998)

Date	Time (UTC)	Centre Lat. ° N /Long. ° E	C.I. No..	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated Pressure drop at the centre	Grade
11.10.98	1200	14.0/67.5	1.5	1002	25	4	D
	1800	15.0/66.5	1.5	1002	25	4	D
12.10.98	0000	15.0/66.0	1.5	1000	25	4	D
	0300	14.5/66.5	1.5	1000	25	4	D
	0600	15.0/65.0	1.5	1000	25	4	D
	0900	14.5/66.5	2.0	998	30	6	DD
	12	15.0/66.0	2.0	998	30	6	DD
	18	15.0/65.5	2.0	998	30	6	DD
	00	15.0/65.5	2.0	998	30	6	DD
13.10.98	0300	15.5/65.0	1.5	998	30	6	DD
	06	15.5/64.5	1.5	998	30	6	DD
	12	16.0/64.0	1.5	998	25	6	D
	18	16.0/64.0	1.5	1000	25	4	D
	00	16.5/63.5	1.5	1002	25	4	D
14.10.98	03	17.0/63.0	1.5	1004	25	4	D
	06	17.0/62.5	1.5	1004	25	4	D
	12	17.5/62.0	1.5	1004	25	4	D
	18	16.5/61.0	1.5	1000	25	4	D
	00	16.5/62.5	1.5	1000	25	4	D
15.10.98	03	16.0/63.0	1.5	1000	25	4	D
	06	16.0/63.5	1.5	998	25	4	D
	12	16.5/64.0	2.0	994	30	6	DD

Table 2.5.1 (continued)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I. No..	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre.	Grade
15.10.98	18	16.5/64.0	2.0.	996	30	6	DD
16.10.98	00	17.0/64.5	2.0.	996	30	6	DD
	03	17.0/64.5	2.0	996	30	6	DD
	06	18.5/66.0	2.0	998	30	6	DD
	12	19.0/68.0	2.5	996	35	8	CS
	18	20.0/69.5	2.5	996	35	8	CS
17.10.98	00	20.5/70.0	2.5	998	35	8	CS
Crossed Gujarat coast near Veraval (42909) between 0100 and 0200 UTC							
17.10.98	03	22.5/73.0	Over land				DD

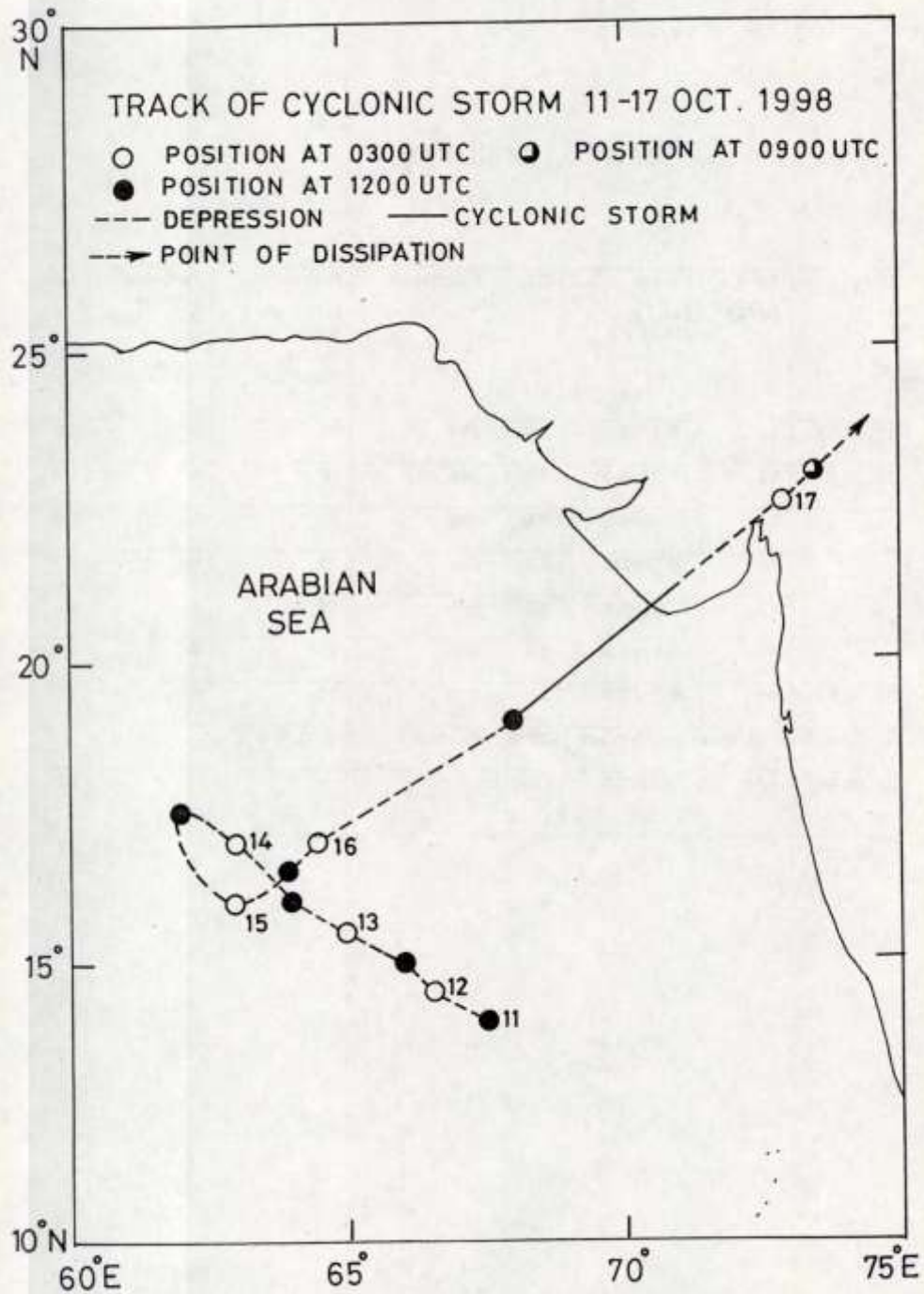


FIG. 2.5.1

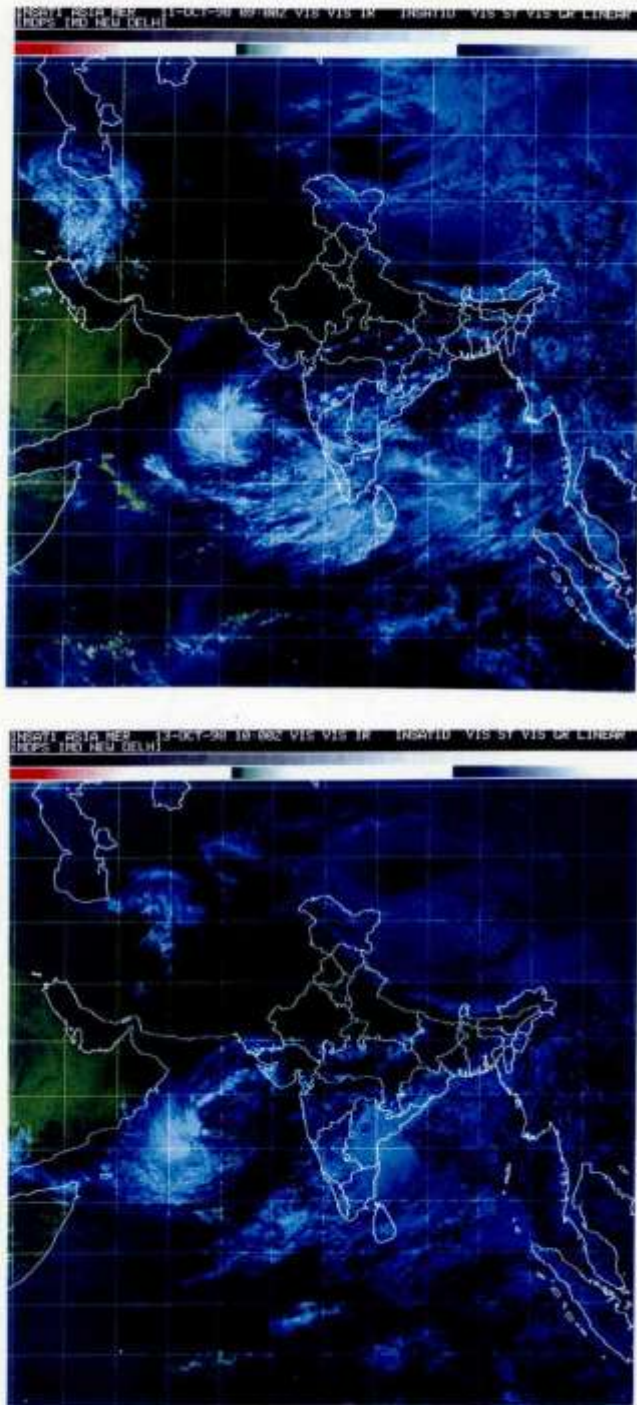


FIG. 2-5-2

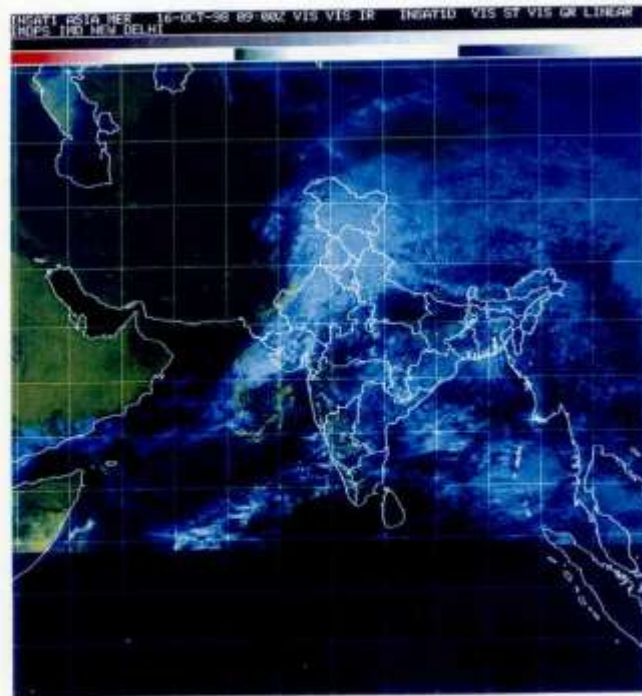
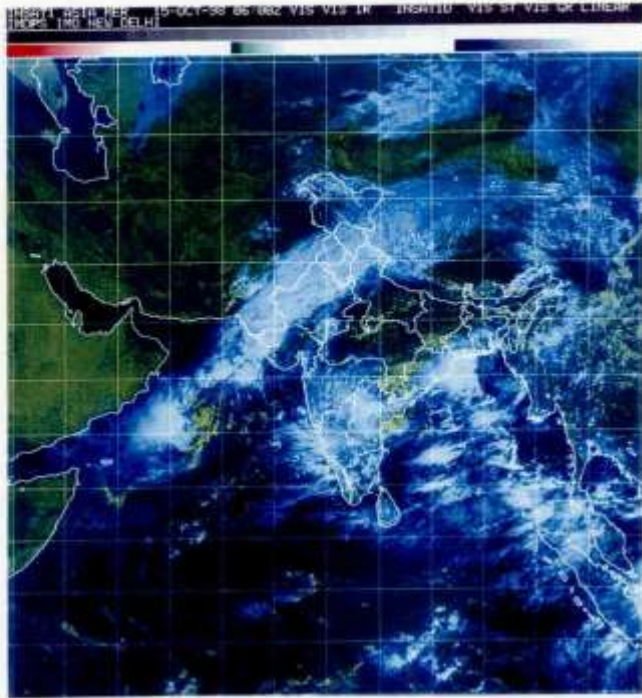


FIG. 2-5-2 contd.

2.6 Deep Depression over the Bay of Bengal (October 13-15, 1998)

In the continued monsoon activity over Central Bay of Bengal a depression formed in the monsoon shear zone over west central Bay of Bengal at 12 UTC of October 13 near Lat. 15.5°N / Long. 82.5°E . It moved slightly westwards and concentrated into a deep depression centred near 15.5°N / Long. 82.0°E at 18 UTC of the same day. At this stage the system came under the range of Cyclone Detection Radar (CDR), Machilipatnam which detected the centre at 0300 UTC of 14th near Lat. 15.5°N / Long. 81.9°E . The system was continuously tracked by CDR Machilipatnam. It crossed coast near Narsapur (43187) at 16 UTC of the same day. It weakened into a depression which was centred about 100 kms west of Kakinada (43189) at 18 UTC of 14th. The system subsequently moved in a northwesterly direction and weakened gradually.

Best track positions and other parameters are included in Table 2.6.1. The track of the system is given in Fig.2.6.1. The Fig.2.5.2 may be referred for the cloudiness associated with this system also. A few radar images of CDR Machilipatnam are included in Fig. 2.6.2.

Weather realised.

Under the influence of this system coastal Andhra Pradesh recorded significant amounts of rainfall from 13.10.98 to 15.10.98. Some of the chief amounts are given below.

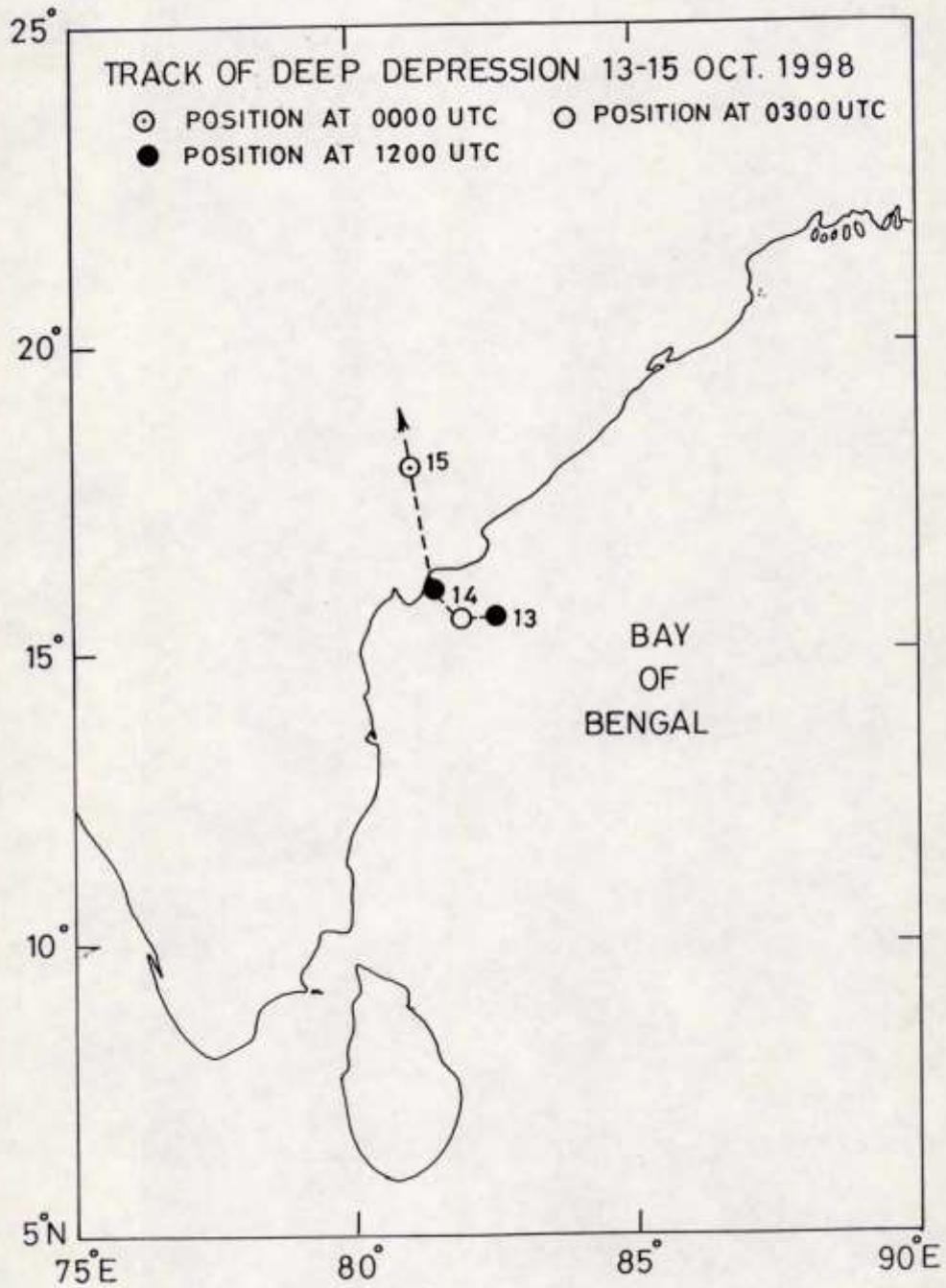
Station	Date	Amount of rainfall (cm)
Kalingapatnam	13.10.98	11
	14.10.98	12
Avanigadda	15.10.98	15

Damage report

Lives lost	101
Bridges submerged	50
Damage to crops	52,657 acres
Breaches to tanks	Rs.600 Crores

Table 2.6.1
Best track position and other parameters for the Bay of Bengal
Deep Depression (October 13-15, 1998)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I. No.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
13.10.98	1200	15.5/82.5	1.5	1000	25	4	D
	1800	15.5/82.0	2.0	1000	30	6	DD
14.10.98	0000	15.5/82.0	2.0	1000	30	6	DD
	0300	15.5/82.0	2.0	1000	30	6	DD
	0600	15.5/82.0	2.0	1000	30	6	DD
	1200	16.0/81.5	2.0	998	30	6	DD
The system crossed Andhra Pradesh coast near Narsapur (43187) at 1600 UTC							
14.10.98	1800	17.0/81.5				4	D
15.10.98	0000	18.0/81.0				4	D



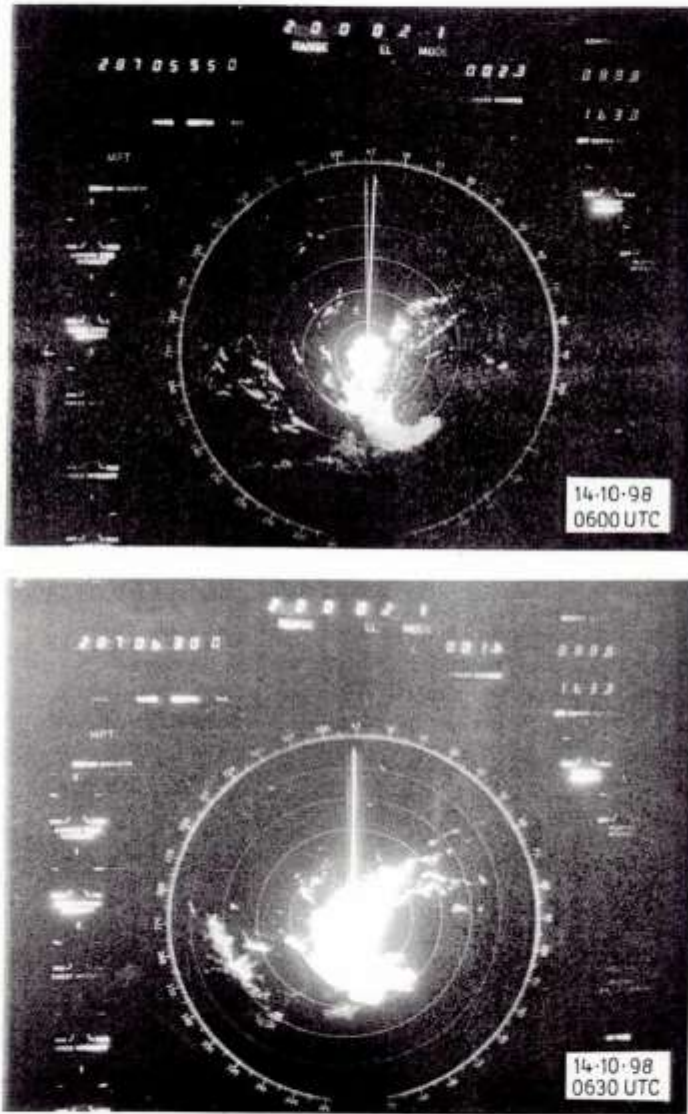


FIG. 2-6-2

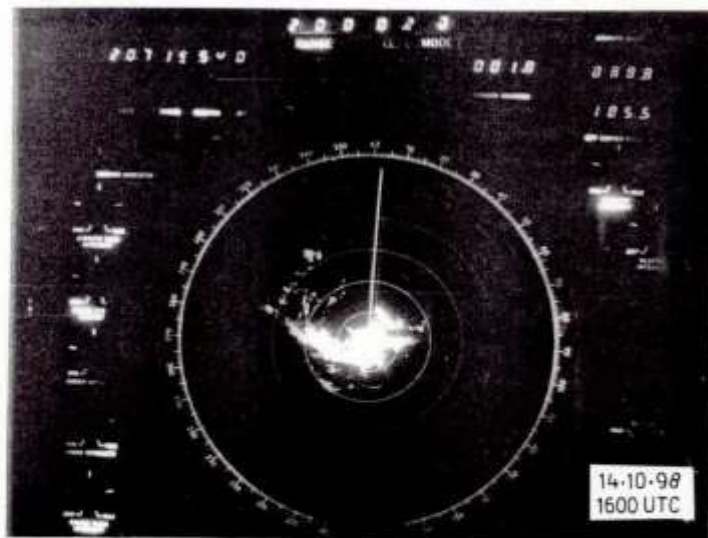


FIG. 2-6-2 contd.

2.7 Deep Depression over the Bay of Bengal (October 26- 29, 1998)

The last system formed as a depression over the southeast Bay at 09 UTC on October 26 near Lat.11.0°N /Long.90.0°E. It moved northwestwards and intensified into a deep depression at 12 UTC on 27th when it was located near Lat.13.0°N/Long.87.0° E. Hereafter it moved westwards and lay centred at 00 UTC of 29th near Lat. 13.0°N/Long.83.0°E. It again took a northwestward course and weakened into a depression at 09 UTC of 29th when it was centred at Lat. 14.0°N/Long.82.5°E. The system further weakened into a low pressure area over west central Bay off Andhra Pradesh coast in the evening of October 29.

The system was tracked mainly with the help of INSAT cloud imagery.

Best track positions and other parameters are included in Table 2.7.1. The track of the system is given in Fig.2.7.1. A few INSAT cloud images are shown in Fig. 2.7.2

Weather realised

The system dissipated over the sea.

Damage report

It did not cause any damage to life and property.

Table 2.7.1
Best track position and other parameters for Bay of Bengal
Deep Depression (October 26-29, 1998)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I. No	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
26.10.98	0900	11.0/90.0	1.5	1002	25	4	D
	1200	11.5/88.5	1.5	1002	25	4	D
	1800	12.0/88.0	1.5	1004	25	4	D
27.10.98	0000	12.0/88.0	1.5	1004	25	4	D
	0300	12.0/88.0	1.5	1004	25	4	D
	0600	12.5/87.0	1.5	1004	25	4	D
	1200	13.0/87.0	2.0	1002	30	6	DD
	1800	13.0/86.0	2.0	1002	30	6	DD
28.10.98	0000	13.0/85.5	2.0	1002	30	6	DD
	0300	13.0/85.0	2.0	1004	30	6	DD
	0600	13.0/84.5	2.0	1004	30	6	DD
	1200	13.0/84.0	2.0	1004	30	6	DD
	1800	13.0/83.5	2.0	1004	30	6	DD
29.10.98	0000	13.0/83.0	2.0	1004	30	6	DD
	0300	13.5/83.0	2.0	1004	30	6	DD
	0600	13.8/83.0	2.0	1004	30	6	DD
	0900	14.0/82.5	1.5	1004	25	4	D
The system weakened into a well marked low pressure area over west central Bay of Bengal off Andhra Pradesh coast in the evening of October 29							

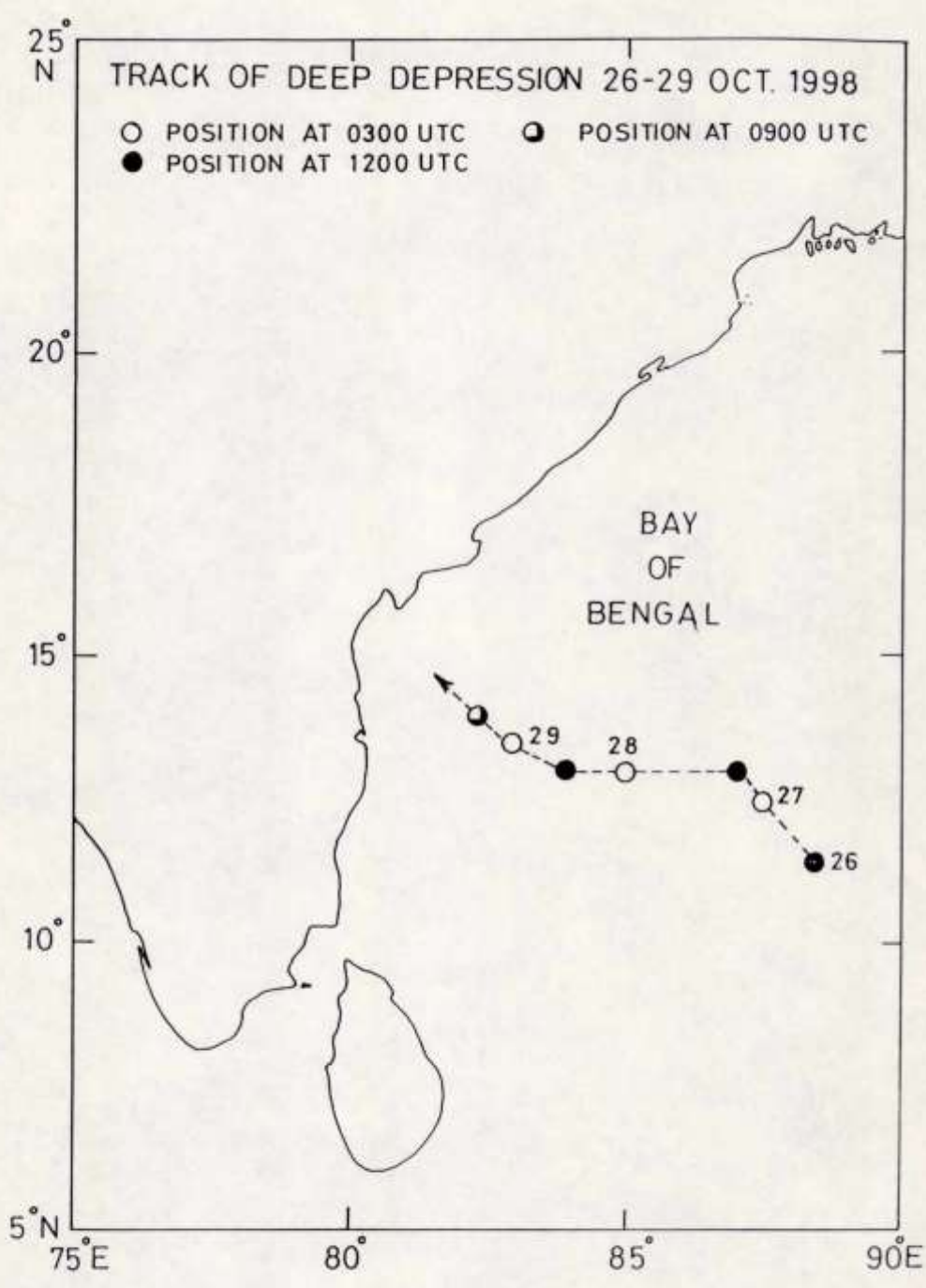


FIG. 2.7.1

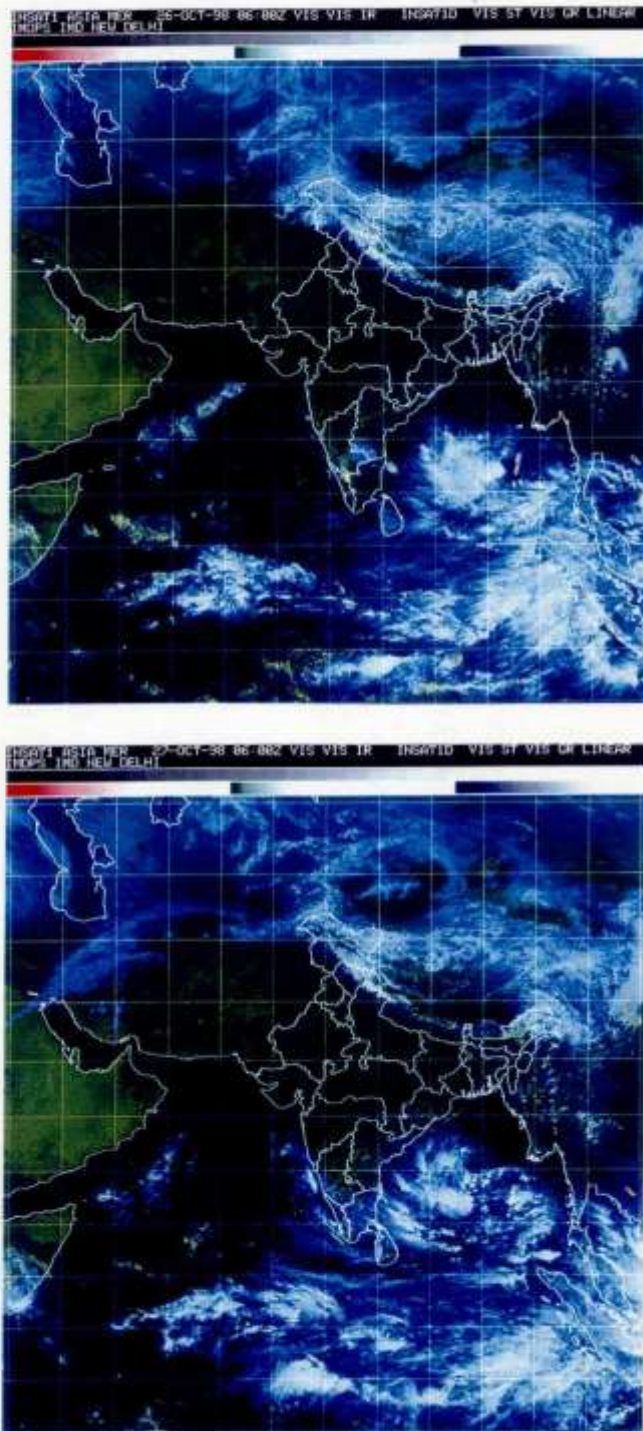


FIG.2-7-2

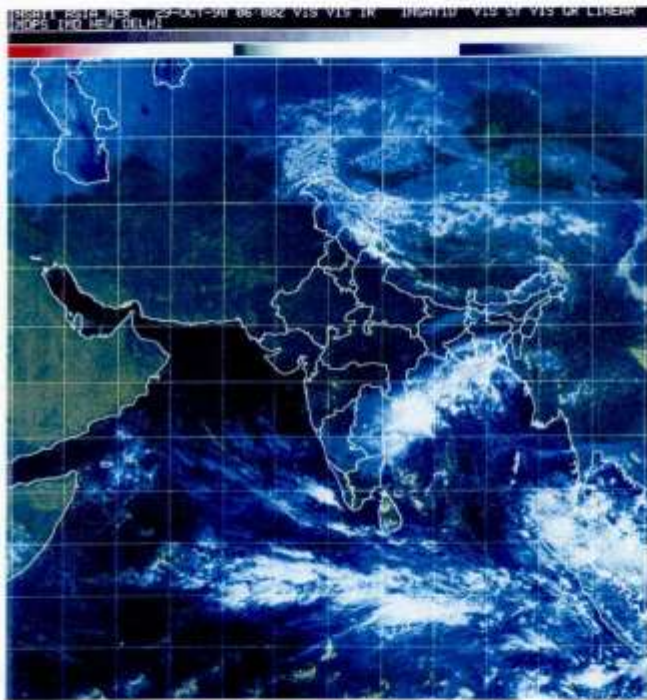


FIG. 2-7-2 contd.

**2.8 Very Severe Cyclonic Storm over the Bay of Bengal
(November 13 - 16, 1998)
(BOB 98 02 11 13 16)**

This system developed over the Bay of Bengal and rapidly intensified to the stage of a very severe cyclonic storm before crossing north Andhra Pradesh coast near Visakhapatnam around 1200 UTC of November 15.

A disturbance was seen in the satellite imagery in the southeast Bay of Bengal and neighbourhood on November 13. It showed improved organisation in the satellite imagery at 1200 UTC of the same day. Its intensity is fixed at the depression stage at this time when it was located near lat. 13.0° N/ Long. 87.5° E. Tight spiral band structure indicates that the system intensified to the deep depression stage at 0300 UTC of November 14 when it was located near Lat 13.5° N/ Long. 86.5° E. While moving northwestwards, and with the rapid intensification process being continued, the system acquired intensity of cyclonic storm by 0900 UTC near Lat 14.0° N/ Long. 86.0° E. It became a severe cyclonic storm with its centre near Lat 15.0° N/ Long. 85.0° E at 1800 UTC of the same day. While continuing to move in the same direction it intensified to a very severe cyclonic storm with its centre near lat. 16.0° N/ Long. 84.0° E. at 0300 UTC of November 15. Tight banding eye pattern was seen in the INSAT imagery at this stage. After crossing coast, on account of land interaction it weakened immediately into a severe cyclonic storm at 1200 UTC near lat. 17.5° N/ Long. 83.0° E. Hereafter the weakening was more rapid. It took a northward course and weakened into a depression over East Madhya Pradesh near lat. 21.0° Deg. N/ Long 83.0° E by 06 UTC of November 16. It became unimportant over east M.P. later.

The system was tracked with the help of INSAT cloud Imagery and CDRs at Machilipatnam and Visakhapatnam. The radar pictures of Visakhapatnam indicated an eye of diameter of about 20 Km with eye-wall width of about 20 Km at 1000 UTC. The lowest mean sea level pressure of 983.0 hPa was recorded at Waltair (43150) at 1100 UTC of November 15. Gale wind speeds reaching 71 and 73 Kmph were recorded at Waltair and Visakhapatnam (Airport) observatories respectively on November 15 before the system crossed the coast.

Best track positions and other parameters are included in Table 2.8.1. The track of the system is given in Fig.2.8.1. The track predicted by the RSMC -Tropical Cyclone New Delhi Limited Area Forecast Model for various initial positions is given in Fig. 2.8.2. A few INSAT cloud images are shown in Fig. 2.8.3. A few photographs of X-band digital radar at Visakhapatnam are included in Fig.2.8.4.

Weather realised

The significant amount of rainfall (Cm) during 24 hours period ending at 0300 UTC of November 16 , 1998 is as below:

Yellamanchili	15	Chodaveram	12
Anakapalli	10	Palasan	10

Damage report

Total loss of lives was 16 , being the lowest in the recent times due to any such cyclone that crossed Andhra Pradesh Coast.

Table 2.8.1

Best track position and other parameters for the Bay of Bengal
Very Severe Cyclonic Storm (November 13- 16,1998)

Date	Time (UTC)	Centre Lat. ° N /Long. ° E	C.I. No.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
13.11.98	1200	13.0/87.5	1.5	1004	25	4	D
14.11.98	0300	13.5/86.5	1.5	1002	30	6	DD
	0600	14.0/86.0	2.0	1002	30	6	DD
	0900	14.0/86.0	2.5	998	35	8	CS
	1200	14.5/85.5	3.0	996	45	10	CS
	1800	15.0/85.0	3.5	992	55	15	SCS
15.11.98	0000	15.5/84.5	3.5	992	55	15	SCS
	0300	16.0/84.0	4.0	988	65	21	VSCS
	0600	16.5/83.5	4.5	982	77	29	VSCS
	0900	17.0/83.5	4.0	982	65	21	VSCS
Crossed north Andhra Pradesh coast close to Visakhapatnam and south of it between 11 and 12 UTC							
15.11.98	1200	17.5/83.0					SCS
	1800	19.5/82.0					CS
16.11.98	0000	20.0/82.0					CS
	0300	20.5/82.0					DD
	0600	21.0/83.0					D

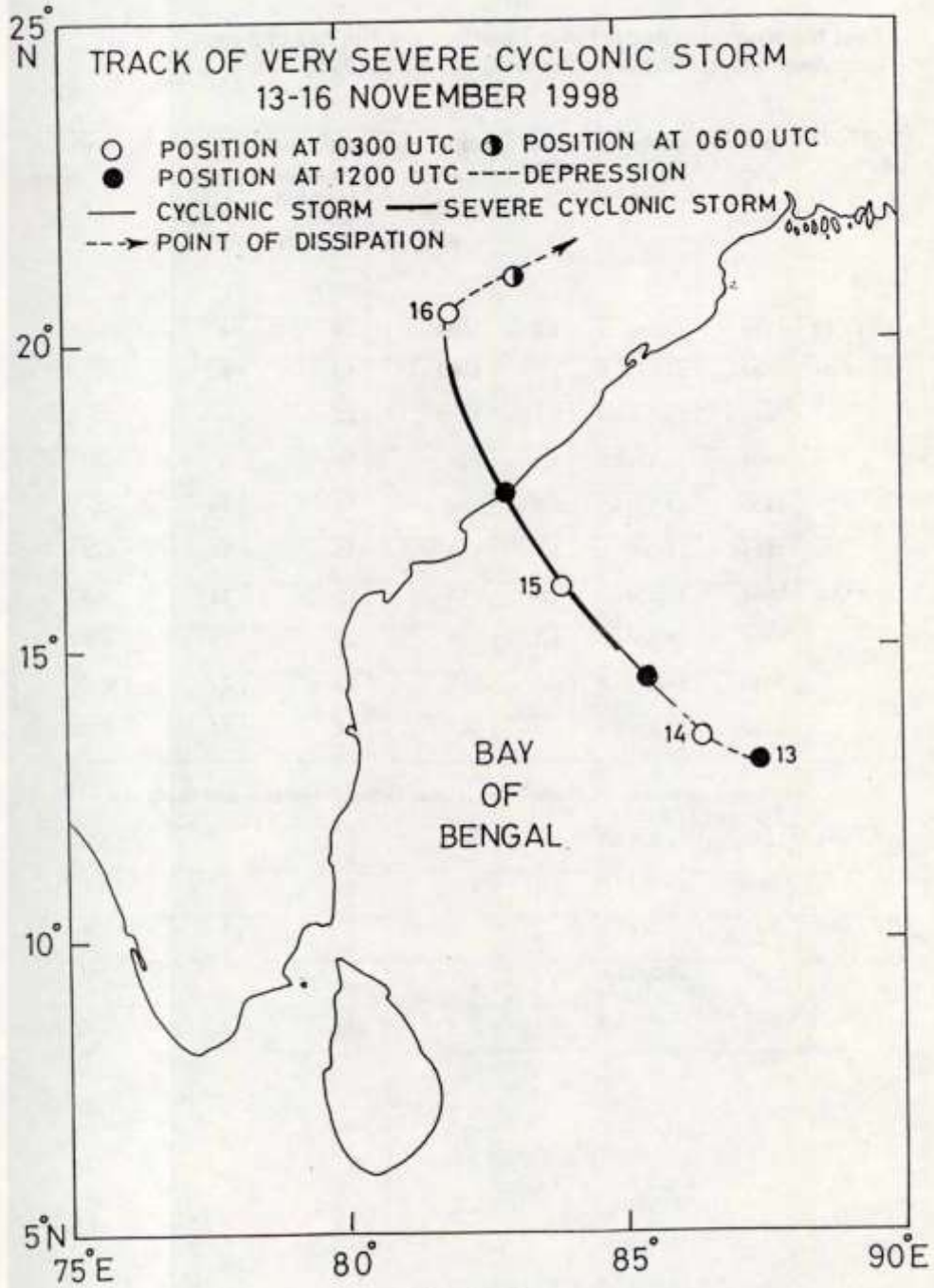


FIG. 2.8.1

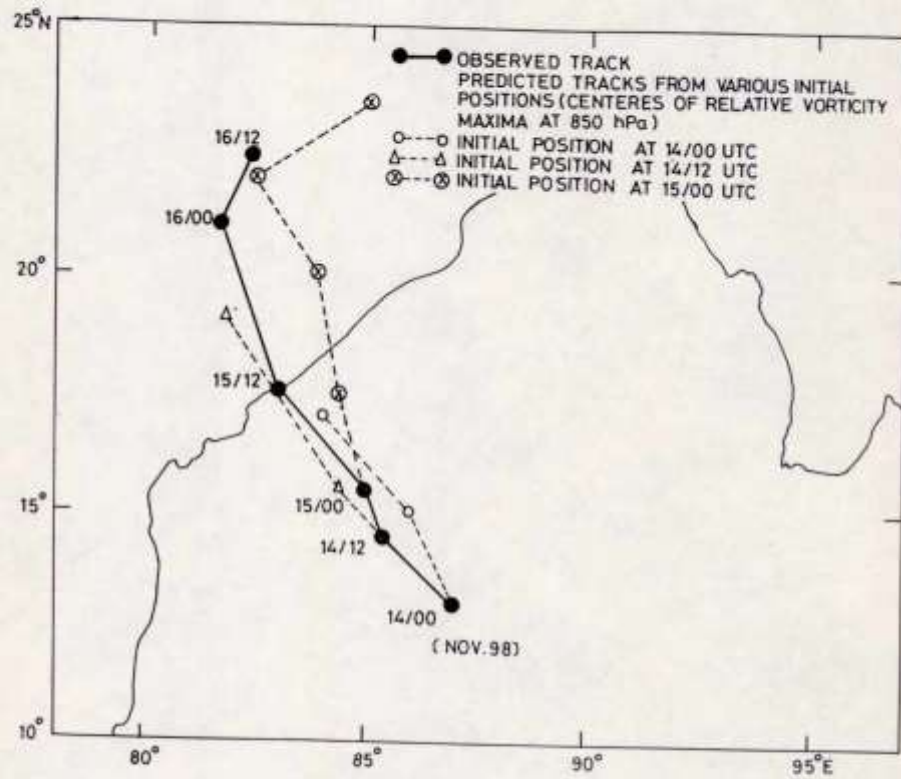


FIG. 2-8-2 TRACK PREDICTED BY IMD LIMITED AREA MODEL

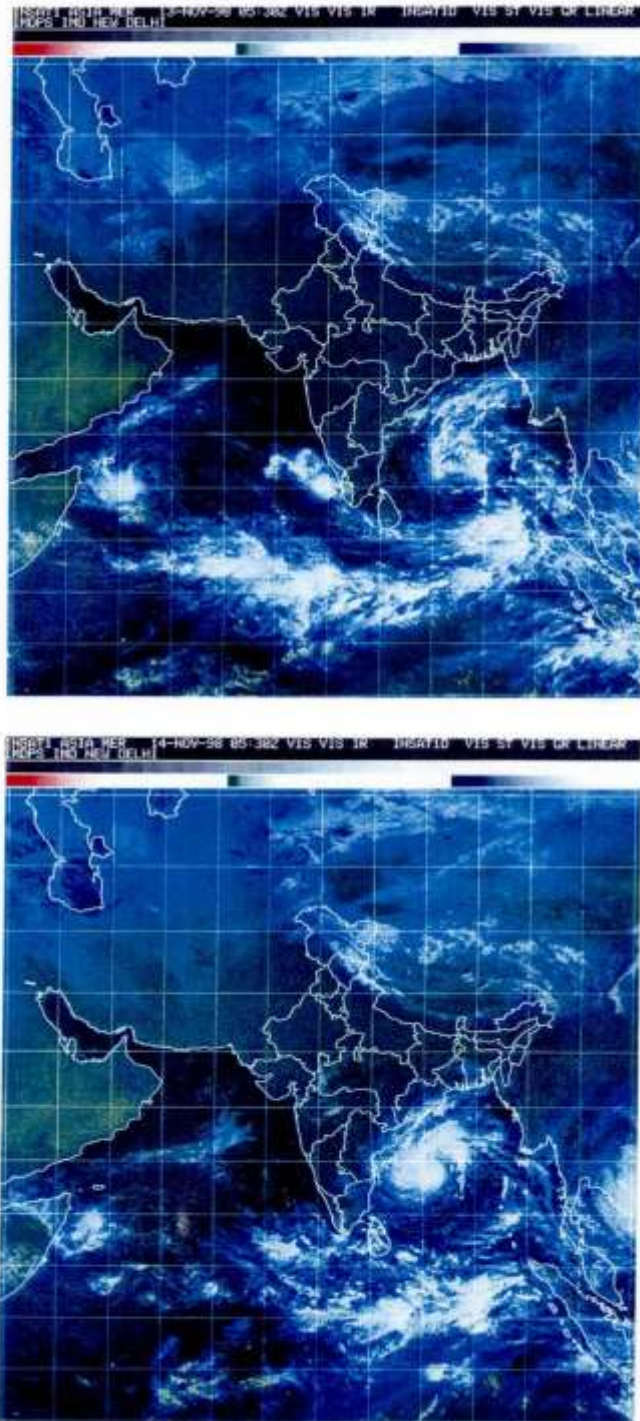


FIG.2-8-3

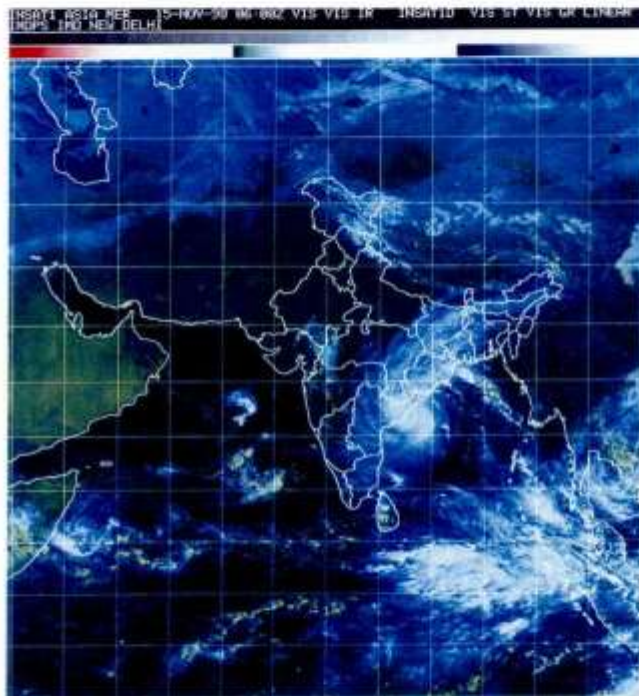


FIG. 2-8-3 contd.

2.9 Very Severe Cyclonic Storm over the Bay of Bengal (November 19 - 23, 1998) (BOB 03 98 11 19 23)

This system originated over the Andaman sea and acquired the intensity of a very severe cyclonic storm over the Bay of Bengal before undergoing recurvature. It got sheared off at the time of crossing West Bengal coast about 30 Km east of Sagar Island around noon of November 22.

Initial development occurred as a depression over the Andaman Sea near Lat.12.0° N / Long 92.5° E at 03 UTC of November 19. Moving in a northwesterly direction, it intensified into a deep depression near Lat.12.5° N / Long 91.5° E by 12 UTC of the same day. Continuing to move in the same direction under the steering flow associated with the ridge to the northeast, it further intensified into a cyclonic storm at 03 UTC of November 20 over west central and adjoining east central Bay of Bengal near Lat.14.5° N / Long 88.5° E when a coma cloud organisation was noticed in the satellite imagery. The system then moved in a northnorthwesterly direction and intensified into a severe cyclonic storm which lay centred near Lat.17.5° N / Long 87.5° E at 06 UTC of November 21. The system continued to move in the same direction and intensified into a very severe cyclonic storm near Lat.19.5° N / Long 87.5° E at 1800 UTC of the same day when highly organised core convection accompanied with a moat was seen in the satellite imagery. Hereafter the system recurved and came under the influence of the strong vertical wind shear associated with stronger westerlies aloft. Deep convection was sheared off northeastwards just before the landfall. The system weakened to the stage of a severe cyclonic storm at 03 UTC of November 22 near Lat.21.5° N / Long 88.5° E. It crossed West Bengal coast east of Sagar Island around noon of November 22 and rapidly weakened into a deep depression which lay centred near Lat. 22.5° N / Long 90.0° E at 12 UTC of the same day. After landfall the system moved eastnortheastwards. It further weakened into a depression at 03 UTC of November 23 near Lat.23.0° N / Long 90.5° E. It further moved eastnortheastwards and dissipated gradually.

Best track positions and other parameters are included in Table 2.9.1. The track of the system is given in Fig.2.9.1. The track predicted by the RSMC -Tropical Cyclone New Delhi Limited Area Forecast Model for various initial positions is given in Fig. 2.9.2. The speed of movement of the system is given in Fig. 2.9.3. A few INSAT cloud images are shown in Fig. 2.9.3.

Weather realised

Under the influence of this system heavy rainfall (Cm) was reported from a few places. Some of the chief amounts of rainfall are given below:

Sagar Island	22.11.98	16
Krishnagar	23.11.98	10

Damage report

Parts of Sagar Island were submerged affecting 25000 people in 8 villages and 3000 mud houses collapsed. 300,000 people were affected in South 24-Parganas districts of West Bengal. 8000 houses were damaged fully and 19000 houses damaged partially in 24-Parganas district and about 316925 hectares land of paddy crops were completely destroyed in Midnapur district. More than 100 trees uprooted in Calcutta and suburbs.

Maximum wind speed at M.O. Calcutta rose to 66 Kmph gusting to 73 Kmph between 22/0530 to 22/0550 UTC.

Table -2.9.1
Best track position and other parameters for the Bay of Bengal
Very Severe Cyclonic Storm (November 19-23, 1998)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I. No.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
19.11.98	0300	12.0/92.5	1.5	1002	25	4	D
	0600	12.0/92.5	1.5	1002	25	4	D
	1200	12.5/91.5	2.0	1000	30	6	DD
	1200	12.5/91.5	2.0	1000	30	6	DD
	1800	12.5/91.0	2.0	1002	30	6	DD
20.11.98	0000	14.0/89.0	2.0	1002	30	6	DD
	0300	14.5/88.5	2.5	1000	35	8	CS
	0600	15.0/88.0	2.5	998	35	10	CS
	0900	15.5/88.0	2.5	996	35	10	CS
	1200	15.5/88.0	3.0	996	45	10	CS
	1800	16.0/88.0	3.0	996	45	10	CS
21.11.98	0000	16.5/87.5	3.0	996	45	10	CS
	0300	17.0/87.5	3.0	992	55	16	CS
	0600	17.5/87.5	3.5	992	55	16	SCS
	0900	18.0/87.5	3.5	992	55	16	SCS
	1200	19.0/87.5	4.0	984	65	24	VSCS
	1800	19.5/87.5	4.0	984	65	24	VSCS
22.11.98	0000	20.5/88.0	4.0	984	65	24	VSCS
	0300	21.5/88.5	3.5	990	60	18	SCS
	0600	22.0/89.0	3.5	998	55	10	SCS
The system crossed West Bengal coast east of Sagar Island around noon of 22 nd . After crossing coast it moved eastnortheast wards and rapidly weakened into a deep depression at 1200 UTC							
22.11.98	1200	22.5/90.0					DD
23.11.98	0300	23.0/90.5					D

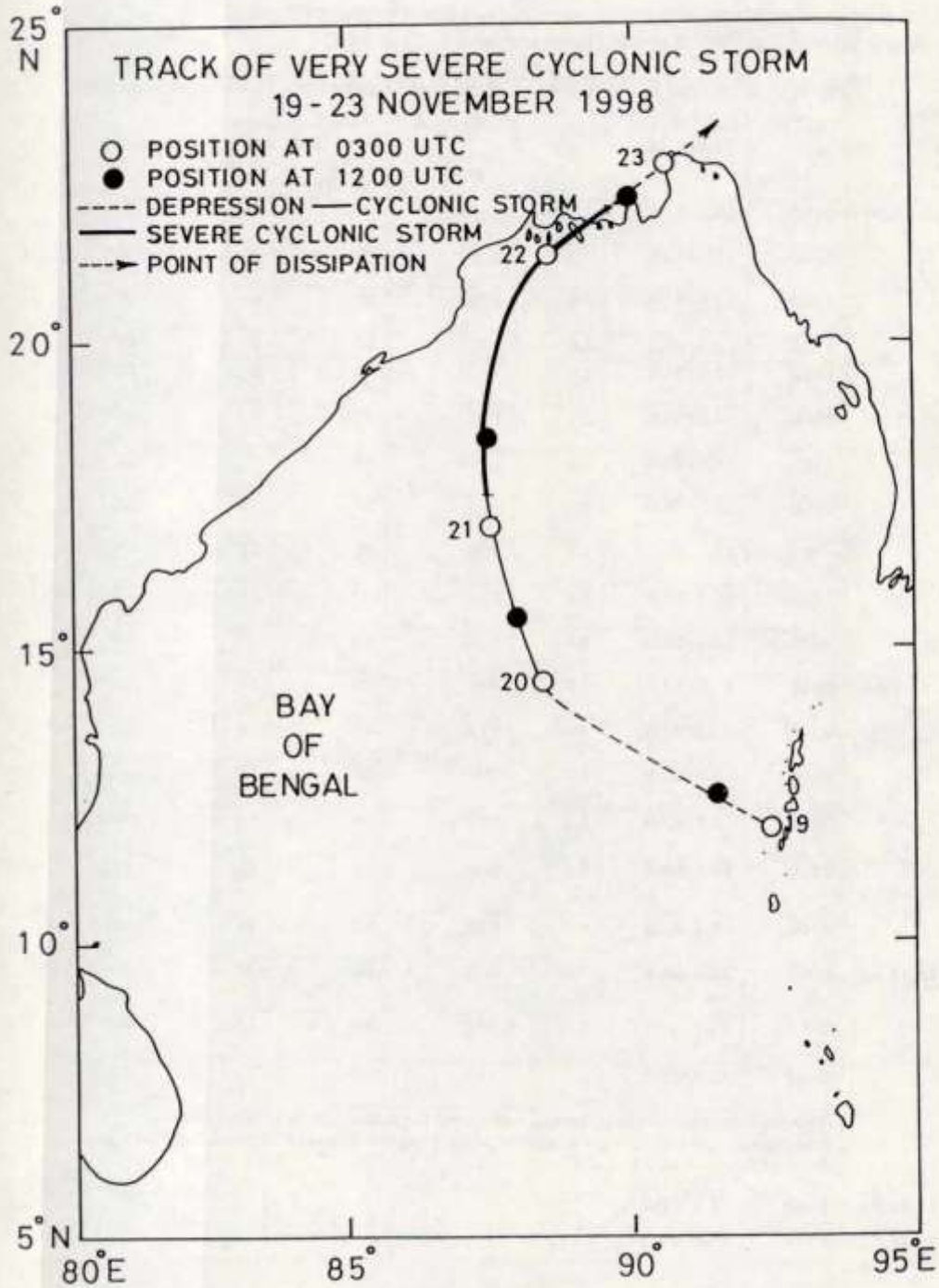


FIG. 2.9.1

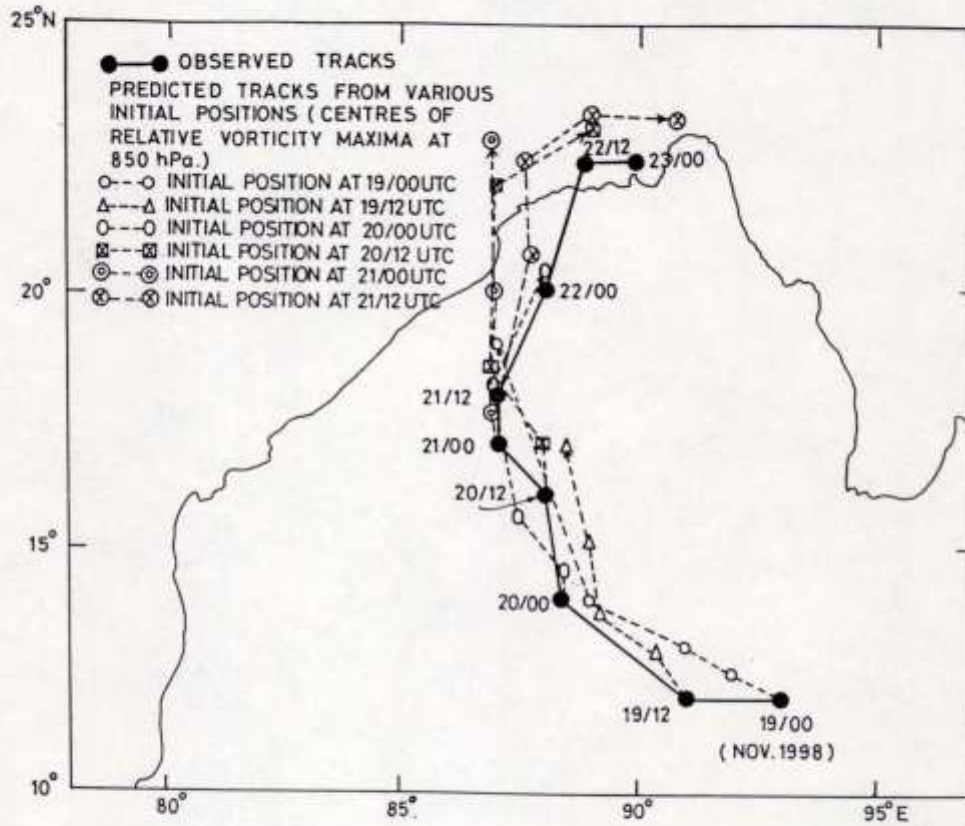


FIG. 2-9-2 TRACK PREDICTED BY IMD LIMITED AREA MODEL

Speed of the movement of the VSCS over Bay of Bengal (Nov. 19-22 1998)

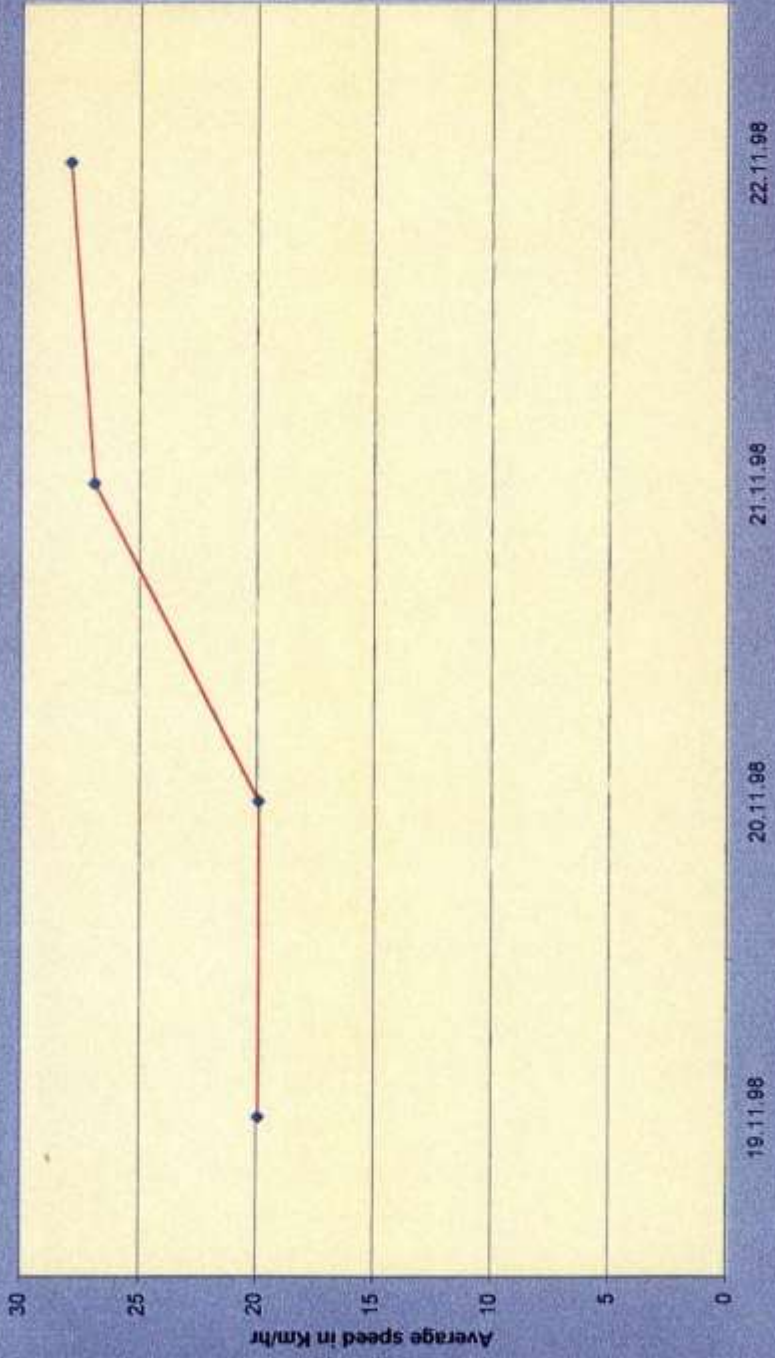


Fig. 2.9.3

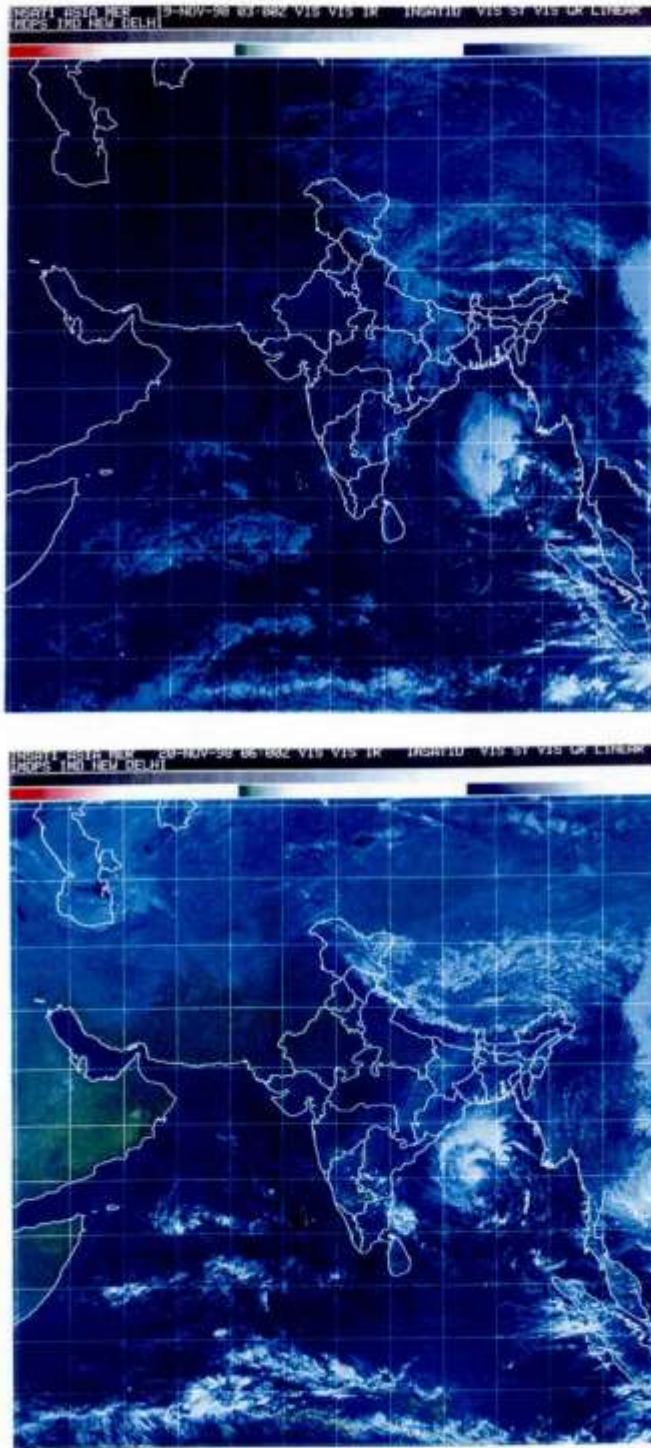


FIG. 2-9-4



FIG. 2-9-4 contd.

2.10 Severe Cyclonic Storm over the Arabian Sea (December 13-17, 1998) (ARB 98 03 12 13 17)

This was an unusual system that originated over the southeast Arabian sea which while moving northnorthwestwards in the middle of December, intensified to the stage of a severe cyclonic storm over south central Arabian sea. However, it weakened and dissipated over the west Arabian sea itself.

A well marked low pressure area formed over southeast Arabian sea in the evening of December 12. It concentrated into a depression at 00 UTC of December 13 over southeastern and adjoining east central Arabian sea near Lat. $11.0^{\circ}\text{N}/\text{Long.}68.5^{\circ}\text{E}$. It rapidly deepened further into a deep depression by 03 UTC of the same day. Well defined spiralling cloud structure was noticed at this stage. Moving in a northwesterly direction the banding structure got more organised. The system intensified further into a cyclonic storm at 09 UTC on December 13 near Lat. $11.5^{\circ}\text{N}/\text{Long.}68.0^{\circ}\text{E}$. While moving in a northnorthwesterly direction under the steering flow of the sub-tropical ridge it intensified into a severe cyclonic storm at 09 UTC of December 14. It then moved in a northerly direction upto 00 UTC of December 15 when it was located near Lat. $15.0^{\circ}\text{N}/\text{Long.}67.0^{\circ}\text{E}$. While maintaining its intensity it moved in a northwesterly direction upto 12 UTC of December 15 when it was located near Lat. $17.0^{\circ}\text{N}/\text{Long.}64.5^{\circ}\text{E}$. A ship PCSS (Lat. $17.6^{\circ}\text{N}/\text{Long.}66.4^{\circ}\text{E}$) at 00 UTC of 16th reported wind $160^{\circ}/26$ knots and pressure 1009.2 hPa. Another ship 9VFC (Lat. $19.7^{\circ}\text{N}/\text{Long.}66.0^{\circ}\text{E}$) at 0000 UTC of 16th reported wind $090^{\circ}/48$ knots and pressure 1008.4 hPa. The system took a westnorthwesterly course and weakened into a cyclonic storm at 0300 UTC on December 16. Low level cloud line centre seen in the satellite imagery indicated the shearing of the system. It further weakened into a deep depression near Lat. $18.5^{\circ}\text{N}/\text{Long.}61.0^{\circ}\text{E}$ at 09 UTC on December 16. The system rapidly weakened into a depression over west central Arabian sea and neighbourhood at 12 UTC on December 16. Later the system dissipated over the same area.

Best track positions and other parameters are included in Table 2.10.1. The track of the system is given in Fig.2.10.1. The track predicted by the RSMC -Tropical Cyclone, New Delhi Limited Area Forecast Model for various initial positions is given in Fig. 2.10.2. A few INSAT cloud images are shown in Fig. 2.10.3

Weather realised

The system dissipated over sea.

Damage report

As the system dissipated over sea, no damage has been reported.

Table 2.10.1

Best track position and other parameters for the Arabian Sea
Severe Cyclonic Storm (December 13-17, 1998)

Date	Time (UTC)	Centre Lat. ° N / Long. ° E	C.I.NO.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated Pressure drop at the centre	Grade
13.12.98	0000	11.0/68.5	1.5	1004	25	4	D
	0300	11.0/68.5	2.0	1002	30	6	DD
	0600	11.2/68.3	2.0	1000	35	8	DD
	0900	11.5/68.0	2.5	1000	35	8	CS
	1200	12.0/67.5	2.5	1000	35	8	CS
	1800	12.5/67.5	2.5	1000	35	8	CS
14.12.98	0000	12.5/67.5	2.5	1000	35	8	CS
	0300	13.0/67.5	3.0	998	45	10	CS
	0600	13.2/67.3.3	3.0	998	45	10	CS
	0900	13.5/67.0	3.5	993	55	15	SCS
	1200	14.0/67.0	3.5	993	55	15	SCS
	1800	14.5/67.0	3.5	993	55	15	SCS
15.12.98	0000	15.0/67.0	3.5	993	55	15	SCS
	0300	16.0/66.0	3.5	993	55	15	SCS
	0600	16.5/65.5	3.5	993	55	15	SCS
	0900	16.5/65.0	3.0	993	55	15	SCS
	1200	17.0/64.4	3.0	993	55	15	SCS
	1800	17.3/64.0	3.0	993	55	15	SCS

Table 2.10.1.(continued)

Date	Time (UTC)	Centre Lat. ° N /Long. ° E	C.I. NO.	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
16.12.98	0000	17.5/63.5	3.0	993	55	15	SCS
	0300	18.0/62.5	2.5	998	45	10	CS
	0600	18.5/61.5	2.5	998	35	10	CS
	0900	18.5/61.0	2.0	1002	30	6	DD
	1200	19.0/60.0	1.5	1004	25	4	D
	1800	19.5/59.5	1.5		25	4	D
17.12.98	0000	19.5/59.0	1.5		25	4	D
	0300	19.5/59.0	1.5		25	4	D

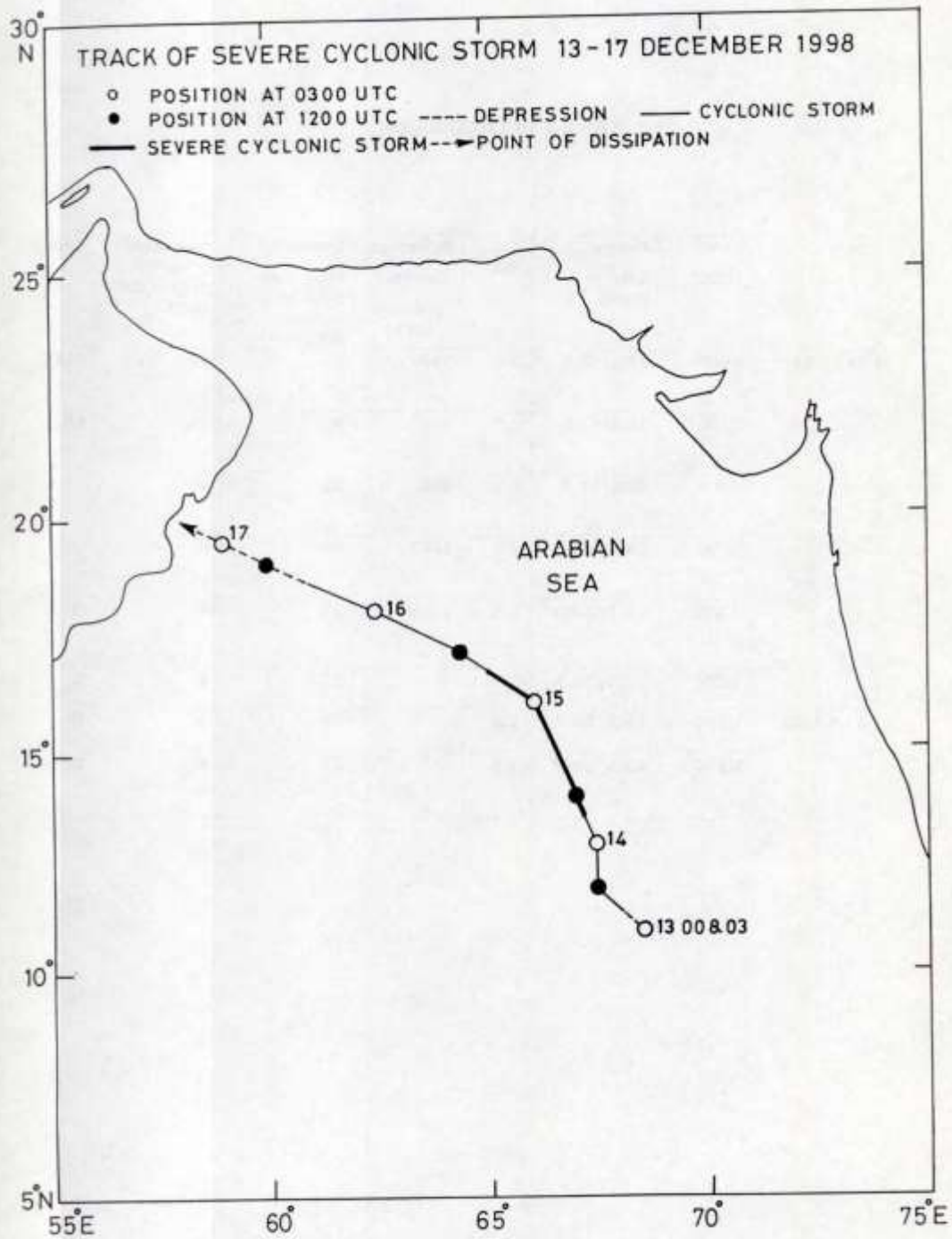


FIG. 2.10.1

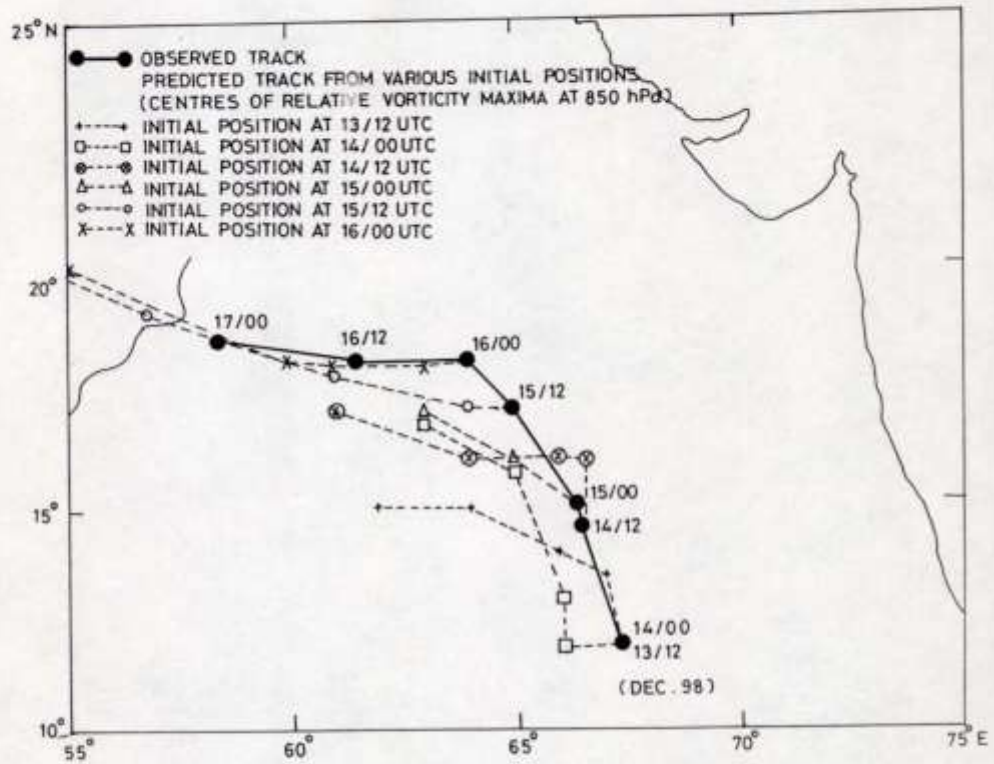


FIG. 2-10-2 TRACK PREDICTED BY IMD LIMITED AREA MODEL

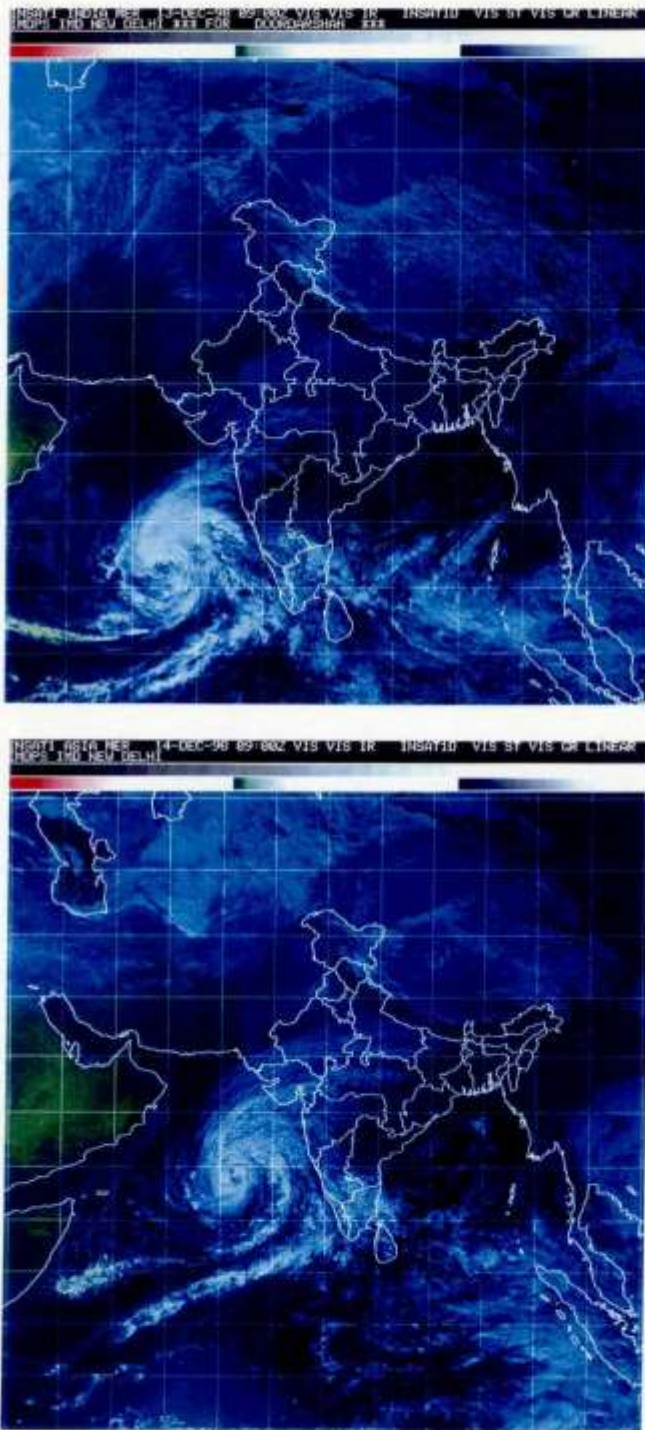


FIG. 2-10-3

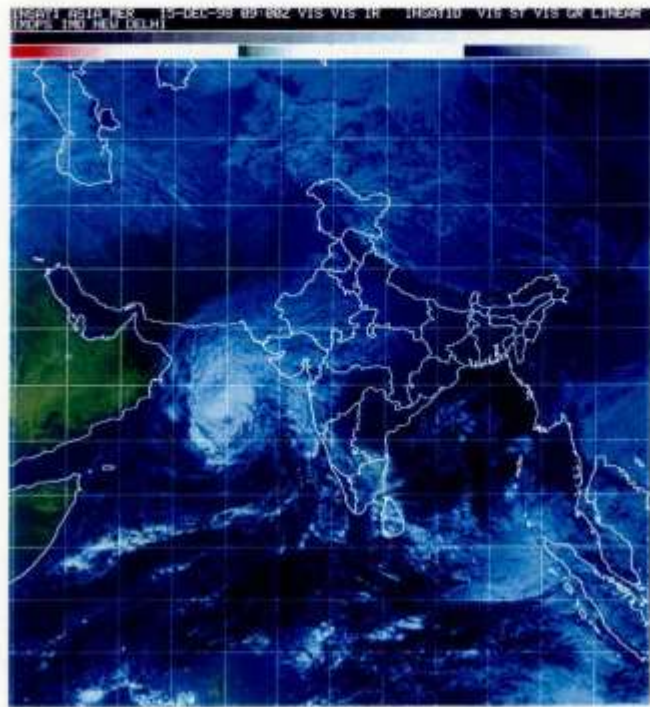


FIG. 2-10-3 contd.

Chapter 3

Track Prediction

3.1 Track Prediction Models

Track prediction is made operationally by RSMC- Tropical cyclones New Delhi by utilising models based on climatology, persistence and combination of both (CLIPPER), analogue and the numerical weather prediction model of RSMC-Tropical cyclones New Delhi .

The errors in the predicted positions from Persistence, Climatology and CLIPPER for the tropical cyclones in North Indian Ocean during 1998 are given in table 3.1. In the 12 hours prediction persistence forecast performed better than the other two. This was also the case in 24 hour predictions except for Arabian Sea Cyclone in December 1998. Persistence forecast appears to perform better than the remaining two in majority of the cases during 36 and 48 hours forecast also.

3.3.1 The Limited Area Forecast Model (LAM) of RSMC - Tropical Cyclones New Delhi

Commencing from the post monsoon season of 1998, the Limited Area Model (16L) was run in conjunction with the bogusing scheme developed in IMD in real time operations to predict the movement of cyclonic storms in the Bay of Bengal and the Arabian sea .The forecast tracks from different initial conditions have been included in sections 2.8,2.9 and 2.10. Numerical guidance information obtained from the operational runs were disseminated to the Area Cyclone Warning Centres (ACWCs)/ Cyclone Warning Centres (CWCs) of IMD. This guidance was also taken into consideration while framing RSMC Cyclone Advisory Bulletins. A computer programme was developed to calculate various types of forecast errors of the predicted vs observed tracks in order to evaluate the performance of the model .The composite forecast errors in respect of the three cyclonic storms which form during post monsoon season are as follows

24 hours forecast:

Mean position error : 105 Km

Vector errors

(Difference of the vector lengths
from Day (0) to Day (1) observed and
Day (0) to Day (1) forecast positions)

Mean	: - 73 Km(slow bias)
RMS	: 121 Km
RMS deviation angle	: 28 ^o
:	

48 hours forecasts:

Mean position error : 163 Km

Vector errors

(Difference of the vector lengths

from Day (0) to Day 2 observed and
Day (0) to Day 2 forecast positions)

Mean : - 3 Km
RMS : 176 Km
RMS deviation angle : 21^o

The results indicate a better performance of the forecast model as compared to the experimental results reported last year. Qualitatively speaking, the model predications even in 48 hours forecasts did capture the general trend of movement. However, numerical forecast could not be generated in respect of May cyclone in the Bay of Bengal and June cyclone in the Arabian sea operationally.

Table 3.1

Forecast position errors for Tropical cyclones in the Bay of Bengal and the Arabian Sea in 1998 based on Climatology (C), Persistence(P) and CLIPPER(CL) Models.

Date	12 Hours			24 Hours			36 Hours			48 Hours		
	P.	C.	CL	P	C	CL	P	C	CL	P	C	CL
17-20 May	114	78	103	168	160	145	184	258	170	216	361	249
5-10 June	68	65	101	143	166	148	104	267	246	401	416	303
11-17 October	77	135	97	108	215	150	217	287	242	292	309	328
13-16 November	63	140	102	107	225	205	280	280	235	-	-	-
19-22 November	167	152	165	280	327	346	385	325	223	460	470	410
13-17 December	29	170	280	430	203	-	-	375	-	-	570	-



DAMAGE TO COCONUT AND KHARK FARMS IN GUJARAT DURING JUNE 1998 VERY SEVERE CYCLONIC STORM.