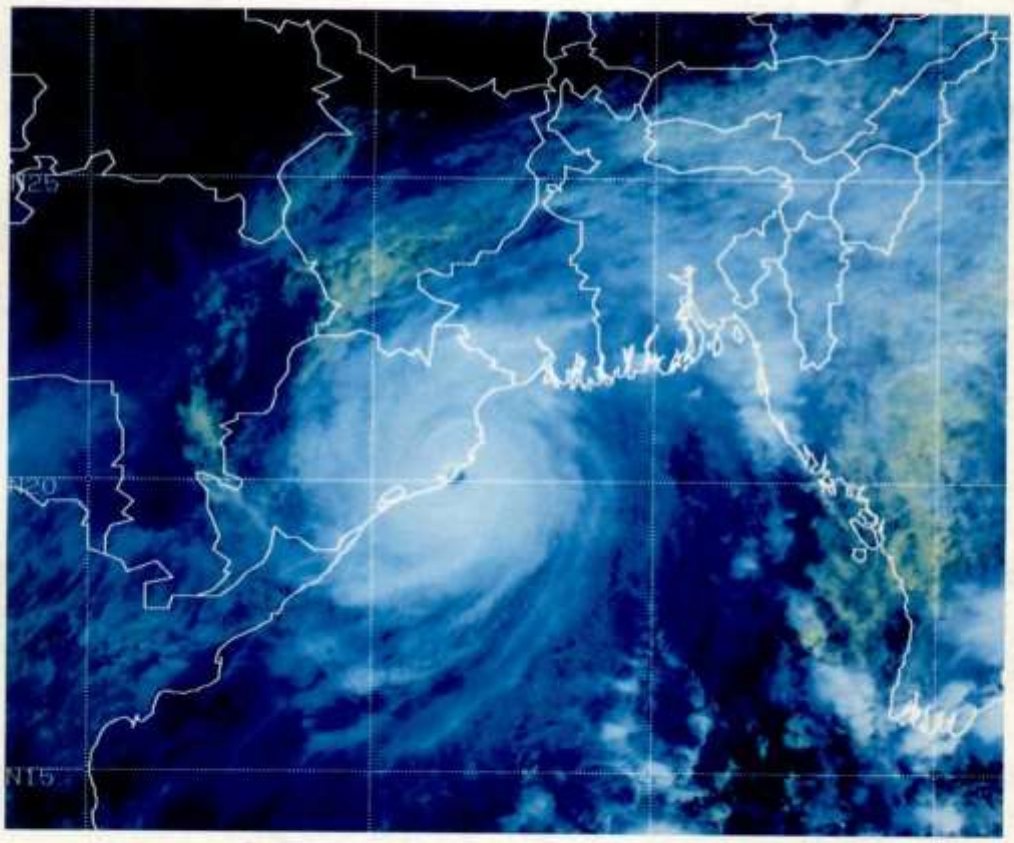
भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Report On Cyclonic Disturbances Over North Indian Ocean During 1999



Super Cyclonic Storm of 29 October 1999

RSMC-TROPICAL CYCLONES NEW DELHI
FEBRUARY 2000

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REPORT ON
CYCLONIC DISTURBANCES
OVER NORTH INDIAN OCEAN

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CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 1999

CONTENTS

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INTRODUCTION

The North Indian Ocean witnessed a decrease in the number of cyclonic storms and depressions during 1999 (4 cyclones & 4 depressions) as compared to 1998 (6 Cyclones & 6 depressions) . The significant feature of the year was the absence of cyclonic activity in the month of November and formation of a Super Cyclonic Storm in the month of October .

Out of the four cyclonic storms which developed over the North Indian Ocean during this year, one formed in the Arabian sea and three in the Bay of Bengal. The one in the Arabian sea became very severe cyclonic storm and was the second most intense system of the century to cross Sind coast of Pakistan. Two out of three cyclonic storms in the Bay of Bengal intensified into very severe cyclonic storms. One of these two acquired the intensity of Super Cyclonic Storm and was the most intense system over the last 114 years and caused huge loss of life and damage to property.

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 to WMO/ESCAP Panel countries . The number of advisories issued during the cyclone period given on 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 1999. 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 as 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 61 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 (VSCS)	Wind speed between 64 and 119 kt. (119 and 221 kmph)
7. Super Cyclonic Storm (SuCS)	Wind speed 120 kt and above. (222 kmph and above)

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

List of cyclonic disturbances in chronological order

* * *

1. Cyclonic Storm over the Bay of Bengal
   (1-3 February 1999)

2. Very Severe Cyclonic Storm over the Arabian Sea
   (16 – 22 May 1999)

3. Deep Depression over the Bay of Bengal
   (17 – 18 June 1999)

4. Deep Depression over the Bay of Bengal
   (27– 29 July 1999)

5. Depression over the Bay of Bengal
   (6 – 8 August 1999)

6. Very Severe cyclonic storm over the Bay of Bengal
   (15 – 19 October 1999)

7. Super Cyclonic Storm over the Bay of Bengal
   (25-31 October 1999)

8. Depression over the Bay of Bengal
   (8-10 December 1999)

Activities of RSMC- Tropical Cyclones New Delhi

Limited Area Model

RSMC -Tropical cyclones New Delhi continued to run its Limited Area Model (LAM) for providing numerical guidance for tropical cyclone track prediction. Quasi- Lagrangian Model (QLM) based on NCEP Washington, Hurricane Model was also installed on Cray and Cyber Computer systems. A few experimental runs were made for tropical cyclone track prediction during cyclone season of 1999 using QLM Model.

Tropical Weather Outlook

Tropical Weather Outlook was issued daily at 06 UTC for use by the Member countries of WMO/ ESCAP Panel region. This contained description of synoptic systems over North Indian Ocean and sub-tropical ridge position at 200 hpa level. In addition , second weather outlook was also issued at 18 UTC in situations where a tropical depression was expected to attain the 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 1 October, 1998 .

Tropical Cyclone Advisories

These bulletins were issued at 03,06,09,12,15,18 and 21 UTC based on the charts at 00 ,03, 06, 09, 12, 15,18 and 21 UTC for the benefit of the Member countries of the Panel region. These bulletins contained the current position of the 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 71 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 were also taken at hourly interval . The bulletins contained detailed information on cloud system centre, movement and its intensity (T- number on Dvorak's scale) as well as a description of cloud organisation. Satellite derived information on tropical disturbances was also included in RSMC bulletins cited above.

Statistical data relating to Cyclonic disturbances in the North Indian Ocean During 1999

1. Synoptic class distribution of Cyclonic Disturbances (CI ≥ 2.0)

S.No	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct.	Nov	Dec.	Life Time (days)
1.	CS		↔											3
2.	VSCS					↔								7
3.	DD						↔							2
4.	DD							↔						3
5.	VSCS										↔			3
6.	SuCS										↔			7

Note : Two disturbances did not intensify even to the stage of T-2.0 .

Average Lifetime=	4.1(days)

2. Frequency distribution of different intensity classes

CI	≥2.0	≥2.5	≥3.0	≥5.0	≥6.0	≥7.0
No. Of Disturbances	6	4	4	3	1	1
No. of days with Cyclone Intensity(≥2.5)		8.6	7.5	3.4	0.6	0.12

Note: CI=Current Intensity on Dvorak's Scale

3. Basin-wise distribution of disturbances

Bay of Bengal	7
Arabian Sea	1

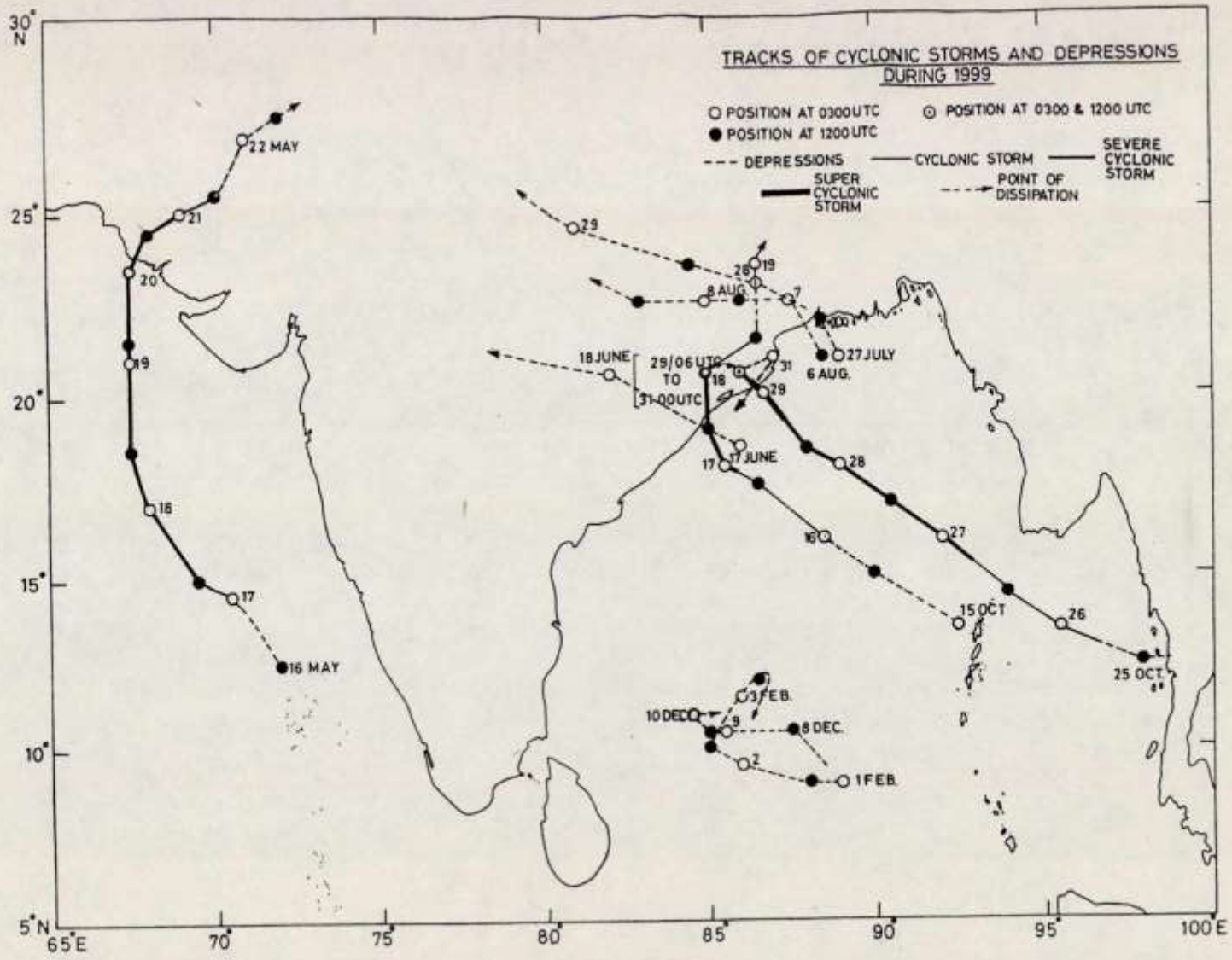

TRACKS OF CYCLONIC STORMS AND DEPRESSIONS
DURING 1999
POSITION AT 0300 UTC
POSITION AT 0300 & 1200 UTC
POSITION AT 1200 UTC
DEPRESSIONS
CYCLONIC STORM
SEVERE CYCLONIC STORM
SUPER CYCLONIC STORM
POINT OF DISSIPATION
22 MAY
16 MAY
8 AUG.
6 AUG.
27 JULY
18 JUNE
29/06 UTC TO 31-00 UTC
17 JUNE
15 OCT
25 OCT.
3 FEB.
10 DEC.
8 DEC.
1 FEB.
30° N
25°
20°
15°
10°
5° N
65° E
70°
75°
80°
85°
90°
95°
100° E

FIG. 1.1

CHAPTER 2

BRIEF DESCRIPTION OF THE SYSTEMS

2.1 Cyclonic Storm over the Bay of Bengal (1- 3 February 1999) (BOB 99 01 02 01 03)

The first cyclonic disturbance of this year formed as a depression over the central parts of south-east Bay of Bengal on 1 February 1999. Moving initially in a westerly direction and then in a northerly and northeasterly direction it intensified into a cyclonic storm during the night of 2 February. While continuing to move in a north-easterly direction the system weakened into a depression over the northwestern parts of southeast Bay of Bengal by the midnight of 3 February. It finally dissipated over the sea itself.

The last week of January 1999 witnessed a progressive northward propagation of equatorial trough in the Bay of Bengal from about 3^0 North latitude on 25 January to 8^0 North latitude by 31 January. A broad low pressure area developed over the Bay of Bengal on the morning of 31 January in which 1008 hPa isobar covered the areas of the Bay of Bengal to the south of 15^0 North latitude. Within this broad low pressure region the area of southeast Bay of Bengal witnessed further low pressure of 1006 hPa. The signature of this inner low pressure area was seen in INSAT cloud imagery of 310300 UTC of in the form of deep convection in which cloud top temperature (CTT) of two convective cloud clusters (CCCs) reached -25^0 C and below. The region of convection was located on the western periphery of the sub-tropical anticyclone at 200 hPa level which was covering North West Pacific and parts of Bay of Bengal at 310000 UTC (Fig. 2.1.1). The sub-tropical ridge line at 200 hPa was running along 8^0 North latitude over the Bay of Bengal. The flow over Indian region at 200 hPa level was mainly westerly upto the southern tip of India. The surface winds were southwesterly 10 kt in the Bay of Bengal upto 0000 UTC of 1 February. Improved cloud organisation was seen in the cloud imagery at 010300 UTC when two curved cloud bands were seen merging into each other over the central region. At this time a depression was declared near lat. 9.0^0 N / long. 89.0^0 E.

Though there was certain amount of diurnal variation in the convection, the system tracked westwartds till 011800 UTC without showing further intensification. Thereafter the system tracked west-northwestwards till 020300 UTC. At this time the depression once again started showing signs of intensification. The CCC looked like a comma head . At this stage the system was reflected in the wind field also at 500 hPa level along Tamil Nadu coast. However, the winds at the lower levels did not show any strengthening. The system attained the intensity of deep depression (DD) at 020600 UTC near Lat. 9.5^0 N / Long. 85.5^0 E.

It was upgraded to the minimal cyclonic storm (CS) stage at 021800 UTC near lat. 11.0° N. / long. 85.0° E. The system came under the influence of pronounced vertical wind shear as it encountered stronger southwesterly flow aloft. The cloud got sheared off leaving only a shear pattern. It took a northeastward track under the influence of upper air southwesterly flow and was located at 030300 UTC near lat. 11.5° N/ long.86.0° E. Moving northwestwards it weakened into a deep depression at 030900 UTC near lat. 12.0° N/ long. 86.0° E. It then moved slightly eastwards and weakened into a depression at 031200 UTC near lat. 12.0° N/ Long. 86.5° E. It remained practically stationary till 031800 UTC and weakened further into a low pressure area.The low pressure area drifted southwestwards under the influence of the northeasterly flow in the lower and middle troposphere.

Development of a cyclonic storm in the north Indian Ocean during the month of February is rare. In the history of cyclones in the north Indian Ocean (since 1891), a cyclonic storm had earlier developed over south-west Bay of Bengal in the year 1944 which crossed Tamil Nadu coast.

The track of the system in given in Fig. 2.1.2. The best track positions and other parameters are given in Table 2.1.1. A few selected satellite pictures are included in Fig. 2.1.3.

Weather realised

As the system weakened and dissipated over the sea area, no adverse weather was experienced over the Indian coast.

Damage :

No damage to life and property was reported.

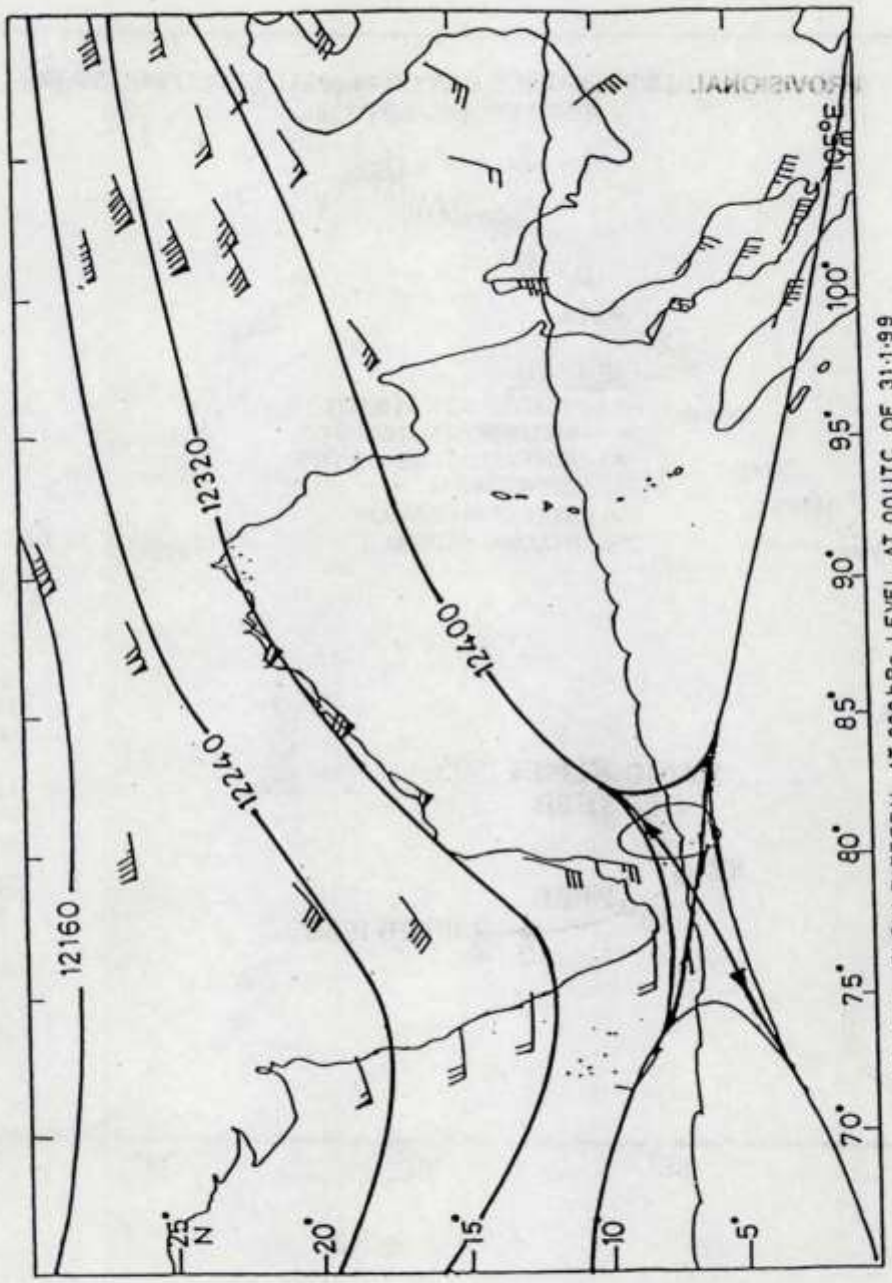


FIG. 2.11 FLOW PATTERN AT 200hPa LEVEL AT 00UTC OF 31-1-99

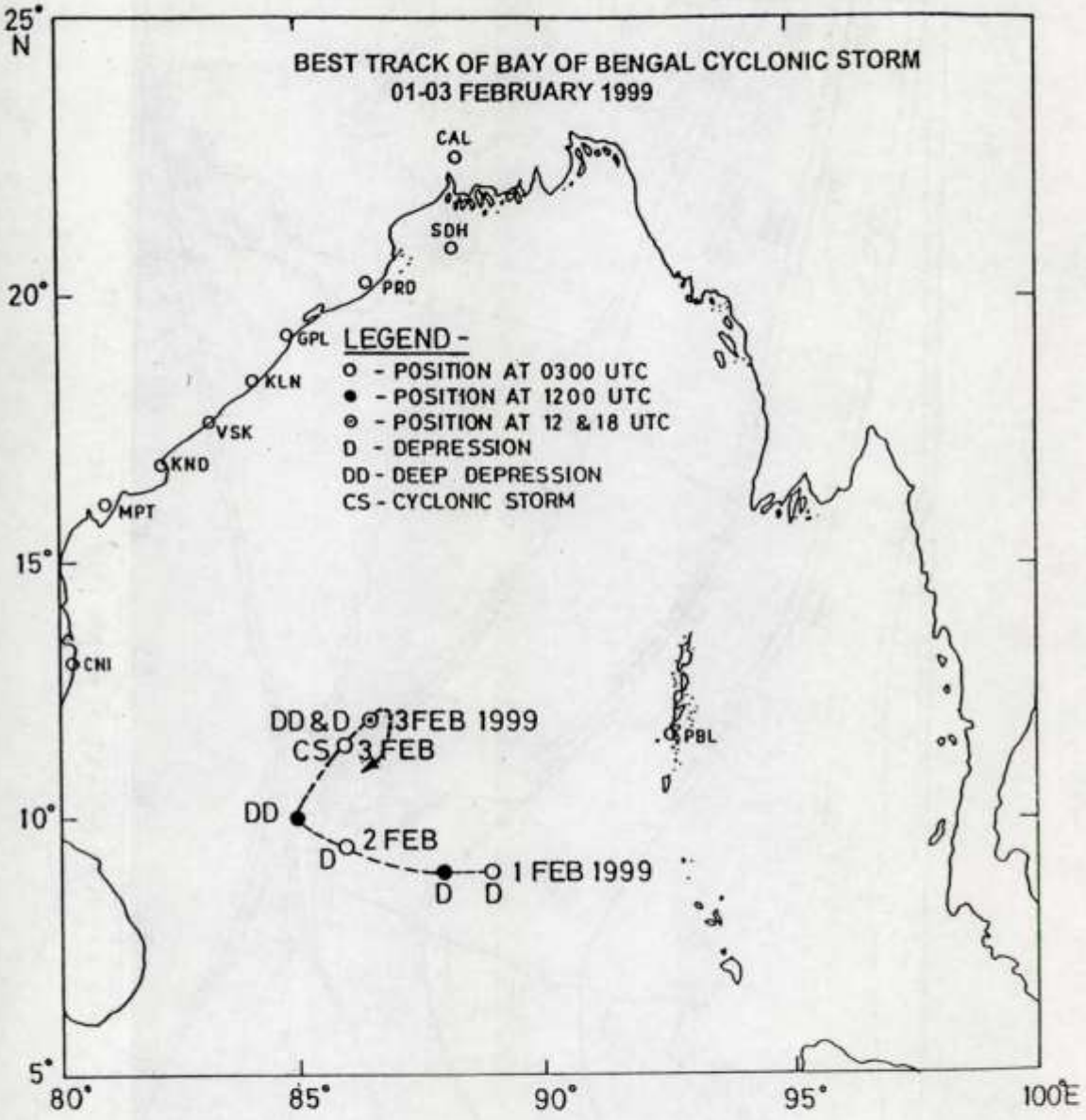

BEST TRACK OF BAY OF BENGAL CYCLONIC STORM
01-03 FEBRUARY 1999
25° N
20°
15°
10°
5°
80°
85°
90°
95°
100°E
CAL
SDH
PRD
GPL
KLN
VSK
KND
MPT
CNI
PBL
LEGEND -
O - POSITION AT 0300 UTC
● - POSITION AT 1200 UTC
⊙ - POSITION AT 12 &18 UTC
D - DEPRESSION
DD - DEEP DEPRESSION
CS - CYCLONIC STORM
DD&D 3FEB 1999
CS 3 FEB
DD
D
2 FEB
D
D
1 FEB 1999

FIG. 2.1.2

Table 2.1.1

Best track positions and other parameters for the Bay of Bengal cyclonic storm (February 1-3 1999)

Date	Time (UTC)	Centre Lat. ^{0}N / Long .^{0}E	C. I NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kt)	Estimated Pressure drop at the centre (hPa)	Grade
1.2.99	03	9.0/89.0	1.5	1006	25	4	D
	12	9.0/88.0	1.5	1004	25	4	D
2.2.99	03	9.5/86.0	1.5	1006	25	4	D
	06	9.5/85.5	2.0	1006	30	6	DD
	09	9.5/85.5	2.0	1006	30	6	DD
	12	10.0/85.0	2.0	1004	30	6	DD
	18	11.0/85.0	2.5	1002	35	10	CS
3.2.99	00	11.5/86.0	3.0	998	50	12	CS
	03	11.5/86.0	3.0	998	50	12	CS
	06	12.0/86.0	2.5	1002	35	10	CS
	09	12.0/86.0	2.0	1002	30	8	DD
	12	12.0/86.5	1.5	1004	25	6	D
	18	12.0/86.5	1.5	1008	25	6	D

Worked from Dvorak

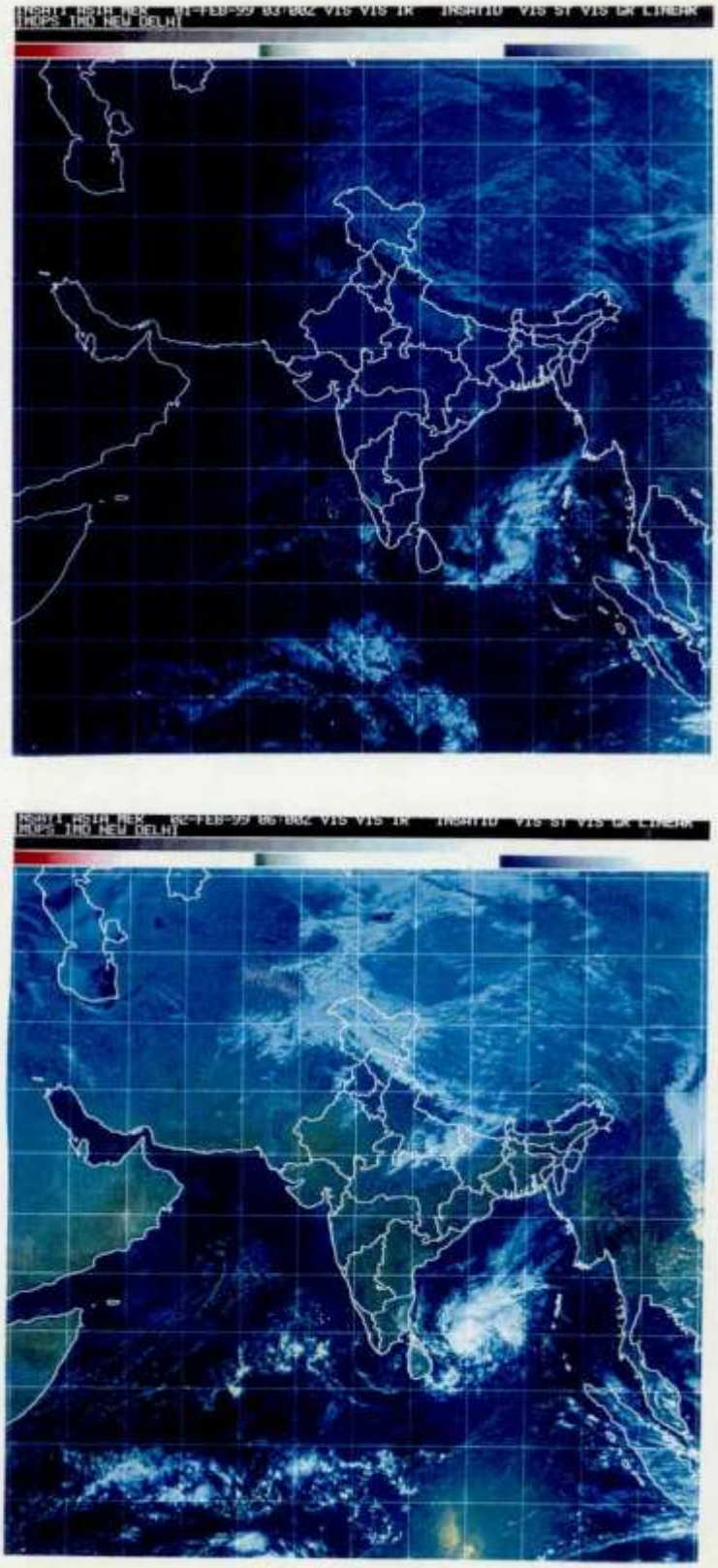
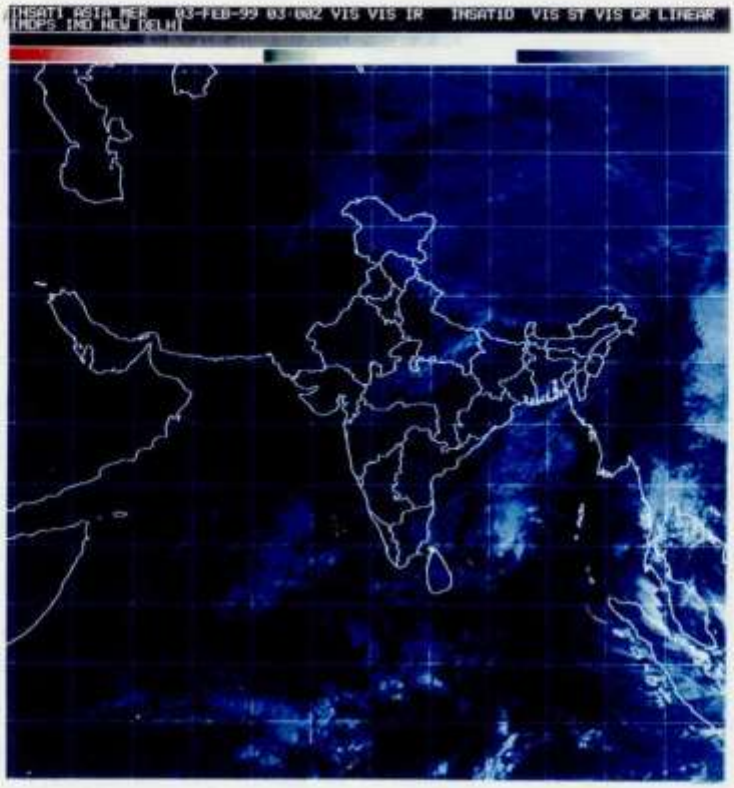


FIG. 2.1.3



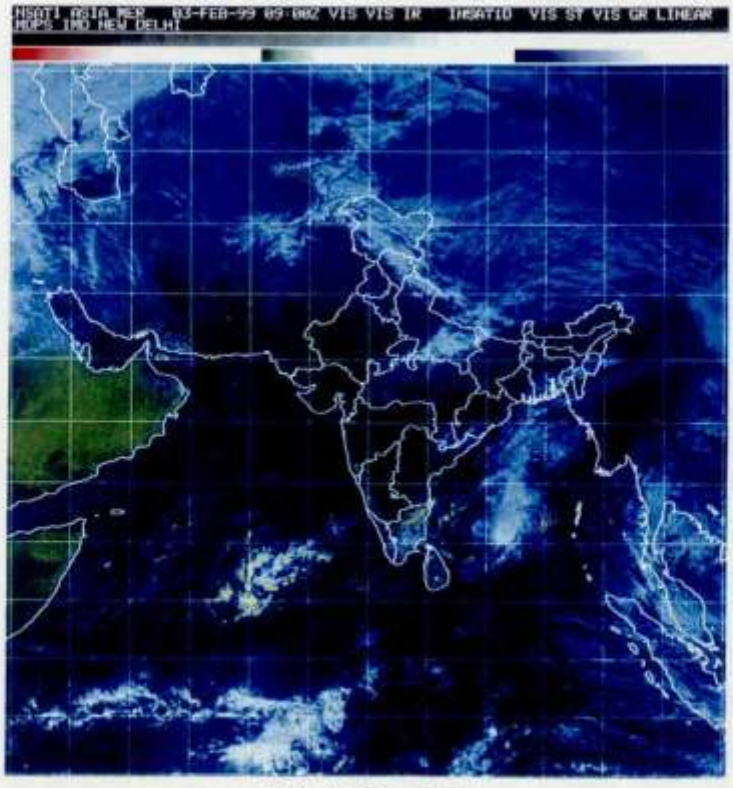


FIG. 2.1.3 contd.

2.2 Very Severe Cyclonic Storm over the Arabian Sea (16- 22 May 1999) (ARB 99 01 05 16 22)

It was the case of one of rare and intense storms that crossed into Pakistan coast of Sind which has not been visited by any tropical cyclone since 1948. It developed as a depression from a pre-existing disturbance over Lakshadweep area and neighbourhood and had an initial northwesterly course which later on became meridianal. It acquired intensity of very severe cyclonic storm in which estimated wind speed exceeded 100 knots.

After the initial development on 16 May, the system moved in a northwesterly direction and rapidly intensified to the stage of very severe cyclonic storm by 171200 UTC. After 180300 UTC, it took a northward course, skirted the Indian coast line of Gujarat State before crossing Pakistan coast close to the international border on 20 May. It weakened into a cyclonic storm over southeastern parts of Pakistan in the morning of 21 May. Moving northeastwards, it came close to Jaisalmer (42328) in west Rajasthan as a deep depression at 221800 UTC and eventually dissipated over North Rajasthan and neighbourhood on the same day.

As per records available on tropical cyclones in the Arabian Sea, 8 cyclones had earlier made landfall in Pakistan. The last severe cyclonic storm had crossed Pakistan coast on 8 June 1948.

A cyclonic circulation extending upto 700 hPa level developed over east central Arabian sea off Kerala / Karnataka coast at 00 UTC of 13 May. Convective clouds persisted over Lakshadweep and neighbourhood in association with the cyclonic circulation that extended upto middle trophosheric levels on 14 May. A low pressure area (1004 hPa) formed over eastentral Arabian sea off Kerala / Karnataka coast at 140600 UTC . The Inter Tropical Convergence Zone (ITCZ) was quite active over South Arabian Sea between 5^{0} to 10^{0} N latitudes and 60^{0} to 75^{0} E longitude. A low level circulation centre emerged from ITCZ cloudiness in association with the developing low on 15 May over southeast Arabian and neighbourhood. Subsequent satellite imagery indicated northwestward drift of the cloud system which also became more tightly curved around the circulation centre by 161200 UTC . It was classified as depression (D) synoptically near lat.12.5^{0} N / long. 72.0^{0} E at this point of time.

Continuing to move in a northwesterly direction, the system further intensified into a deep depression (DD) by 161800 UTC near lat.13.0^{0} N/ long. 71.5^{0} E. The system was classified as a cyclonic storm (CS) near Lat. 14.5^{0} N/ Long. 70.5^{0} E at 170300 UTC. The system showed rather fast development and by 170530 UTC, central dense overcast (CDO) had formed in the central region of the convective cloud mass which also displayed a small indistinct "eye". At 171200 UTC the buoy DS-1 at lat 15.5^{0} N / long. 69.2^{0} recorded wind 060^{0}/ 60 knots and the system was upgraded to the stage of a very severe cyclonic storm (VSCS) near lat. 15.0^{0} N/ long. 69.5^{0} E. It continued to move northwestwards till 180300 UTC when it was located near lat. 17.0^{0} N/ long. 67.5^{0} E .

The CDO size at this stage was about 2 degree in diameter and feeder bands were well developed. The system then took a northerly course along Long. 68.0° E.The CDO size increased after 180900 UTC to more than 2° in diameter and the convective bands got relatively more tightly curved around the CDO. Continuing to move in a northerly direction , it was located near lat. 18.5° N/ long. 67.5° E at 181200 UTC when it peaked its intensity in which estimated wind speed reached 105 knots with estimated central pressure of 950 hPa.

The Cyclone Detection Radar (CDR) Bhuj started giving hourly position of the VSCS from 191900 UTC. These positions agreed well with the INSAT positions. At 200000 UTC the VSCS was located near lAT. 23.3° N / long. 67.8° E. Thereafter, it started moving in a north-northeasterly direction . At 200300 UTC it was located near lat. 23.5° N / long. 68.5° E and was already affecting the coastal areas. The movement of the VSCS was rather slow (8-10 kt) from 17 to 19 May. It got considerably reduced further when it came close to the coast. It crossed Pakistan coast close to international boarder in the afternoon of 20 May and recurved towards northeast after crossing coast. It weakened and entered India in west Rajasthan as a deep depression on 22 May. It became unimportant on the same day over north Rajasthan and neighbourhood.

Winds of the order of 85 knots have been reported between 0330 and 1430 UTC on 20 May, at Naliya Airport in the extreme western parts of Kutch district in Gujarat State. During this period VSCS was tracking northwards and was at a distance of about 100 km west of Naliya. This VSCS had apparently a relatively larger radius of maximum winds as compared to the Gujarat cyclone of 9 June, 1998. No data was available from Pakistan with RSMC -Tropical cyclones New Delhi regarding wind distribution in the core of the cyclone before and after its landfall. Wind started weakening after 201430 UTC as seen from the degeneration of the cloud pattern associated with the system . Barmer (42435) in west Rajasthan reported southwesterly winds of 33 knots at 202100 UTC. At this time the storm was located over Pakistan at a distance of about 250 km southwest of Barmer. Winds continued to be southerly 20-25 knots till 221530 UTC at Barmer.

The strong winds observed at Naliya are consistent with the observations of multiple concentric and somewhat symmetric eyewalls seen on 19 May when the intensification process had already stopped . The visible satellite imagery of 190900 UTC showed three distinct eyewalls particularly on the eastern side of the centre. On the western side the outermost spiraling wall cloud was seen merging with the second wall cloud from the center. Two circular and concentric walls stand out clearly with the inner and outer eyewalls having an average radius of about 10 and 40 km respectively. The multiple eyewalls had started forming in the forenoon of 19 May. The inner eyewall thinned out later. The outer eyewall replaced the inner eyewall after 200300 UTC.

The track of the system is given in Fig. 2.2.1. The track predicted by RSMC-Tropical cyclones New Delhi Limited Area Forecast Model (LAM) for various initial positions is given in Fig. 2.2.2. The best track positions and other parameters are given in Table 2.2.1. A few selected satellite pictures are included in Fig. 2.2.3. A few radar photographs from CDR Bhuj are included in Fig. 2.2.4.

Weather realized:

The system caused exceptionally heavy rainfall in Kutch. Naliya recorded the heaviest 24- hours rainfall of 37 cm on 21st May. The cumulative raifall for the period 16-23 May 1999 is shown in figure. 2.2.5.

Damage:

Gujarat

The system caused severe damage in Kutch and Jamnargar districts where complete break down of electricity and telephone lines were reported. Flattening of thatched huts and damage to roads were also reported due to heavy rains.

Loss of life : 453 (mostly fishermen)
Loss of property : Rs. 80 Crores.
Partially damaged : 5153

(Source: State Government of Gujarat)

Rajasthan

Loss of life : 1
Cattle heads perished : 5104
Houses Completely damaged : 50
Partially damaged : 5153

(Source: State Government of Rajasthan)

Pakistan:

Detail of losses/damages due to cyclone/thunderstorm reported by the Relief Department Sindh upto 29-05-1999 (Preliminary Estimates)

S.NO	District	Villages Affected	Persons Affected	Area Affected (acres)	Crop area Affected (acres)	House Damag -ed	House Demol -shed	Deaths	Relief Camps Establis- hed	Persons in Relief Camps	Cattle Head Lost
1	Thatta	3,758	247,482	1,073,279	285,977	55,048	38,509	118	3	3,139	5,667
2	Badin	1,485	350,000	380,000	115,000	7,960	5,640	50	17	6,113	1,051
	Total	5,243	597,482	1,453,279	400,977	63,008	44,149	168	20	9,252	6,718

(Source :Government of Pakistan : Pakistan Meteorological Department)

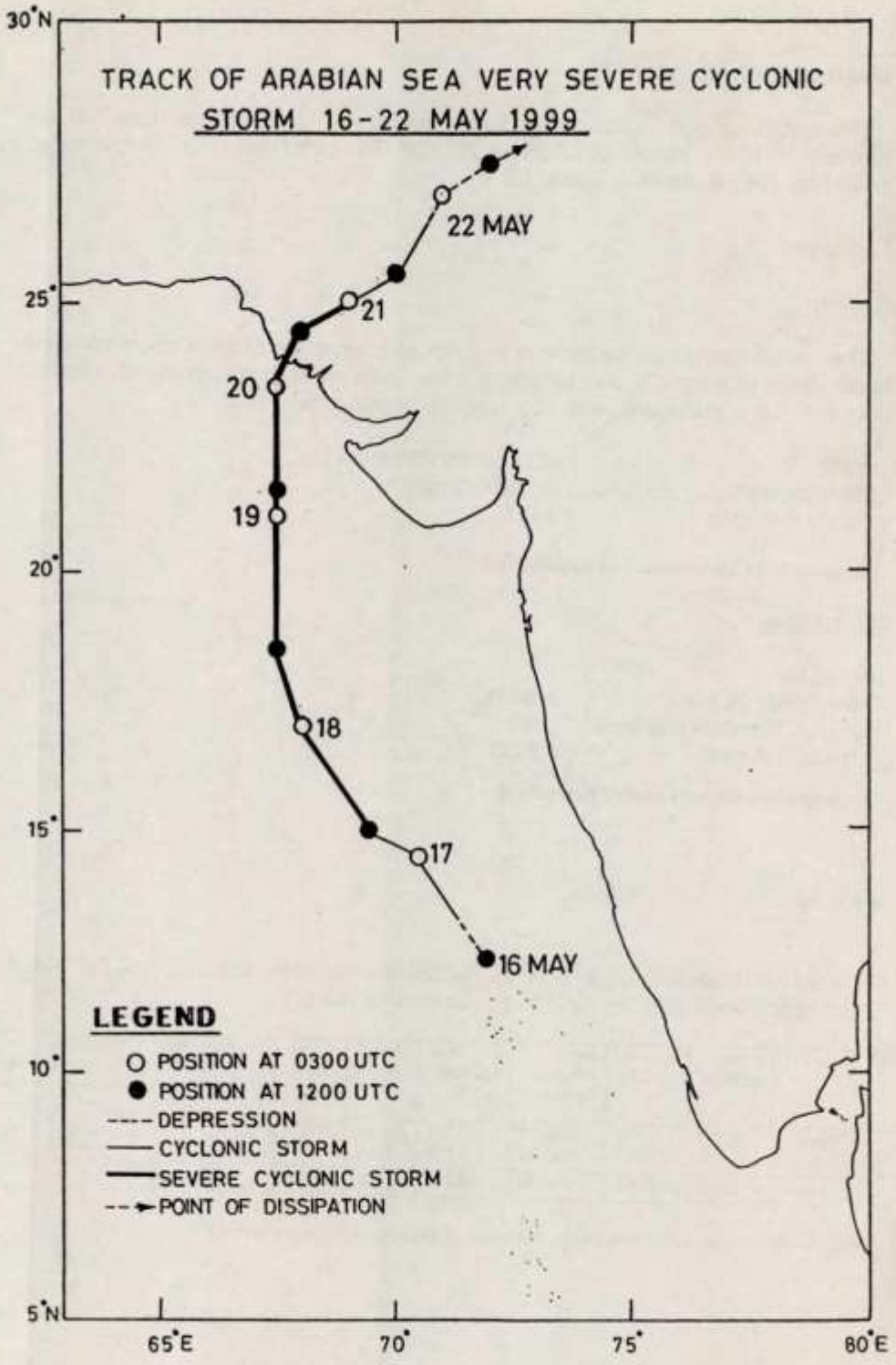

TRACK OF ARABIAN SEA VERY SEVERE CYCLONIC STORM 16-22 MAY 1999
30°N
25°
20°
15°
10°
5°N
65°E
70°
75°
80°E
22 MAY
21
20
19
18
17
16 MAY
LEGEND
O POSITION AT 0300 UTC
● POSITION AT 1200 UTC
---- DEPRESSION
—— CYCLONIC STORM
━━ SEVERE CYCLONIC STORM
--→ POINT OF DISSIPATION

FIG. 2.2.1

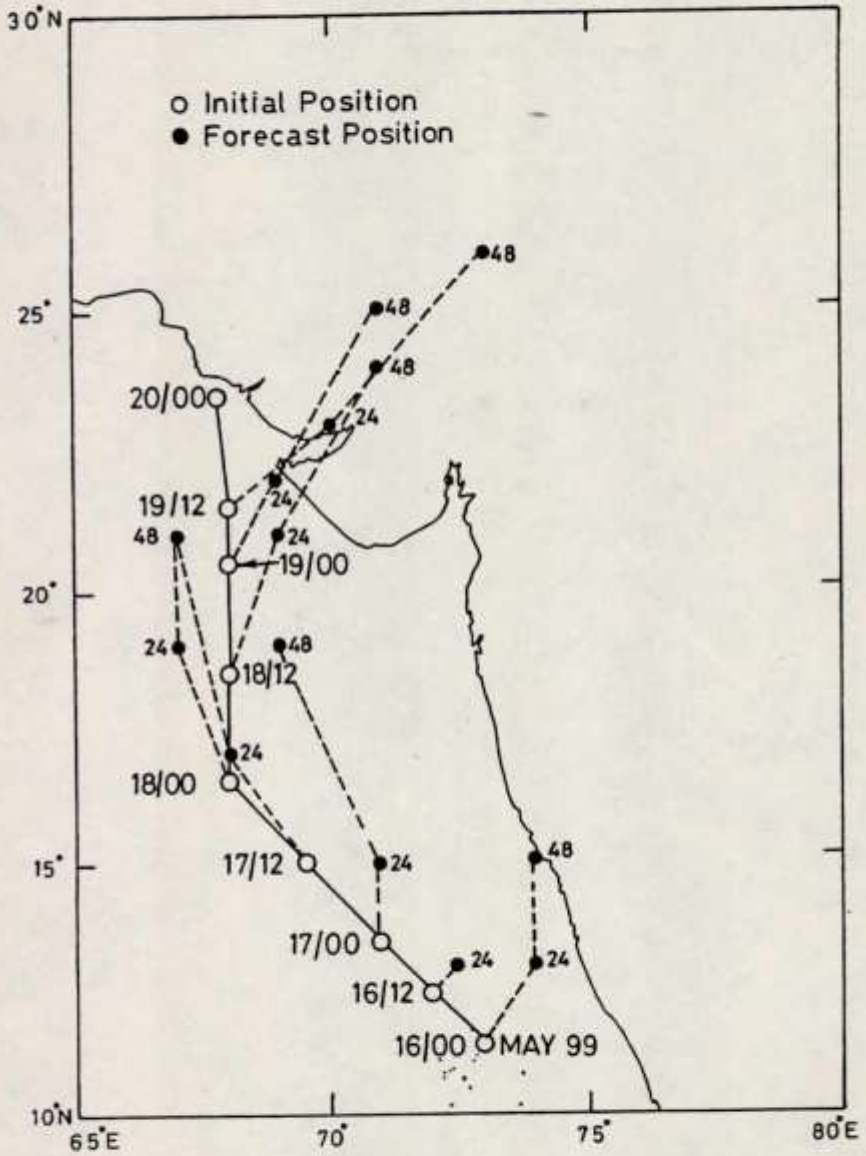


FIG. 2.2.2 TRACK PREDICTED BY IMD LIMITED AREA MODEL

Table 2.2.1

Best track and other parameters for the Arabian sea Very Severe Cyclonic storm (16-22 May ,1999)

Date	Time (UTC)	Centre Lat. ^{0}N / Long. ^{0}E	C.I. No..	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated Pressure drop at the centre (hPa)	Grade
16.5.99	12	12.5/72.0	2.0	1000	25	4	D
	15	12.7/71.8	2.0	1000	25	4	D
	18	12.9/71.6	2.0	1000	25	6	DD
	21	13.0/71.5	2.0	998	30	8	DD
17.5.99	00	13.5/71.0	2.0	998	30	8	DD
	03	14.5/70.5	2.5	996	35	10	CS
	06	15.0/70.0	3.0	996	45	10	CS
	09	15.0/69.5	3.5	992	55	16	SCS
	12	15.0/69.5	4.0	984	64	20	VSCS
	15	15.5/69.0	4.0	984	64	20	VSCS
	18	16.0/68.5	4.0	984	64	20	VSCS
	21	16.0/68.5	4.0	980	64	26	VSCS
18.5.99	00	16.5/68.5	4.5	976	80	30	VSCS
	03	17.0/67.5	4.5	976	80	30	VSCS
	06	18.0/67.5	5.0	964	90	40	VSCS
	09	17.8/67.6	5.0	964	90	40	VSCS
	12	18.5/67.5	5.5	950	105	52	VSCS
	15	18.5/67.5	5.5	948	105	52	VSCS
	18	19.0/67.5	5.5	948	105	54	VSCS
	21	20.0/67.5	5.5	948	105	54	VSCS
19.5.99	00	20.5/67.5	5.5	948	105	54	VSCS
	03	21.0/67.5	5.5	948	105	54	VSCS
	06	21.0/67.5	5.5	948	105	54	VSCS

Table 2.2.1(Continued)

Best track and other parameters for the Arabian sea
Very Severe Cyclonic storm (16-22 May ,1999)

Date	Time (UTC)	Centre Lat. ^{0}N / Long .$^\circ$E	C.I. No..	Estimated Central pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated Pressure drop at the centre	Grade
19.5.99	09	21.0/67.5	5.5	948	105	54	VSCS
	12	21.5/67.5	5.5	946	105	54	VSCS
	15	22.0/67.5	5.5	946	105	54	VSCS
	18	22.5/67.5	5.5	946	105	54	VSCS
	21	23.0/67.5	5.5	946	105	54	VSCS
20.5.99	00	23.3/67.5	5.5	946	105	56	VSCS
	03	23.5/68.5	5.5	946	105	54	VSCS
	06	23.7/68.5	5.5	946	105	52	VSCS
			Crossed Pakistan coast near International Border in the afternoon of 20th May				
	12	24.5/68.0					VSCS
	18	24.7/68.7					VSCS
21.5.99	00	25.0/69.0					SCS
	03	25.0/69.0					CS
	06	25.o/69.5					CS
	12	25.5/70.0					CS
	18	26.0/70.5					CS
22.5.99	00	26.5/71.0					CS
	03	27.0/71.0					DD
	06	27.3/72.0					DD
	12	27.5/72.0					D

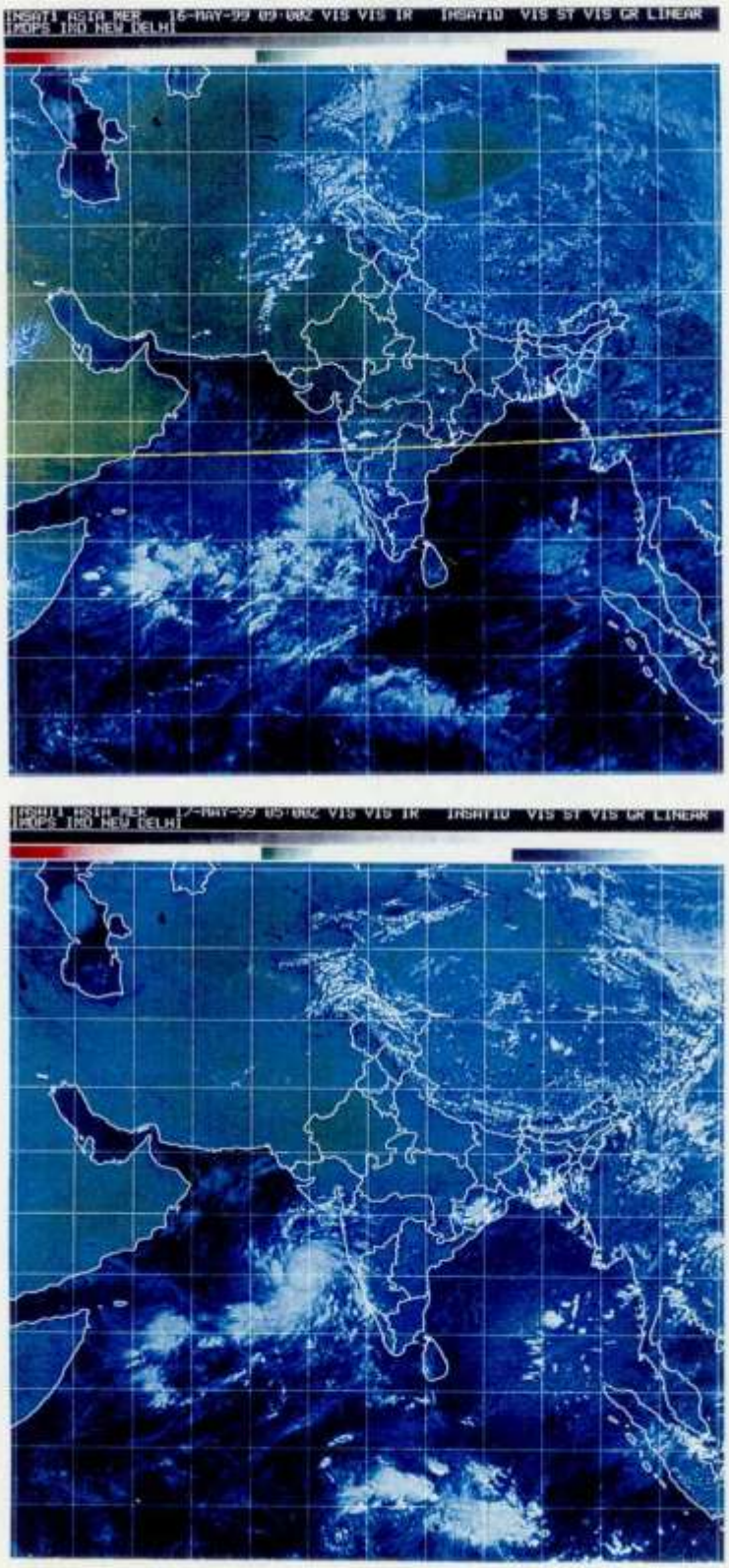

INSAT1 ASIA MER 16-MAY-99 03:00Z VIS VIS IR INSAT1D VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI
INSAT1 ASIA MER 17-MAY-99 05:00Z VIS VIS IR INSAT1D VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI

FIG. 2.2.3

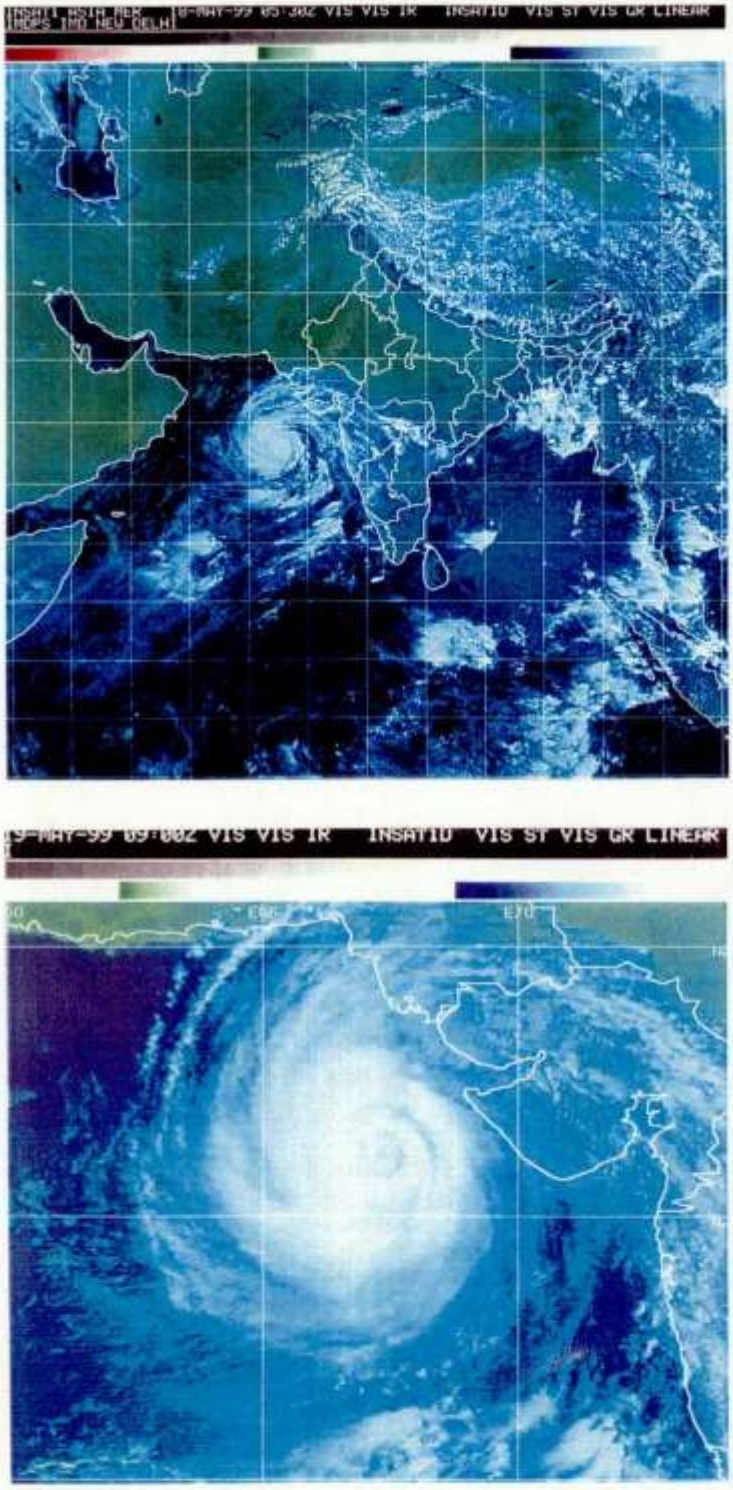

INSAT1 MAIN DER
IMDPS IMD NEW DELHI
INSAT1D VIS ST VIS GR LINEAR
INSAT1D VIS ST VIS GR LINEAR

FIG. 2.2.3

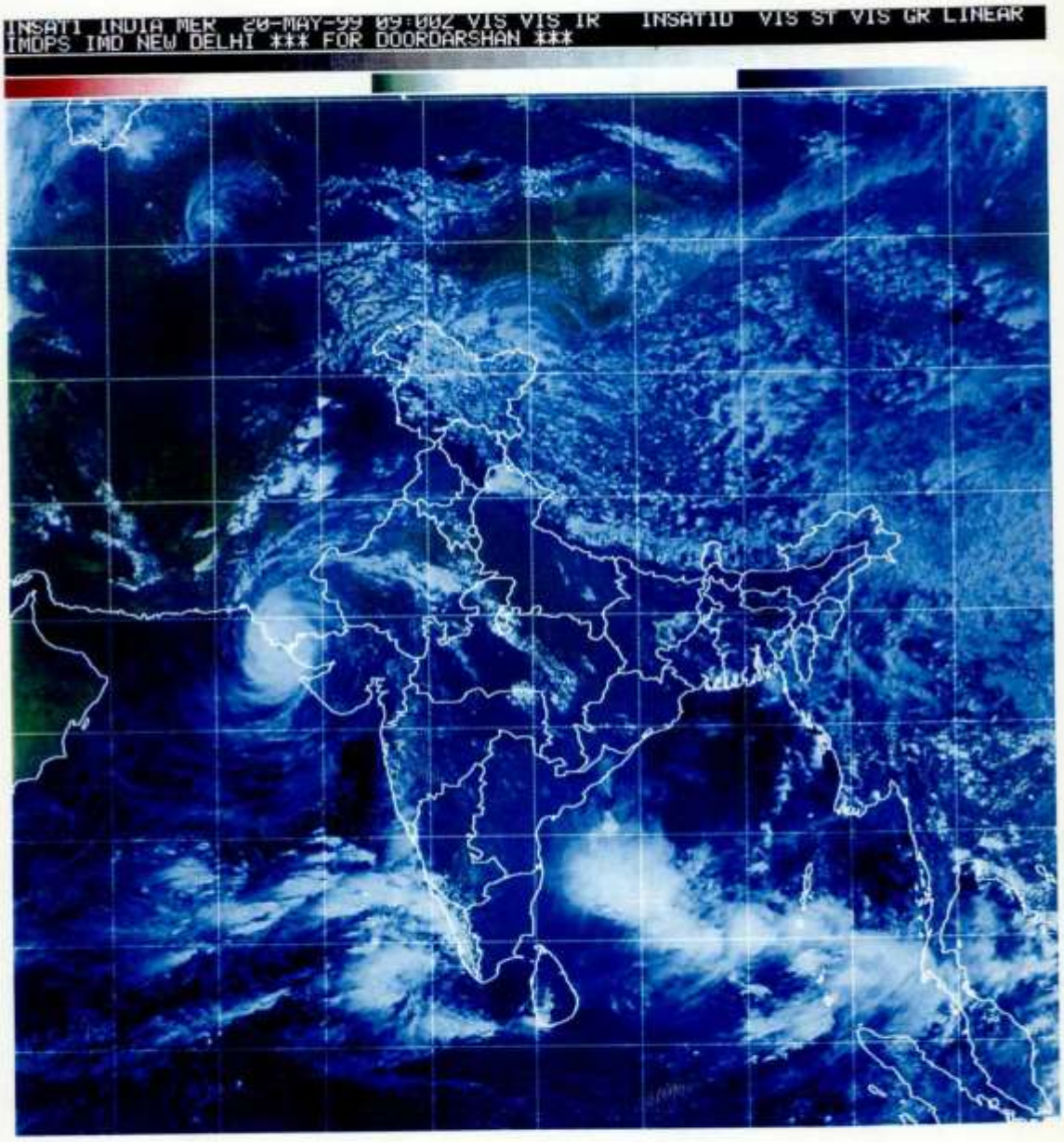


FIG. 2.2.3 contd.

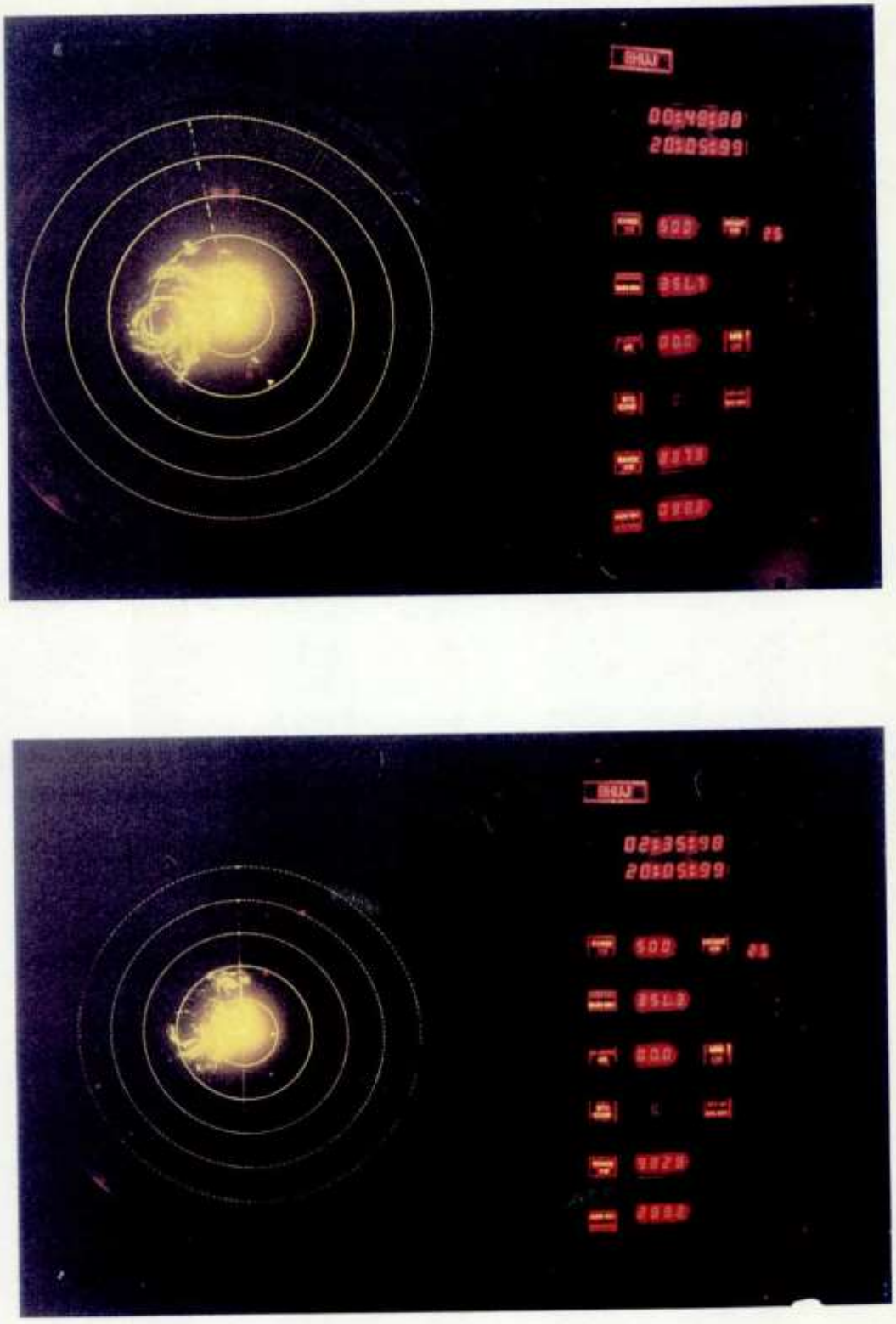


FIG. 2.2.4

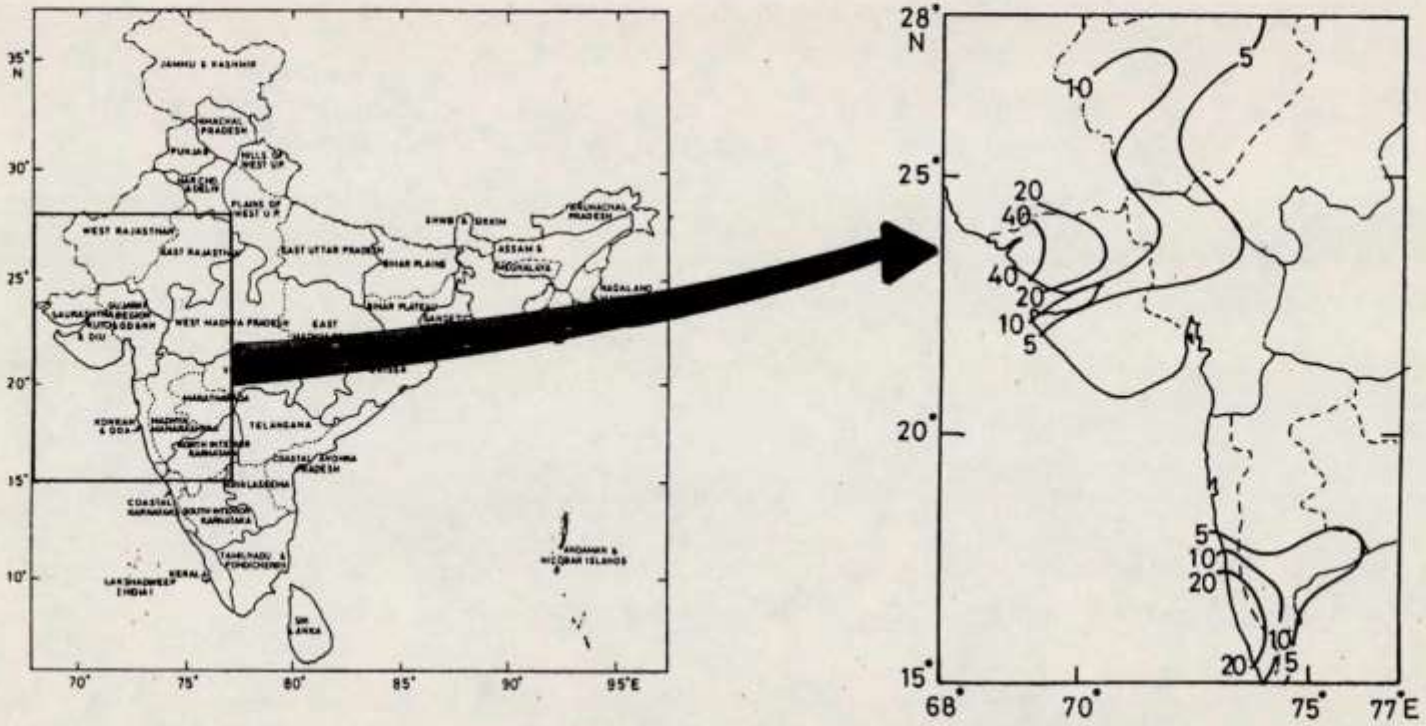

35° N
30°
25°
20°
15°
10°
70°
75°
80°
85°
90°
95°E
28° N
25°
20°
15°
68°
70°
75°
77°E
5
10
20
40
40
20
10
5
5
10
20
10
20
15

FIG. 2.25

2.3 BAY OF BENGAL DEEP DEPRESSION (17- 18 June 1999)

This system developed as the first monsoon depression close to the coast in the northwest Bay of Bengal in the morning of 17 June, 1999. Moving in a northwesterly direction it crossed Orissa coast close to Gopalpur (43049) at night. After crossing coast it moved in a west-northwesterly direction and weakened into a low pressure area over North Vidarbha and adjoining parts of Madhya Pradesh (M.P.) in the evening of 18 June.

During the year 1999, southwest monsoon had covered the Bay of Bengal by 28 May, about 8-10 days in advance compared to its normal date. By 16 June, it had covered peninsular India, eastern India and parts of central India to the east of 82° E longitude. While the monsoon was continuing to advance over the remaining parts of central India, a well marked low pressure area developed over northwest Bay of Bengal off Orissa coast in the morning of 16 June. It concentrated into a Depression (D) at 170300 UTC with its centre near lat. 18.5° N / long. 86.0° E and became deep at 170600 UTC. Spiraling convective cloud bands were seen at this stage in the north and northeastern sectors in the satellite imagery. Thereafter it moved northwestwards and was centred at 171200 UTC near lat. 19.0° N / long. 85.0° E about 40 km southeast of Gopalpur. Continuing to move in a northwesterly direction it crossed Orissa coast close to Gopalpur around 172100 UTC. After crossing coast it continued to move in a Westnorth-westerly direction and weakened into a depression at `180300 UTC neat lat. 20.5° N/ long. 82°.0 E about 100 km south of Raipur (42875). At 180900 UTC it was located near lat. 21.0° N/ long. 79.0° E close to Nagpur (42867). It weakened into a well marked low pressure area at 181200 UTC over north Vidarbha and adjoining M.P. .

The track of the system is given in Fig. 2.3.1. The best track positions and other parameters are given in Table 2.3.1. A few satellite pictures are included in Fig. 2.3.2.

Weather realised

In association with this depression widespread rainfall occurred in Coastal Andhra Pradesh , Telangana, east Madhya Pradesh, fairly widespread in South Coastal Orissa, and scattered in Vidarbha & Marathwada during 17- 18 June. Cumulative rainfall for the period 17 -18 June is shown in Fig. 2.3.3 . The system enhanced the onset process of Southwest Monsoon in peninsular and central parts of India.

Damage :

No damage to life and property was reported.

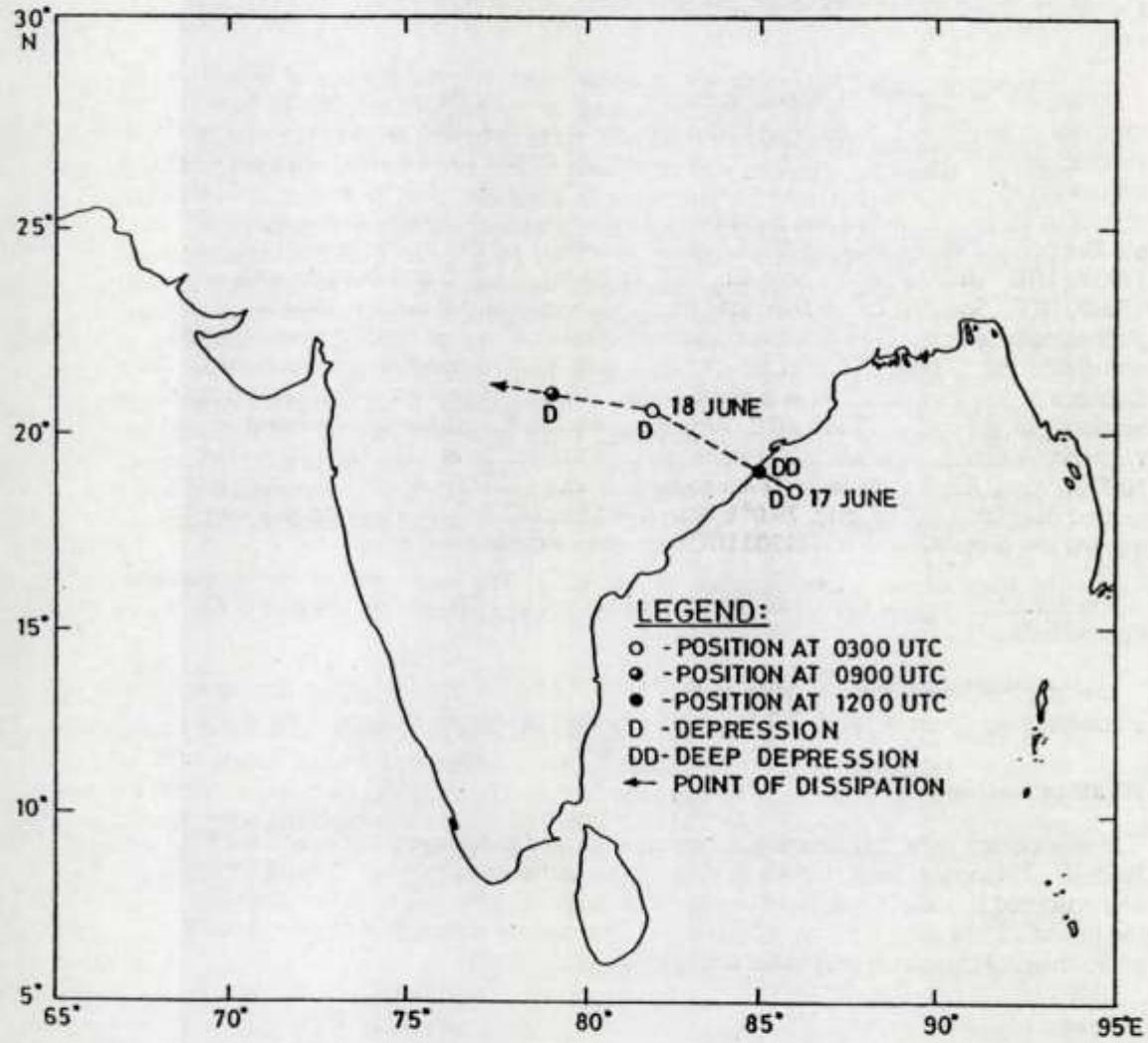
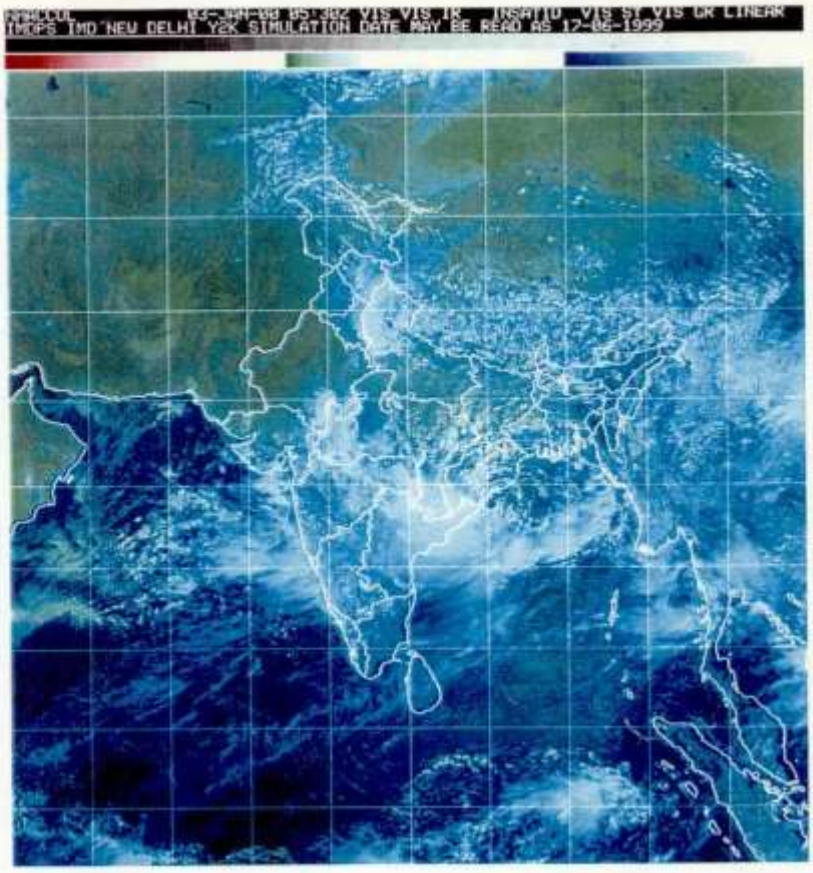

30° N
25°
20°
15°
10°
5°
65°
70°
75°
80°
85°
90°
95°E
D
D
18 JUNE
DD
D
17 JUNE
LEGEND:
o - POSITION AT 0300 UTC
- POSITION AT 0900 UTC
- POSITION AT 1200 UTC
D - DEPRESSION
DD- DEEP DEPRESSION
POINT OF DISSIPATION

FIG. 2.3.1

Table 2.3.1

Best track position and other parameters for the Bay of Bengal Deep Depression (17 – 18 June 1999)

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
17.6.99	03	18.5/86.0	1.5	990	25	6	D
	06	18.5/86.0	2.0	992	30	6	DD
	12	19.0/85.0	2.0	986	30	6	DD
	18	19.5/84.5	2.0	986	30	6	DD
Crossed Orissa Coast close to Gopalpur around 172100 UTC.							
18.6.99	00	19.5/84.0					D
	03	20.5/82.0					D
	06	21.0/82.0					D
	09	21.0/79.0					D


INSAT1 ASIA MER 18-JUN-99 03:00Z VIS VIS IR INSAT1D VIS ST VIS OR LINEAR
IMDPS IMD NEW DELHI Y2K STIMULATION DATE MAY BE READ AS 17-06-1999

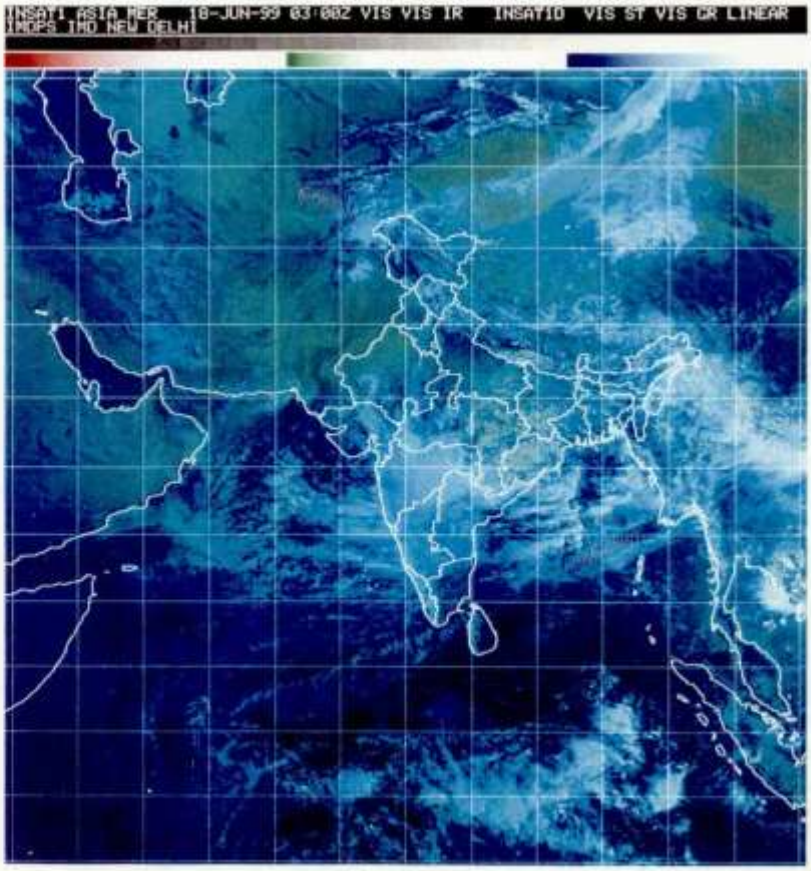

INSAT1 ASIA MER 18-JUN-99 03:00Z VIS VIS IR INSAT1D VIS ST VIS OR LINEAR
IMDPS IMD NEW DELHI

FIG. 2.3.2

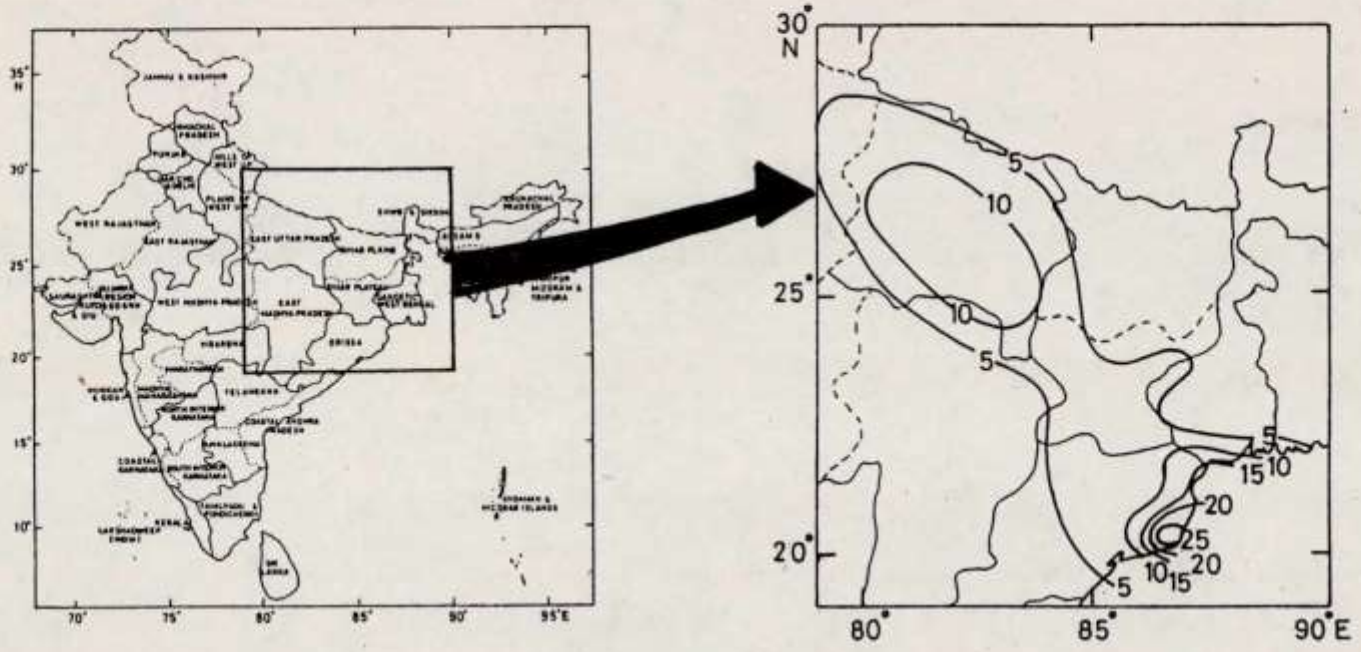


FIG. 2.3.3

2.4 Deep depression over the Bay of Bengal (27-29 July 1999)

The system developed as a depression over northwest Bay of Bengal in the morning of 27 July. It crossed West Bengal coast in the early morning of 28 July as a deep depression and weakened into a well marked low pressure area over northwest Madhya Pradesh (M.P.) in the afternoon of 29 July.

A well marked low pressure formed over northwest Bay of Bengal in the evening of 26 July. It concentrated into a depression at 270300 UTC with its centre near lat. 21.0^0 N / long 89.0^0 E about 200 km south-southeast of Calcutta. Moving westwards it further intensified into a deep depression at 271200 UTC near lat. 21.0^0 N / long 88.5^0 E about 140 km south of Calcutta. Moving northwestwards it crossed Orissa- West Bengal coast in the early morning hours of 28 July and lay centred at 280300 UTC near lat. 23.0^0 N/ long. 86.5^0 E about 50 km southeast of Purulia (42705). Hereafter it moved in a westnorthwesterly direction and weakened into a depression at 281200 UTC near lat. 23.0^0 N/ long. 84.5^0 E about 50 km northwest of Ranchi (42701). The system finally weakened into a well marked low pressure area over northwest M. P. and neighbourhood in the afternoon of 29 July.

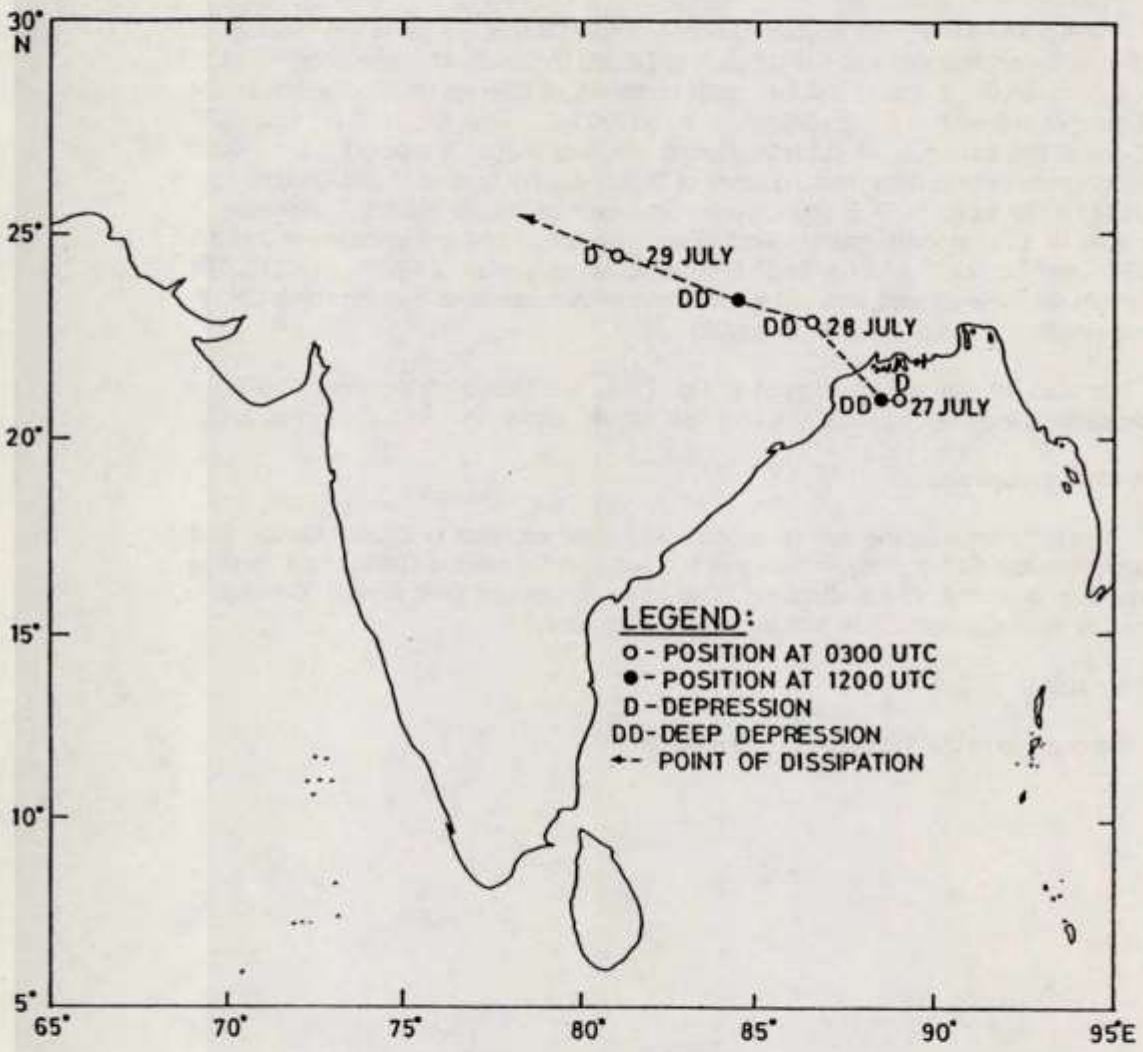
The track of the system is given in Fig. 2.4.1. The best track positions and other parameters are given in Table 2.4.1. A few satellite pictures are included in Fig. 2.4.2.

Weather realised

In association with the system widespread rainfall occurred in Coastal Orissa, East Uttar Pradesh (U.P.) ,fairly widespread in Bihar Plateau, interior Orissa, East Madhya Pradesh, West U.P. and scattered in Bihar Plains & Gangetic West Bengal. Cumulative rainfall for the period 27-29 July is shown in Figure. 2.4.3 .

Damage :

No damage to life and property was reported .


30° N
25°
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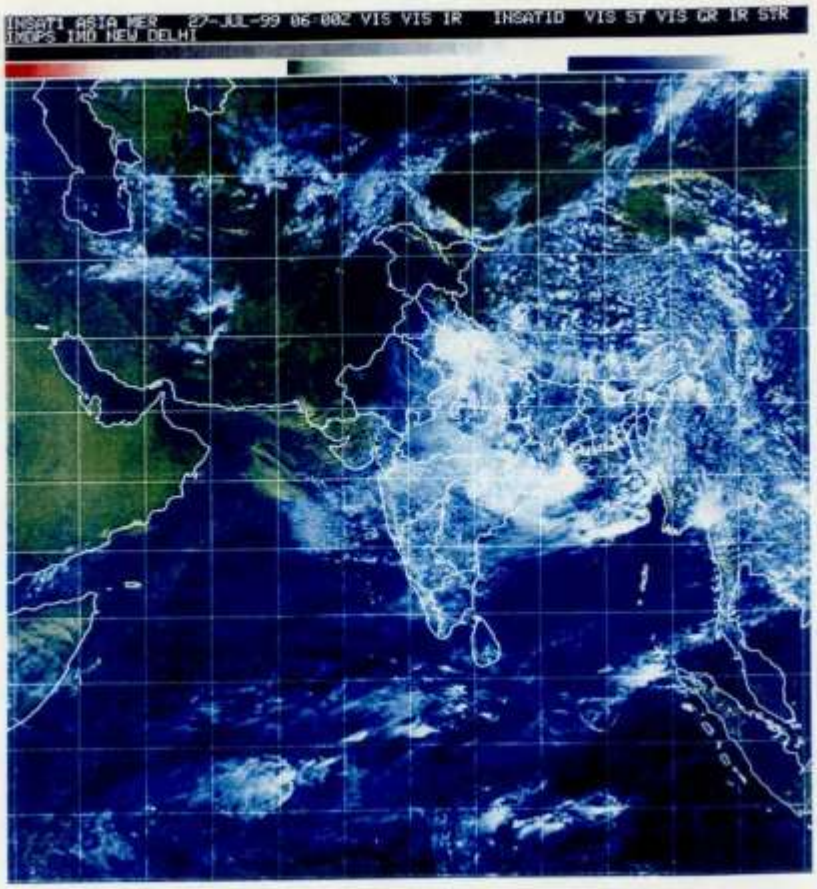
10°
5°
65°
70°
75°
80°
85°
90°
95°E
D
29 JULY
DD
DD
28 JULY
D
DD
27 JULY
LEGEND:
o - POSITION AT 0300 UTC
● - POSITION AT 1200 UTC
D - DEPRESSION
DD - DEEP DEPRESSION
+- POINT OF DISSIPATION

FIG. 2.4.1

Table 2.4.1

Best track position and other parameters for the Bay of Bengal Deep Depression (27-29 July 1999)

Date	Time (UTC)	Centre Lat. ^{0}N /Long .^{0}E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
27.7.99	03	21.0/89.0	1.5	992	20	4	D
	06	21.0/88.5	1.5	992	20	4	D
	12	22.0/88.5	2.0	990	25	6	DD
	18	22.0/87.5	2.0	992	25	6	DD
28.7.99	00	22.5/87.0	2.0	992	25	6	DD
	Crossed Orissa –West Bengal coast in the early morning hours of 28 July.						
	03	23.0/86.5					DD
	06	23.0/84.5					D
	12	23.5/84.5					D
	18	23.5/83.5					D
29.7.99	00	24.0/82.0					D
	03	24.5/81.0					D
	06	25.0/80.0					D


INSAT ASIA MER 27-JUL-99 06:00Z VIS VIS IR INSATID VIS ST VIS GR IR STR
IMDPS IMD NEW DELHI

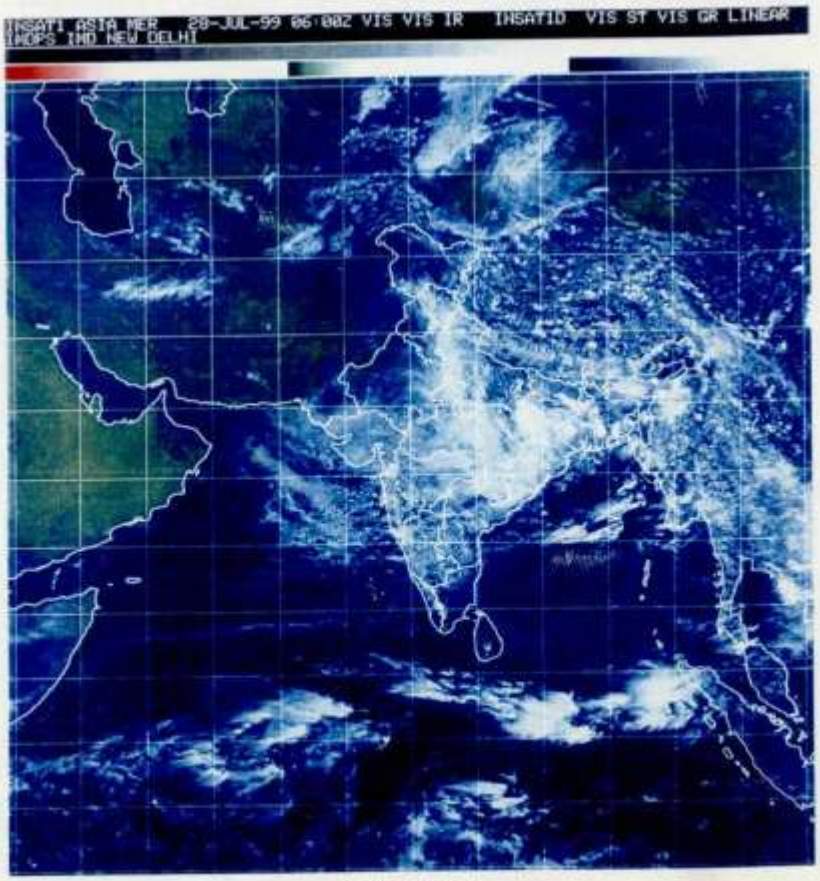

INSAT ASIA MER 28-JUL-99 06:00Z VIS VIS IR INSATID VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI

FIG. 2.4.2

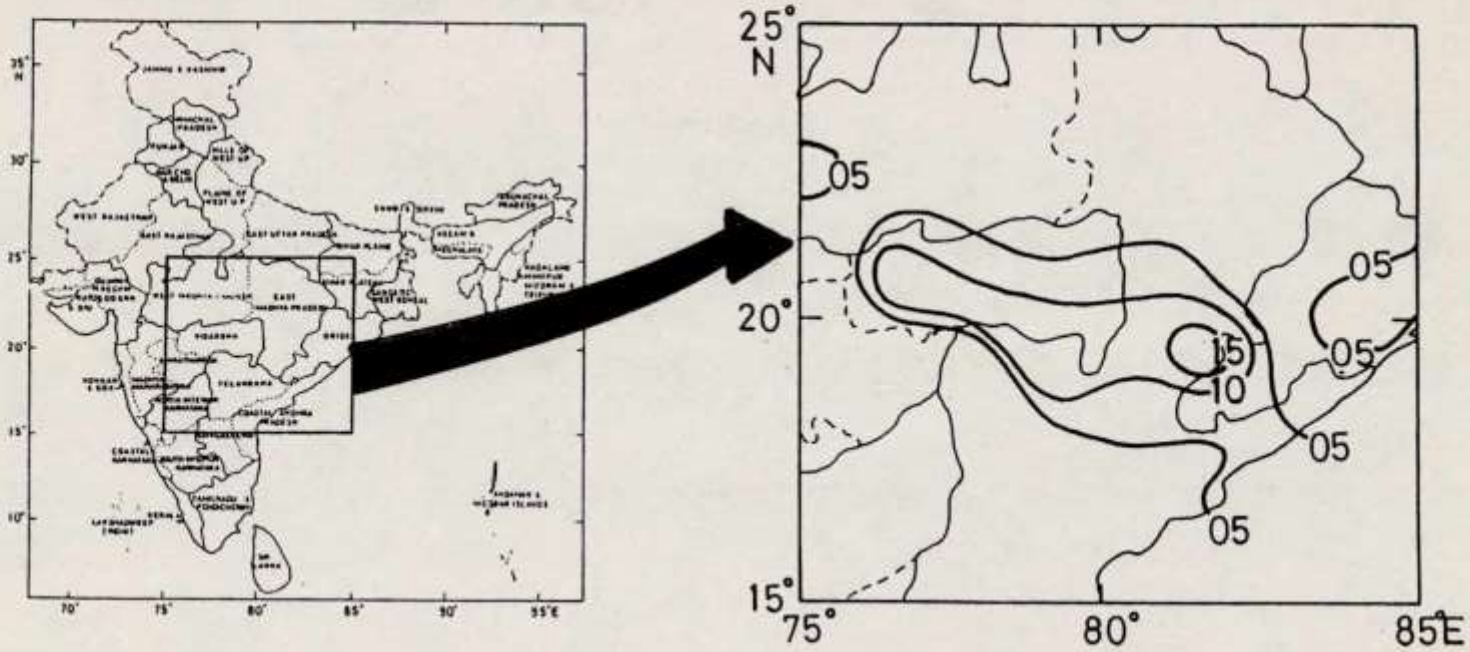


FIG. 2.4.3

2.5 Depression over the Bay of Bengal (6-8 August 1999)

A well marked low pressure area developed over northwest Bay of Bengal off north Orissa- West Bengal coast on the morning of 6 August. It concentrated into a depression and lay centred at 12 UTC near lat. 21.0 deg N/ long. 88.5 deg E about 160 km south of Calcutta (42809). It moved in a west-northwesterly direction and crossed West Bengal coast near Digha during the night of the same day and lay centred at 070300 UTC near lat. 22.5 deg N / Long. 87.5 deg E close to Midnapur (42803) .Thereafter it moved westwards and was located at 071200 UTC near lat. 22.5^0 N / long 86.0^0 E very close to Jamshedpur (42798). Moving in a west-northwesterly direction it was located at 080300 UTC near lat. 22.5^0 N /long 85.0^0 E about 80 km southeast of Ambikapur (42901). Continuing its intensity as depression it moved further westwards and was located at 081200 UTC near lat. 22.5^0 N / long 83.0^0 E about 80 km southeast of Pendra (42779). Thereafter it changed its track slightly and weakened into a well marked low pressure area over north Madhya Pradesh and neighbourhood in the morning of 9 August.

The track of the system is given in Fig. 2.5.1. The best track positions and other parameters are given in Table 2.5.1. A few satellite pictures are included in Fig. 2.5.2. .

Weather realized :

In association with the system widespread rainfall occurred in Orissa & East Madhya Pradesh, fairly widespread in Gangetic West Bengal & Bihar Plateau and scattered in Vidarbha & North Coastal Andhra Pradesh. Realized rainfall is shown in Figure. 2.5.3.

Damage :

No damage to life and property was reported .

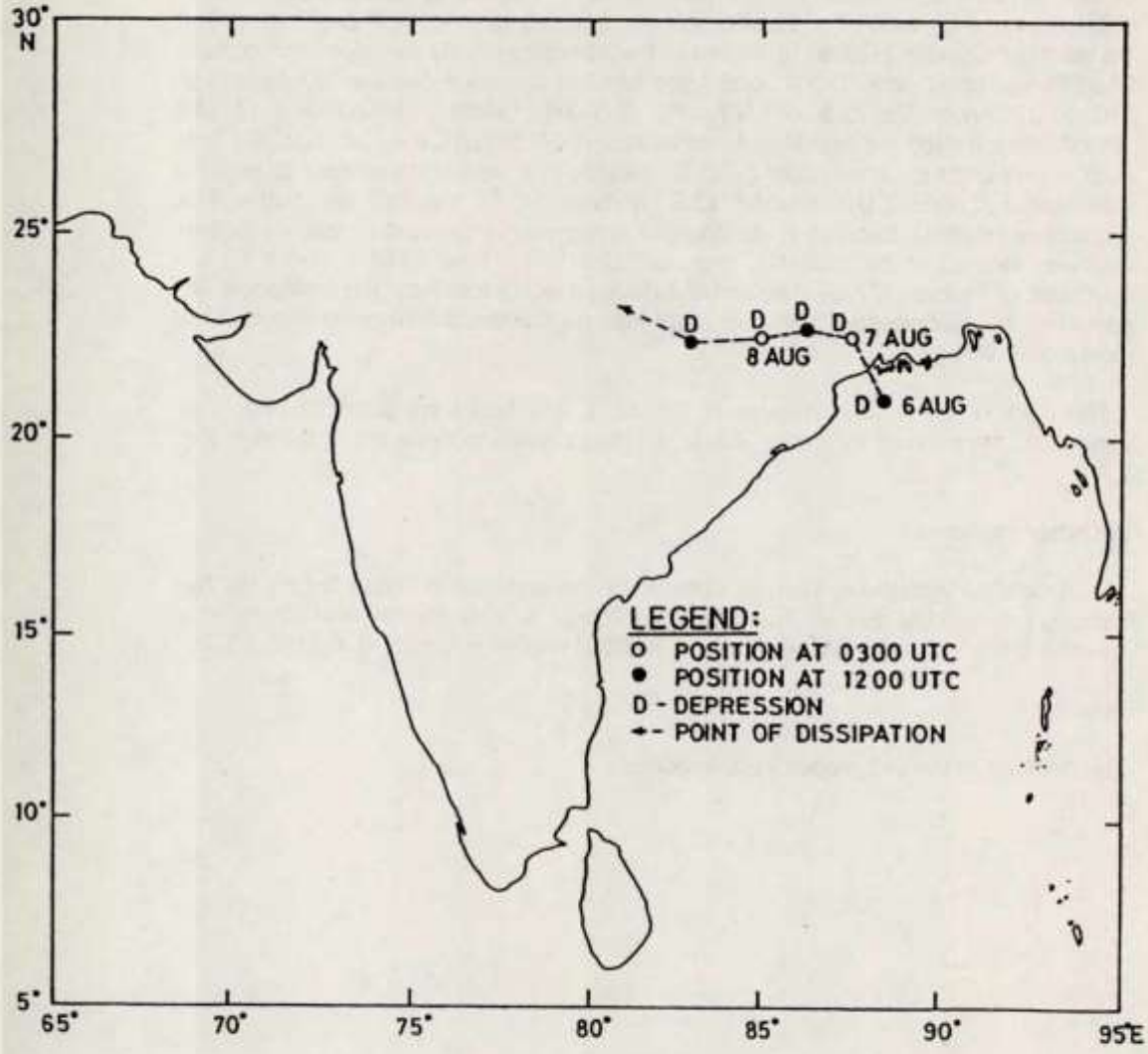
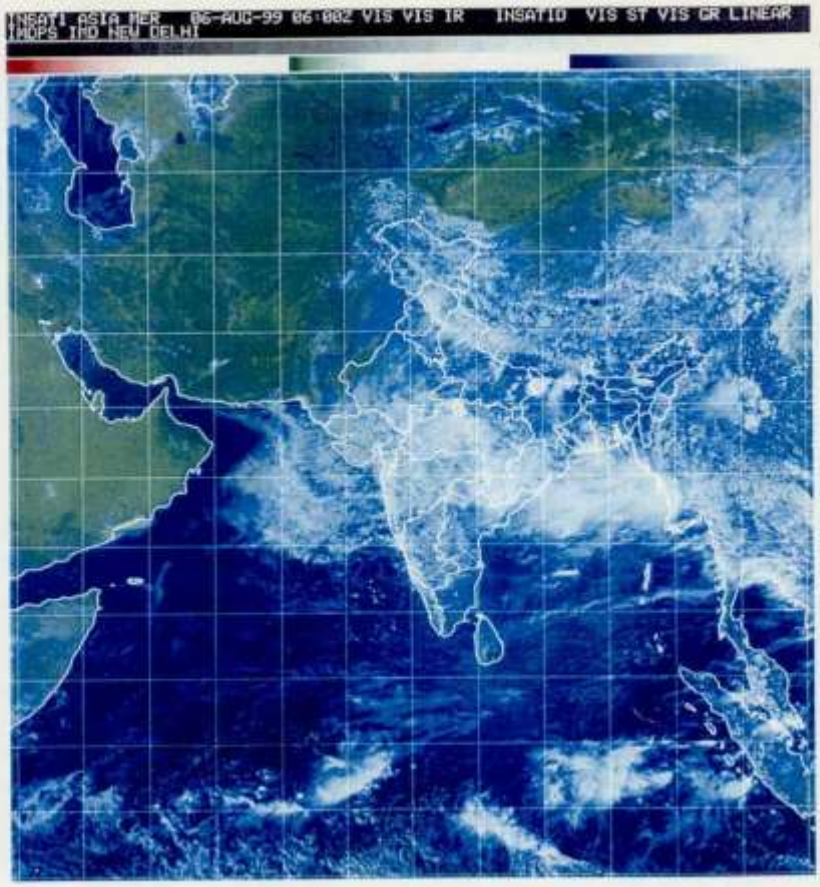

30° N
25°
20°
15°
10°
5°
65°
70°
75°
80°
85°
90°
95°E
D
D
D
D
7 AUG
8 AUG
D
6 AUG
LEGEND:
POSITION AT 0300 UTC
POSITION AT 1200 UTC
D - DEPRESSION
POINT OF DISSIPATION

FIG. 2.5.1

Table 2.5.1

Best track position and other parameters for the depression over Bay of Bengal (6-9 August 1999)

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
6.8.99	12	21.0/88.5	1.5	992	20	4	D
	18	21.0/88.5	1.5	992	20	4	D
7.8.99	03	22.5/87.5	1.5	992	20	4	D
	06	22.5/86.5	1.5	992	20	4	D
	12	22.5/86.0	1.5	992	20	4	D
	18	22.5/86.0	1.5	992	20	4	D
8.8.99	03	22.5/85.0	1.5	992	20	4	D
	06	22.5/84.0	1.5	992	20	4	D
	12	22.5/83.0	1.5	992	20	4	D
	18	22.5/83.0	1.5	992	20	4	D
9.8.99	00	23.5/81.5	1.5	992	20	4	D
	03	**Lay over north Madhya Pradesh as a well marked low pressure area.**					


INSAT ASIA MER 06-AUG-99 06:00Z VIS VIS IR INSATID VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI

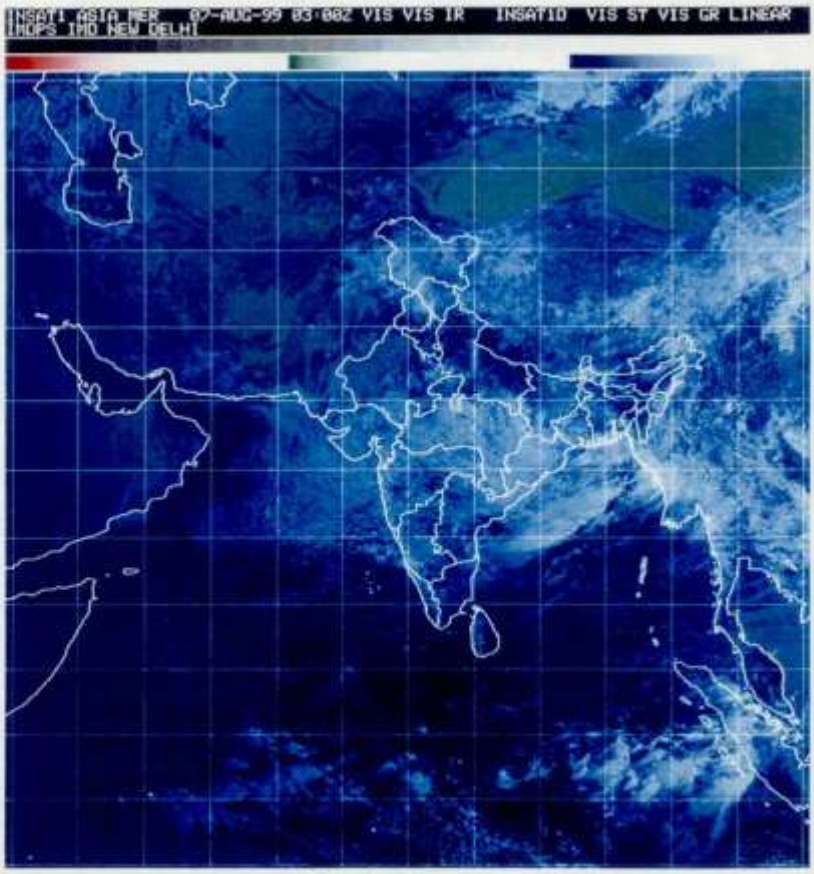

INSAT ASIA MER 07-AUG-99 03:00Z VIS VIS IR INSATID VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI

FIG. 2.5.2

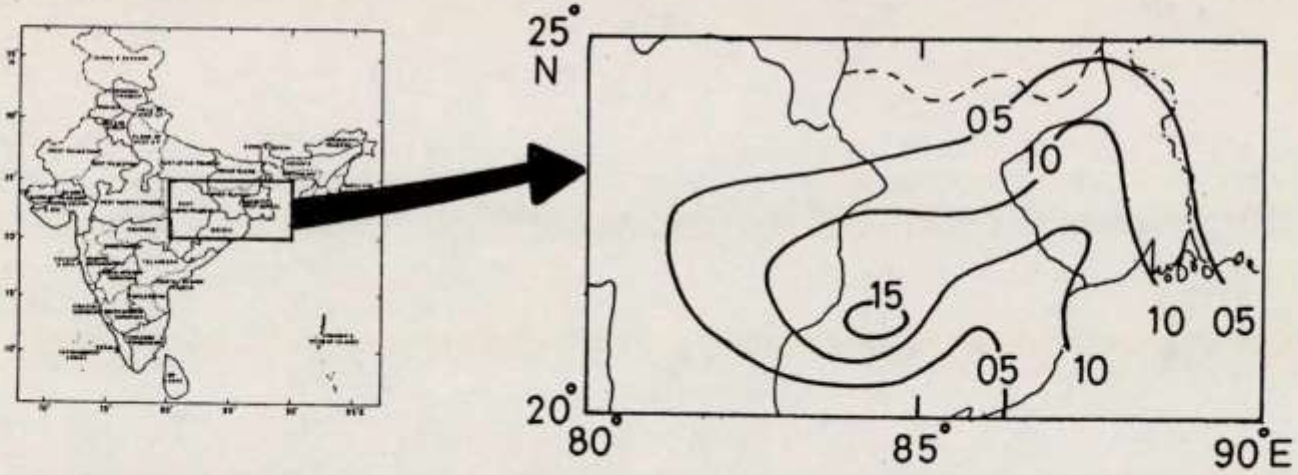


FIG. 2.5.3

2.6 Very Severe Cyclonic Storm over Bay of Bengal (15-19 October 1999) (BOB 02 99 10 15 19)

This was the first storm of the post monsoon season. Its initial development occurred over North Andaman sea in the morning of 15 October. Moving northwestwards it intensified into a very severe cyclonic storm that crossed Orissa coast near Gopalpur (43049) around midnight of 17 October. Moving first in a northerly direction and then northeastward, it weakened into a low pressure area over Sub- Himalayan West Bengal and adjoining areas of Bihar plains and Bangladesh in the afternoon of 19 October.

Under the influence of an easterly wave, a defused low pressure area developed over Gulf of Thailand and Malay Peninsula which entered into North Andaman Sea on 14 October. It concentrated into a depression at 150300 UTC near lat.13.5^0 N/long. 92.5^0 E. The depression moved westnorthwestwards / northwestwards and became deep during the night of 15 October. While it was continuing its northwesterly course the convection increased considerably at night .It was upgraded to a cyclonic storm at 160300 UTC centred near lat.16.0 N /long. 88.5^0. A comma cloud was seen in the cloud imagery at 160600 UTC. The Central Dense Overcast (CDO) increased in size in the afternoon. The system was declared as severe cyclonic storm at 161500 UTC near lat. 17.5^0 N / long.86.5^0 E. No 'EYE' was seen upto 161800 UTC . 'EYE' was first detected in NOAA –14 Channel 4 imagery at 162143 UTC. At this stage it was centred about 350 km southeast of Gopalpur. It concentrated into a very severe cyclonic storm (VSCS) and was located at 170000 UTC near lat. 18.0^0 N / long 85.5^0 E. It then took a north-northwesterly course and crossed Orissa coast near Gopalpur in the early morning hours of 17 October .

This system was also tracked by Cyclone Detection Radars (CDRs) at Paradip and Visakhapatanam. CDR Visakhapatanam reported 'eye' at 170300 UTC with eyewall width of 10 Km , diameter of 16 Km and radius of maximum reflectivity of 13 Km

After crossing coast the VSCS moved in a northerly direction and weakened into a Severe Cyclonic Storm (SCS) in the morning hours of 18 October. Thereafter it moved in a north-northeasterly direction and weakened into a Cyclonic storm (CS) near lat 20.5^0 N / long 85.0^0 E in the afternoon of 18 October and into a depression near lat. 23.0^0 N/long 87.5^0 E in the morning of 19 October. The system finally dissipated over Gangetic West Bengal and adjoining areas of Bangladesh in the afternoon of the same day.

As in the case of November 1996, great operational difficulties were experienced in performing intensity analysis using Dvorak's Technique. Rapid intensification after 161800 UTC could not be easily accounted for. The Current Intensity of this cyclone is re-adjusted taking into consideration the reported wind speeds.

The lowest recorded mean sea level pressure at Gopalpur was 958.9 hPa at 171830 UTC. Maximum wind of 98 Kt was reported at 172000 and 172100 UTC .

Hourly wind observations of Gopalpur at the time of storm crossing the coast were as below :

Date	Time (UTC)	wind (direction / Speed (Kt))
17.10.99	1600	020/50
	1700	050/76
	1800	070/95
	1900	050/10
	2000	180/98
	2100	180/98
	2200	180/90
	2300	180/30

Track of the system is given in Fig. 2.6.1. The track predicted by RSMC-Tropical cyclone New Delhi Limited Area Forecast Model (LAM) for various initial positions is given in Fig .2.6.2. The best track positions and other parameters are included in Table 2.6.1 A few INSAT cloud imagery are shown in Fig. 2.6.3 A few radar images of CDR Visakhapatnam are shown in Fig. 2.6.4

Weather realized :

In association with this system Orissa received very heavy rainfall on 18th. Cumulative rainfall for the period 15-19 October is shown in Fig .2.6.5.

Damage :

Orissa

Lives lost : 197
Persons injured : 402
Loss of crops : Thousands Hectres of land

(SOURCE : Government of Orissa)

Andhra Pradesh

The system affected, Kaviti, Kanchilli and Mandasa of Srikakulam districts of Andhra Pradesh.

Life lost : 1
Damage to property :Three lakh cocoanut trees uprooted and two lakhs trees damaged.

(Sourc: Andhra Pradesh. Government)

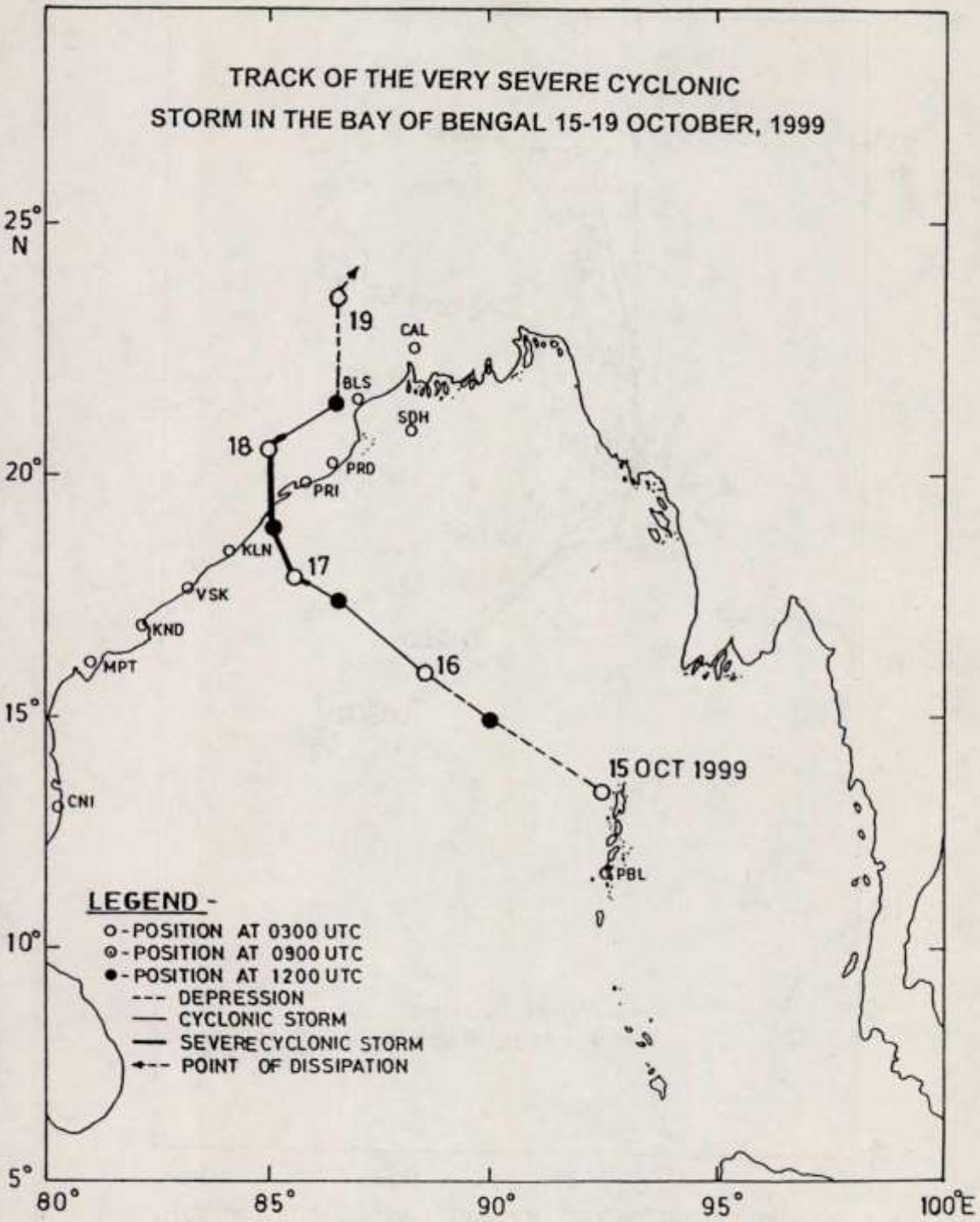

TRACK OF THE VERY SEVERE CYCLONIC
STORM IN THE BAY OF BENGAL 15-19 OCTOBER, 1999
25° N
20°
15°
10°
5°
80°
85°
90°
95°
100°E
19
18
17
16
15 OCT 1999
CAL
BLS
SDH
PRD
PRI
KLN
VSK
KND
MPT
CNI
PBL
LEGEND -
O - POSITION AT 0300 UTC
⊙ - POSITION AT 0900 UTC
● - POSITION AT 1200 UTC
--- DEPRESSION
— CYCLONIC STORM
— SEVERE CYCLONIC STORM
POINT OF DISSIPATION

FIG. 2.6.1

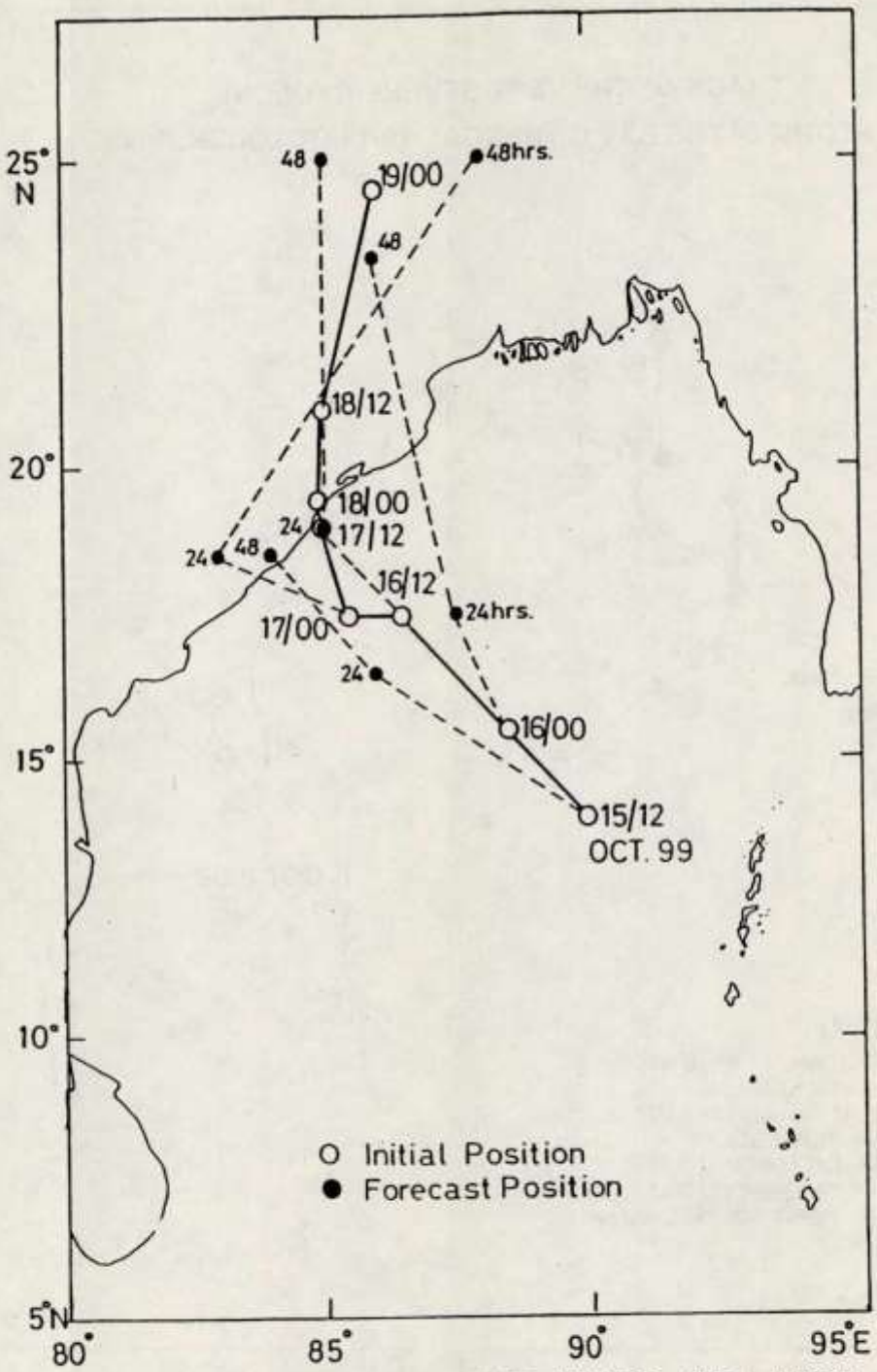


FIG. 2.6.2 TRACK PREDICTED BY IMD LIMITED AREA MODEL

Table 2.6.1

Best track position and other parameters for the Bay of Bengal Very Severe Cyclonic Storm (15-19 October 1999)

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 Grade
15.10.99	03	13.5/92.5	1.5	1004	20	4	D
	06	14.0/91.5	1.5	1002	20	4	D
	12	15.0/90.0	1.5	1002	20	4	D
	18	15.2/89.5	1.5	1002	20	4	D
	21	15.3/89.0	2.0	1000	25 30	6	DD
16.10.99	00	15.5/88.5	2.0	1000	30	8	DD
	03	16.0/88.5	2.5	998	35	10	CS
	06	16.5/88.0	2.5	998	35	10	CS
	09	17.0/87.5	3.0	996	45	12	CS
	12	17.5/86.5	3.0	994	45	12	CS
	15	17.6/86.0	3.5	992	55	16	SCS
	18	17.6/86.0	3.5	992	55	16	SCS
	21	17.7/86.0	3.5	992	55	16	SCS
17.10.99	00	17.7/86.0	4.0	988	65	20	VSCS
	03	18.0/85.5	4.5	978	80	30	VSCS
	06	18.0/85.0	4.5	978	80	30	VSCS
	09	18.5/85.0	4.5	978	80	30	VSCS
	12	19.0/85.0	4.5	978	80	30	VSCS
	15	19.0/85.0	4.5	978	80	30	VSCS

Table 2.6.1 (CONTINUED)

Best track position and other parameters for the Bay of Bengal Very Severe Cyclonic Storm (15-19 October 1999)

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 Grade
17.10.99	18	19.2/85.0	5.0	968	90	40	VSCS
		Crossed Orissa coast near Gopalpur in the early morning hours of 18th . October					
18.10.99	00	19.5/85.0					VSCS
	03	20.5/85.0					SCS
	06	20.5/85.0					SCS
	09	20.5/85.0					CS
	12	21.5/86.5					CS
	15	21.0/86.5					DD
	18	22.5/86.5					DD
	21	23.0/86.5					DD
19.10.99	00	23.0/86.5					D
	03	23.5/86.5					D

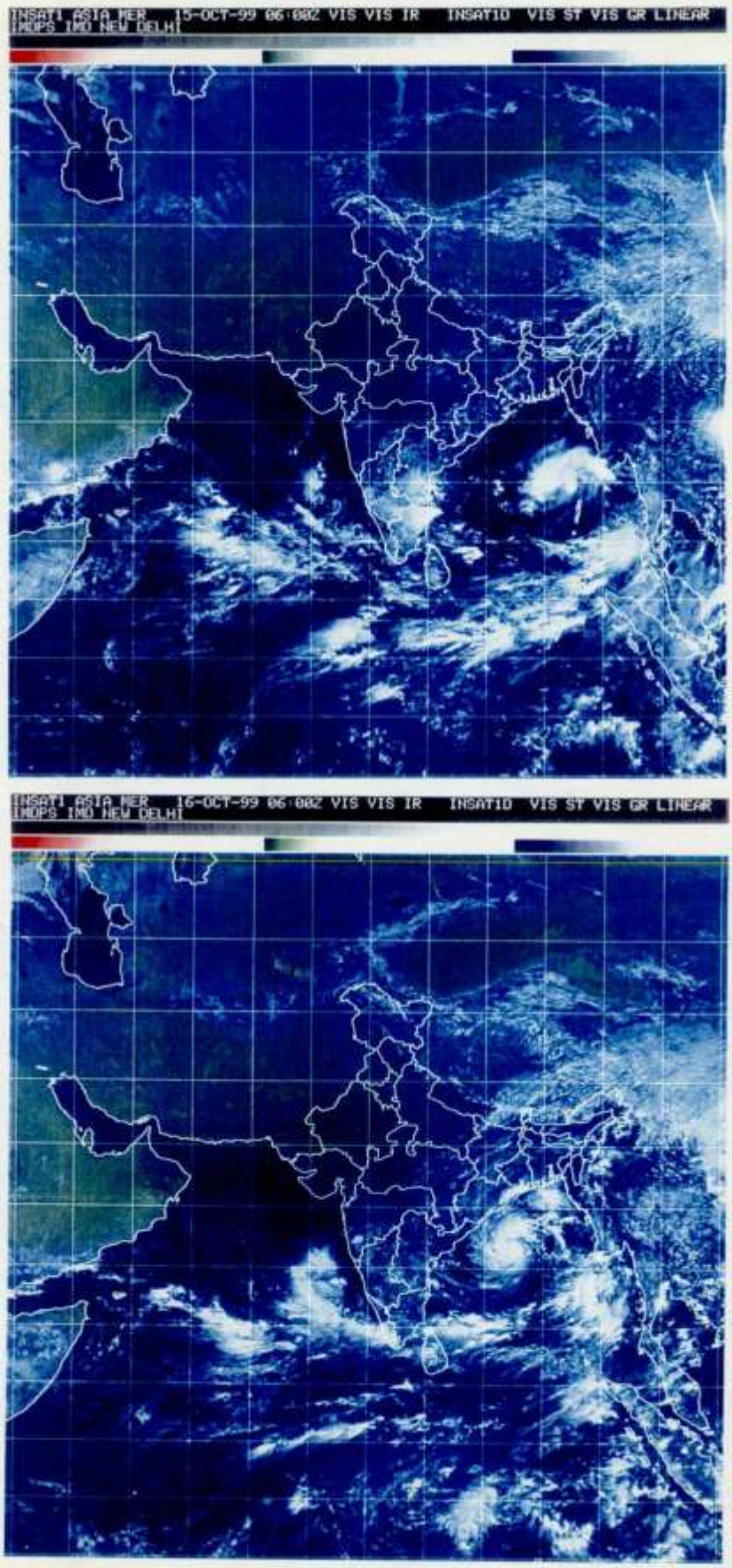

INSAT1 ASIA MER 15-OCT-99 06:00Z VIS VIS IR INSAT1D VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI
INSAT1 ASIA MER 16-OCT-99 06:00Z VIS VIS IR INSAT1D VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI

FIG. 2.6.3

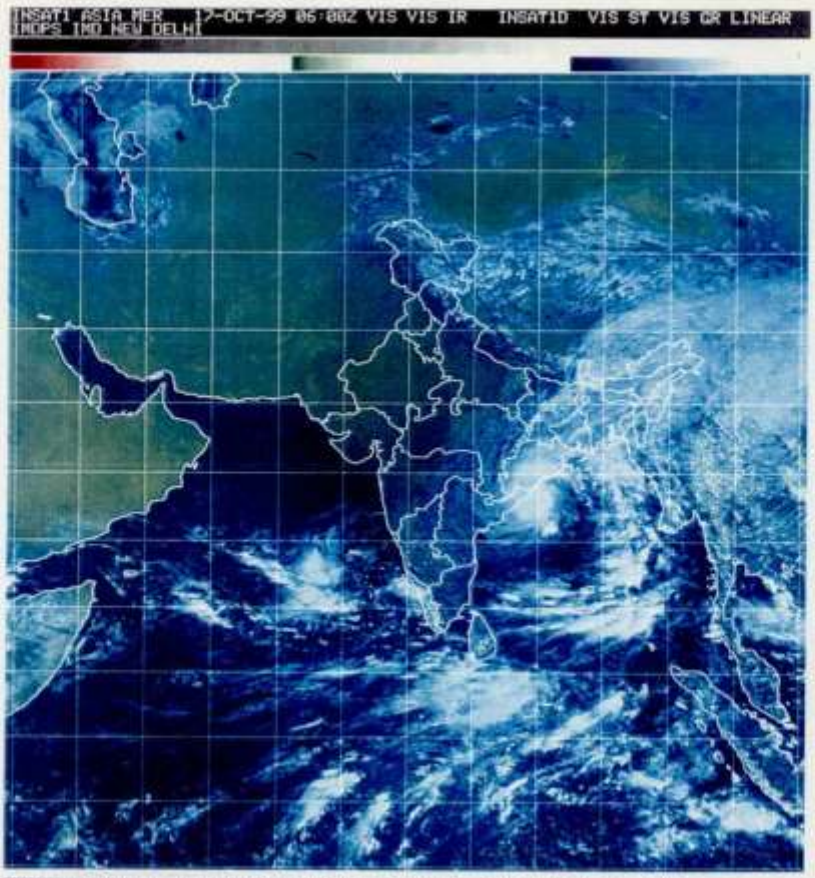


FIG. 2.6.3 contd.


CDR Visakhapatnam
1800 UTC / 16.10.99

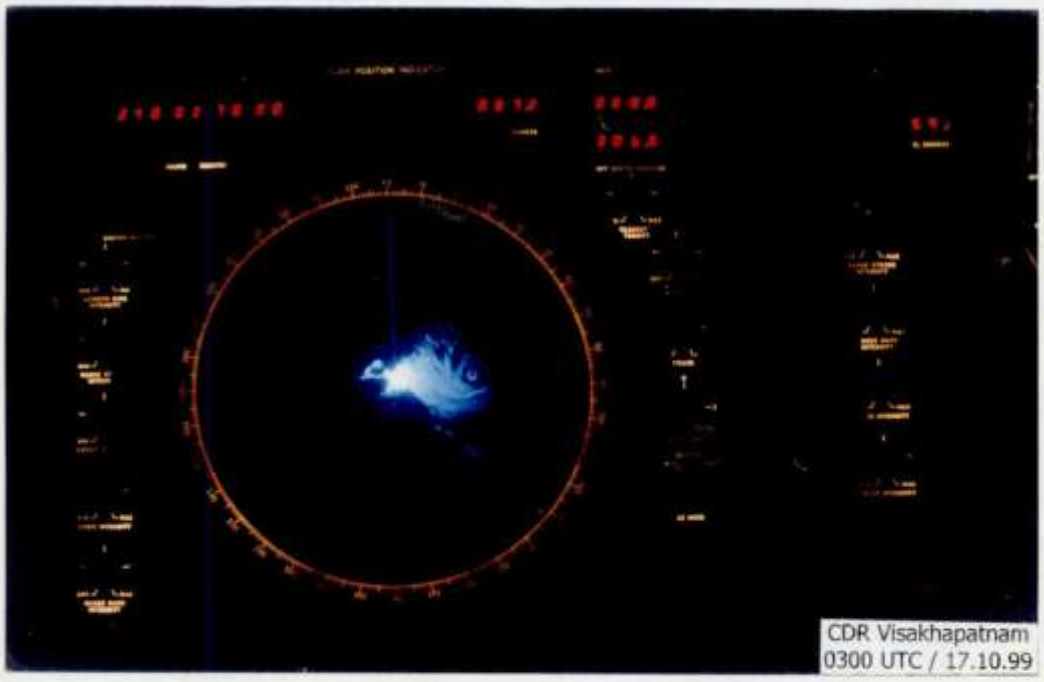

CDR Visakhapatnam
0300 UTC / 17.10.99

FIG. 2.6.4

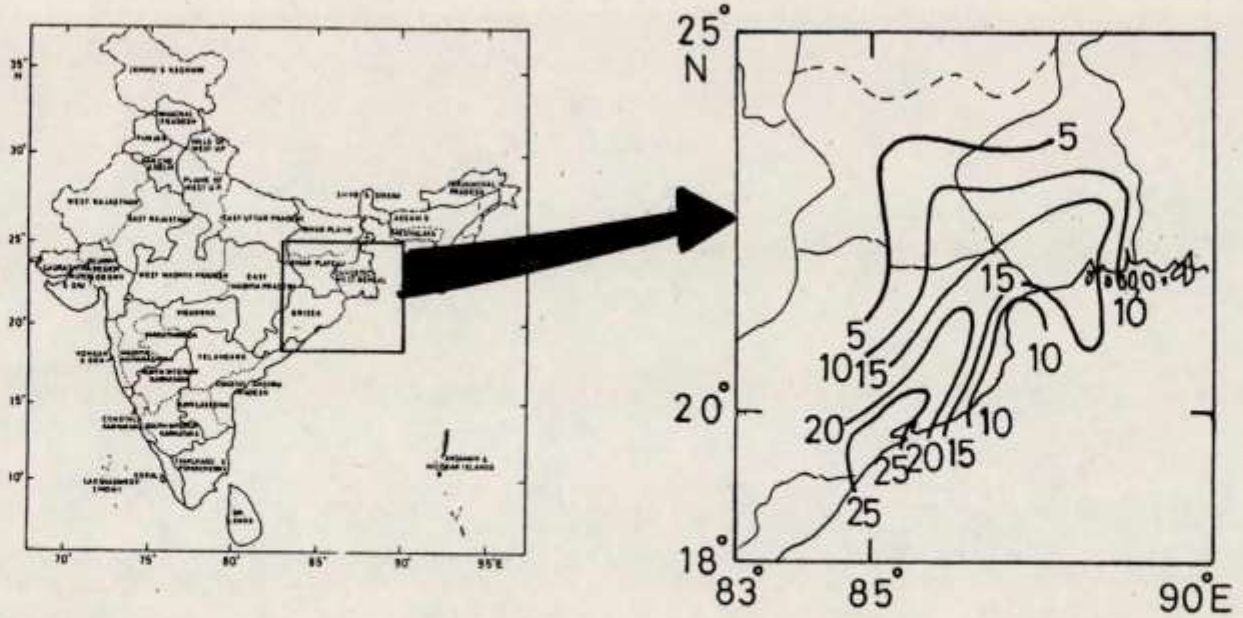


FIG. 2.6.5

2.7 Super Cyclonic Storm over the Bay of Bengal (25-31 October 1999) (BOB 03 99 10 25 31)

It was the most intense tropical cyclone in the history of Orissa for the last 114 years since the False Point cyclone of 19-23 September 1885. This State was battered for more than two days by its fierce winds and intense rain. It also produced huge storm surge and catastrophic floods. The initial disturbance that eventually led to this development was discerned in the Gulf of Thailand on 24 October. While moving westnorthwestward it intensified through several stages of evolution particularly on 28 October when it slowed down its forward motion . It crossed Orissa coast of India close to Paradip (42976) between 0430 and 0630 UTC of 29 October .

Initial vortex was spotted over the Gulf of Thailand at 240000 UTC in the RSMC New Delhi synoptic charts . Moving westwards across Malaysian peninsula, it emerged in North Andaman Sea as a well marked low pressure area in the morning of 25 October. It concentrated into a depression in the evening of the same day and was centred at 251200 UTC near lat. 12.5^0 N/ long. 98.0^0 E. The initial development was seen in the satellite cloud imagery as a curved band pattern. The depression moved in a westnorthwesterly direction and intensified into a cyclonic storm at 260300 UTC near lat. 13.5^0 N / long. 95.0^0 E. The system then took a northwest course under the steering flow of the sub–tropical ridge to its north-east at 200 hPa level.

The system intensified further as the curved cloud band coiled around the centre almost completely . It was classified as a severe cyclonic storm at 270300 UTC near lat. 16.0^0 N / long. 92.0^0 E. At this stage, the storm had come under the influence of 200 hPa ridge axis providing upper level outflow conducive for further development. It came relatively close to upper level ridge and slowed down its forward motion after 270900 UTC as 200 hPa anticyclone got positioned over the system in the evening providing good outflow. It was upgraded to the stage of a very severe cyclonic storm at 271500 UTC near lat. 17.0^0 N / long. 90.5^0 E. While continuing to move northwestwards it deepened further. It was located at 280300 UTC near lat. 17.5^0 N / long. 89.5^0 E. At this time ' Eye' was seen clearly in the visible cloud imagery.

The upper level flow continued to be favourable for ongoing development. Re-examination of satellite data indicates that the system attained the stage of **super cyclonic storm** at 281500 UTC near lat. 19.0^0 N / long. 87.5^0 E. At 281800 UTC a very warm eye with eye temperature of 264^0 K was seen surrounded by a very cold band in which cloud top temperatures were lower then 193^0 K . The estimated central pressure fell by 56 hPa between 280600 and 2801800 UTC indicating that it was a case of rapid development. The lowest estimated central pressure for this storm was 912 hPa. The lowest central pressure in this case was almost the same as in the case of Andhra cyclone of November 1977. This is ,therefore, almost the lowest central pressure encountered so far in any tropical cyclone in the Bay of Bengal.

Like many other cyclones the convective organisation of this super cyclone also weakened before landfall as seen in the satellite images that showed shrinking of the deep layer central overcast, and warming of the cloud tops.

The following table shows the strengthening of winds at Paradip and Bhubaneswar in association with landfall process.

STATION	DATE	TIME (UTC)	WIND DIRECTION/SPEED (Kt)
Paradip	28.10.99	2000	045/25
		2100	045/35
		2200	045/40
		2300	045/40
	29.10.99	0000	045/50
		0100	040/70
		0200	**030/80***
Bhubaneswar	29.10.99	0400	340/70
		0500	340/70
		0600	340/60
		0700	**340/80***

*The wind instruments became unserviceable thereafter. No observations were available from Paradip after 290200 UTC.

The High Speed Wind Recorder (HSWR) at Paradip became unserviceable when the wind speed was 80 Kt. The low speed wind recorder also became unserviceable after recording 80 kt winds.The winds strengthened upto 80 kt at Bhubaneswar by 290700 UTC when the anemometer became unserviceable. However, estimated winds were reported even thereafter from Bhubaneswar. Puri reported maximum wind of southwesterly 95 kt at 290700 UTC

After crossing coast the system tracked very slowly a little further to the northwest , weakened and lay centred at 291200 UTC near lat. 20.5^0 N / long 86.0^0 E near Cuttack (42970) as a very severe cyclonic storm. Remaining practically stationary it weakened further into a severe cyclonic storm at 291800 UTC.

In the morning of 30 October it was located in the COL region at 200 hPa with an anticyclone to its west over western and adjoining areas of central India and another to the east covering areas of parts of north Bay of Bengal upto China Sea. This synoptic situation continued in the evening also. Under these synoptic situations the system remained practically stationary very close to Bhubaneswar (42971). The system weakened into a cyclonic storm at 300300 UTC and maintained this intensity upto 301200UTC. Even thereafter this system remained practically stationary till 310000 UTC. Therefore, the impact of this system over this region of the state with intense rains and strong winds of at least cyclonic force continued for more than 36 hours. Thereafter, the system moved slightly eastward and weakend into a depression at 310300 UTC near Chandbali (42973). While weakening further, the system came under the steering influence of the mid- tropospheric flow pattern that eventually produced southward drift of the system. Drifting southward it further weakened into a well marked low pressure area over coastal Orissa , north coastal Andhra Pradesh and adjoining sea areas of northwest Bay of Bengal by the morning of 1st November.

An interesting aspect of the above system was that the development of this storm took place within a period of two weeks of the landfall of the other very severe cyclonic storm that lashed Ganjam district of Orissa with a wind speed of about 98 kt on 17 October.

The tracks of the two cyclones were separated by about 200 Km. Apparently the first cyclone did not produce any cold water in its wake in the Bay of Bengal which normally happens after passage of a cyclone over the sea. This could have restricted development of the later cyclone that eventually acquired the stage of super cyclonic storm.

Tracking of the system:

The system was tracked through INSAT Cloud imagery and synoptic Observations during the first two days i.e. 25th and 26th October when it was over the Andaman Sea.

Thereafter the system was tracked only with the help of INSAT Cloud imagery till its landfall . Cyclone Detection Radar at Paradip tracked the system from 280600 UTC till 290200 UTC .

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

CDR Paradip observations

CDR Paradip reported circular 'eye' with centre near lat. 18.8^0 N / long. 87.5^0 E at 280800UTC. It estimated eye diameter as 20-29 Km. At 281200 UTC the ' eye 'became more distinct but its size increased at this time. The centre of the 'eye ' was located near lat. 19.2^0 N / long. 87.6^0 E .At 281400 UTC the ' eye ' diameter increased to 30-39 Km but again decreased to 10 to 19 km at 282000 UTC. It is interesting to see that by 282200 UTC the 'eye' again became more distinct as the diameter increased to 30-39 km. The storm became stationary with its centre near lat. 19.6^0 N / long.87.0^0 E till 282300 UTC as per the radar reports. CDR Paradip also reported the Radius of Maximum Reflectivity (RMR) which also showed fluctuations similar to the 'eye' diameter. The eye was seen surrounded by spirals. These observations reveal interactions between the eyewalls which are usually seen in super hurricane and super typhoons. The lowest RMR of 8 km was reported at 282000 UTC and 290200 UTC. Radar observations were available only upto 290200 UTC as the station became unserviceable due to logistic problems thereafter.

Numerical Guidance

The forecast of the movement of the cyclone was attempted by Limited Area Models being run in IMD the FSU based limited area model and NCEP based Quasi – Lagrangian Model (QLM). The track predicted by QLM Model-also run for the super cyclone by RSMC- Tropical cyclones New Delhi for various initial positions is given in Fig .2.7.3. The wind and vorticity forecast fields based on at 280000 UTC initial conditions and valid for 290000 UTC are shown in fig.2.7.4 and 2.7.5. The trend of movement is well captured in this model while most other models indicated northward recurvature before making landfall over Orissa.

Weather realized

The super cyclonic storm caused exceptionally heavy rains (with 24 hours amounts exceeding 20 cm) over some stations in Orissa as given below. Heavy rainfall also occurred in adjoining districts of Gangetic West Bengal . Cumulative rainfall for the period 28 to 31 October 1999 is shown in Fig. 2.7.6.

Station	Date	24 Hours Rainfall (cm) ending at 0300 UTC
Paradip	29.10.99	15
	30.10.99	53
	31.10.99	26
Chandbali	30.10.99	25
	31.10.99	36
Akhuadapada	30.10.99	36
	31.10.99	17
Jajpur	30.10.99	20
Rajghat	31.10.99	25
Nilgiri	30.10.99	23
Balsore	30.10.99	22
Cuttack	30.10.99	25
Jenapur	30.10.99	26
Naraj	30.10.99	21
Anandpur	30.10.99	40
	31.10.99	30
Daitary	29.10.99	15
	30.10.99	12
Keonjhargarh	30.10.99	10
Swampatna	30.10.99	13
Dhenkanal	30.10.99	15
	31.10.99	11
Hindol	30.10.99	11
Kamakhyanagar	30.10.99	10
	31.10.99	19
Balimundli	30.10.99	20
Baripada	30.10.99	11
Jamsolaghat	30.10.99	11
Udala	30.10.99	31
	31.10.99	13
Chandanpur	30.10.99	12
Bhubaneshwar	30.10.99	43
	31.10.99	10
Puri	30.10.99	18
	31.10.99	12
Gopalpur	30.10.99	25
	31.10.99	15

Damage :

Orissa State

(Government of Orissa)

The system caused severe damage in 12 districts of Orissa State namely Jagatsinghpur , Cuttack , Kendrapada ,Puri , Jajpur , Bhadrak , Khurda , Dhenkanal , Balasore , Keonjhar , Mayurbhanj , Nayangarh) where Complete break down of essential services were reported. Erasma and Kujang blocks of district Jagatsinghpur were the worst affected.

Flattening of thatched huts and damage to roads were also reported due to heavy rains.The available information on damages are as below :

Population affected	:129.22 Lakh
Villages affected	:14643
Blocks affected	:97
Crop area affected	:18.42 Lakh Ha.
Houses	:16.49 Lakh
Loss of life	: 9887 (Jagatsinghpur - 8119, Cuttack-471 , Kendrapada-469 ,Puri-301 , Jajpur-188 , Bhadrak-98 , Khurda-91 , Dhenkanal-55 , Balasore-51 , Keonjhar-31 , Mayurbhanj-10 , Nayangarh-3)
Person missing	:40
Person injured	:2507
Lives stock perished	:4.44 Lakh
Fishing boats lost	:9085
Fishing nets lost	:22143

Storm Surge:

Storm surge of about 9.0 m above astronomical tide was reported by the Touring Officer. This appears to be too high for that area of Orissa as it is not knowing to experience that high surge. Independent assessments made by a few other Central Government Establishments indicate a surge of about 5 to 6 metres in that area. The surge penetrated inland upto 35 Km. , washed away everything on its way and inundated vast areas .

The severity of the damage could be imagined from the touring officer's report who visited the affected areas in Bhubaneswar and Paradip between 3-10 November 1999. The city of Bhubaneswar had a deserted look with 60 % of the trees having been flattened on the ground. There was no power supply in the city till 8th November . Huge sand cast and knee deep water logging was reported at Konark which is about 20 Km southeast of Paradip even after 6 days of landfall . At CDR Paradip, the ground floor ,first floor and even the roof where the radom had been placed, were damged due to leakage and accumulation of rain water. A part (4 Km.) of the 18 Km road from city to the Met office was covered by sand dunes of height 1 meter and width ½ Km. Big trawlers for fishing had been picked up and deposited at a distance of 1½ Km to 2 Km from the coast.

For the sake of comparison of the intensity of this super cyclonic storm, the associated maximum wind speed in other intense cyclones in the Bay of Bengal during the period 1970 –1999 are included in Fig.2.7.7. It is clear here that tropical cyclones with intensity of super cyclonic storm have developed in the Bay of Bengal even earlier. But equally intense super cyclone was the one which developed in the Bay of Bengal and that made landfall between Machilipatanam and Aungol (close to Chirala) in Andhra Pradesh ,a state of India on November 19,1977.

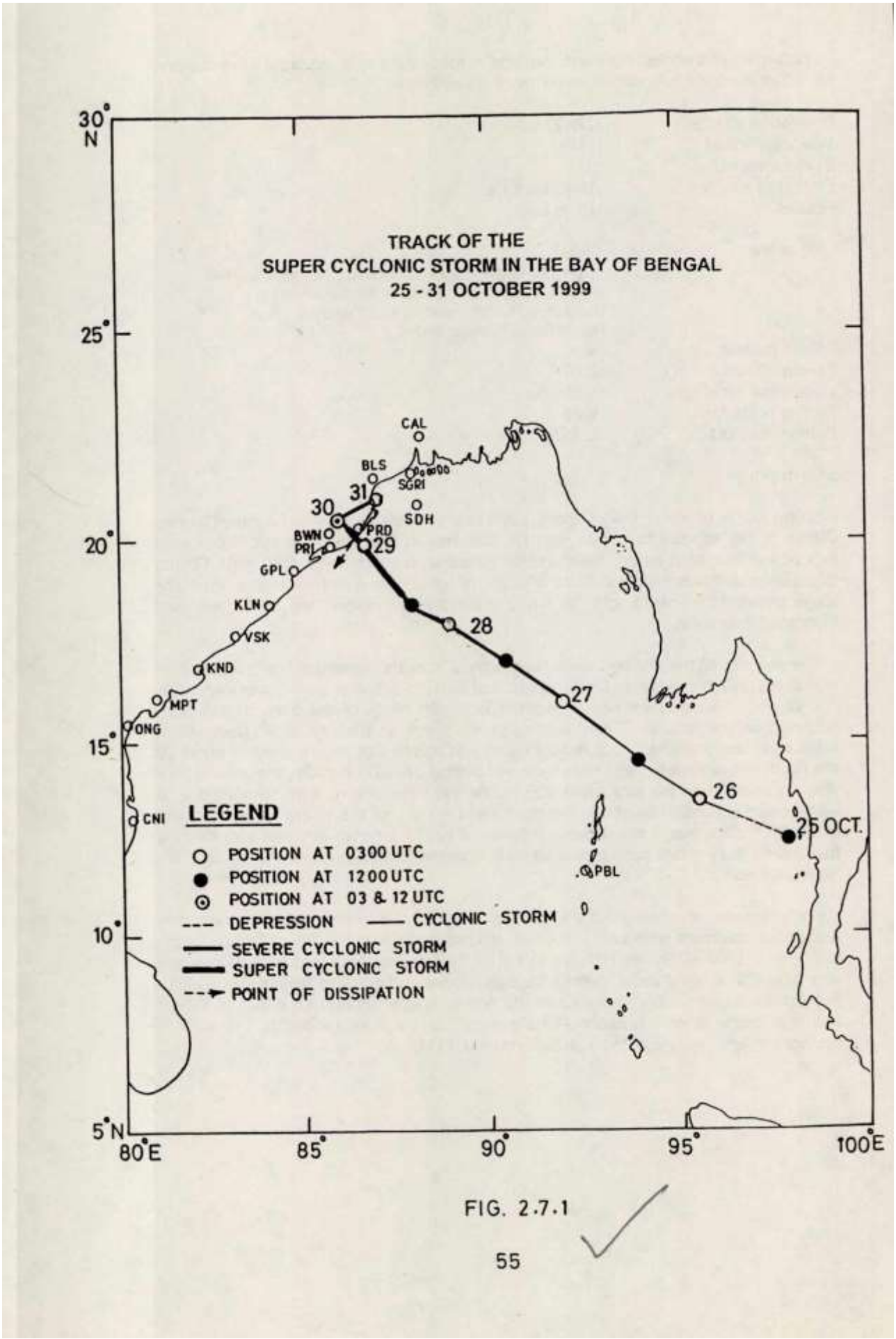

TRACK OF THE
SUPER CYCLONIC STORM IN THE BAY OF BENGAL
25 - 31 OCTOBER 1999
30° N
25°
20°
15°
10°
5° N
80° E
85°
90°
95°
100° E
CAL
BLS
SGRI
SDH
31
30
29
PRD
BWN
PRL
GPL
KLN
VSK
KND
MPT
ONG
CNI
PBL
28
27
26
25 OCT.
LEGEND
POSITION AT 0300 UTC
POSITION AT 1200 UTC
POSITION AT 03 & 12 UTC
DEPRESSION
CYCLONIC STORM
SEVERE CYCLONIC STORM
SUPER CYCLONIC STORM
POINT OF DISSIPATION

FIG. 2.7.1

Table 2.7.1

Best track position and other parameters for Bay of Bengal Super Cyclonic Storm (25-31 October 1999)

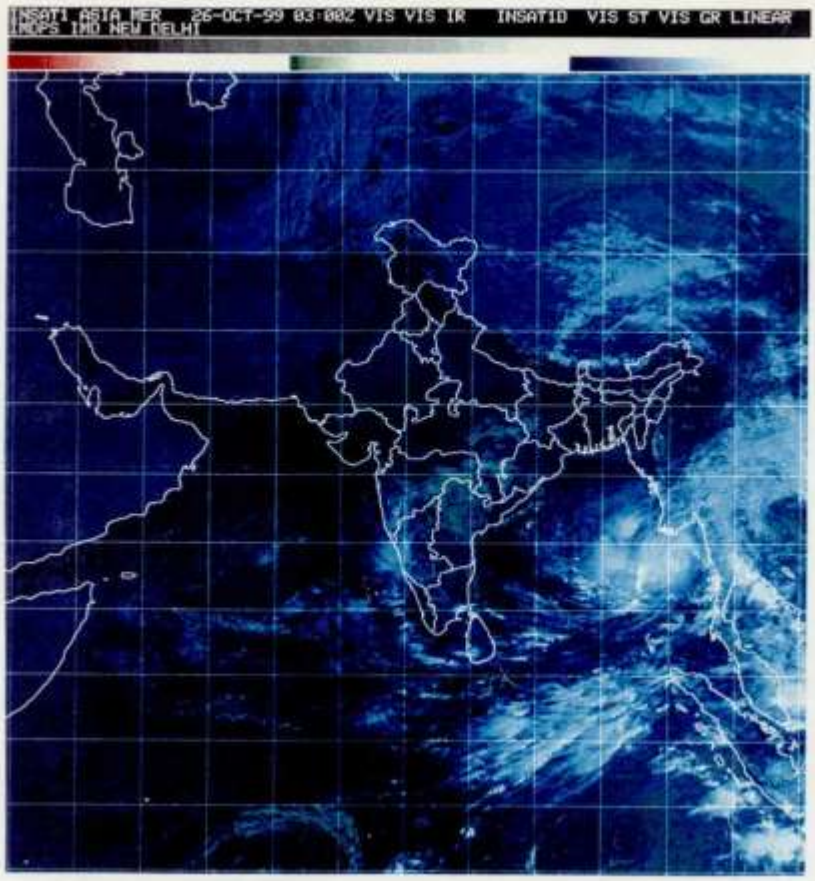
Date	Time (UTC)	Centre Lat. ^{0}N /Long .^{0}E	C.I. No	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
25.10.99	06	12.0/98.5	1.5	1004	25	2	D
	09	12.5/98.5	1.5	1004	25	2	D
	12	12.5/98.0	1.5	1002	25	4	D
	18	12.5/98.0	1.5	1002	25	4	D
26.10.99	00	13.5/96.5	2.0	1002	30	4	DD
	03	13.5/95.5	2.0	1002	35	6	CS
	06	13.5/95.0	2.5	1002	35	6	CS
	09	14.0/94.5	2.5	1002	35	6	CS
	12	14.5/94.0	3.0	998	45	10	CS
	15	15.0/93.5	3.0	998	45	10	CS
	18	15.0/93.5	3.0	998	45	10	CS
	21	15.0/93.0	3.0	998	45	10	CS
27.10.99	00	15.5/93.0	3.0	998	45	10	CS
	03	16.0/92.0	3.5	992	55	16	SCS
	06	16.5/91.5	3.5	992	55	16	SCS
	09	16.5/91.0	3.5	992	55	16	SCS
	12	17.0/90.5	3.5	992	55	16	SCS
	15	17.0/90.5	4.0	986	65	20	VSCS
	18	17.0/90.5	4.0	986	65	20	VSCS
	21	17.0/90.0	4.0	986	65	20	VSCS

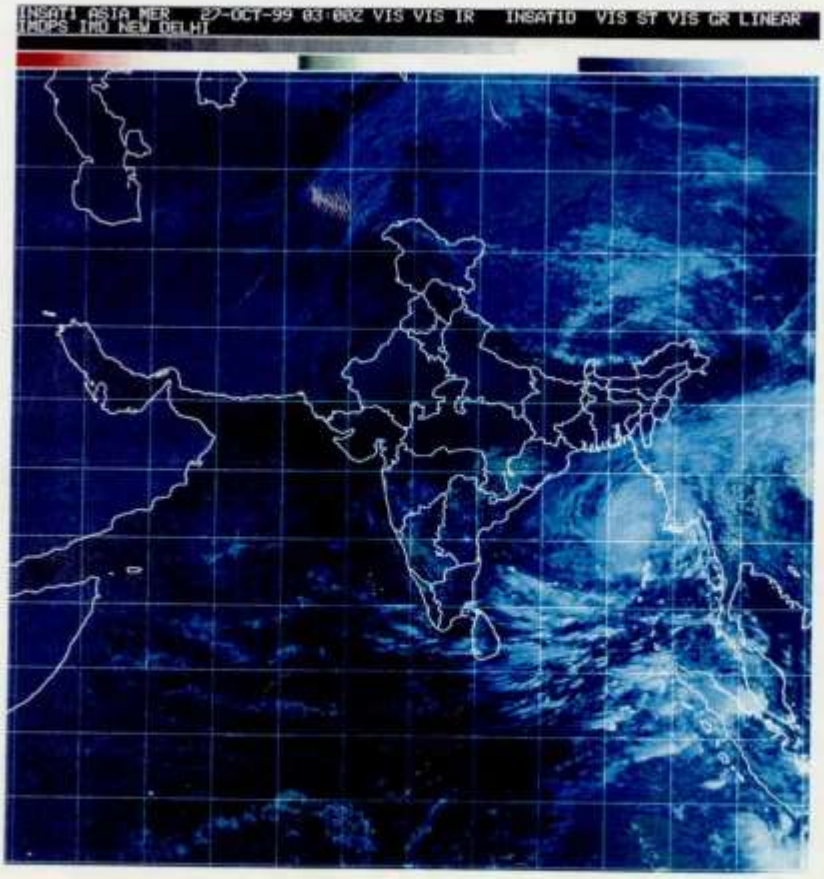
Table 2.7.1 (continued)

Best track position and other parameters for Bay of Bengal

Super Cyclonic Storm (25-31 October 1999)

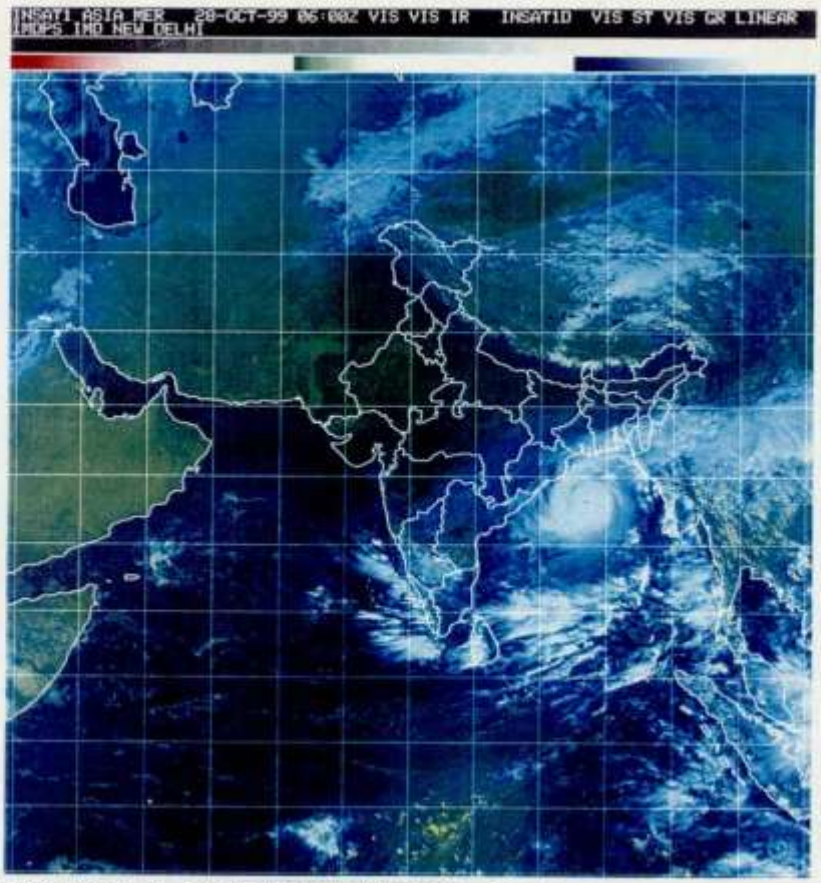
Date	Time (UTC)	Centre Lat. °N /Long .° E	C.I. No	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind(kts)	Estimated pressure drop at the centre	Grade
28. 10. 99	00	17.5/90.0	4.0	986	65	20	VSCS
	03	18.0/89.0	4.5	978	77	30	VSCS
	06	18.0/88.5	5.0	968	90	40	VSCS
	09	18.5/88.0	5.5	956	102	52	VSCS
	12	18.5/88.0	6.0	940	115	66	VSCS
	15	19.0/87.5	6.5	928	127	80	SuCS
	18	19.3/87.0	7.0	912	140	98	SuCS
	21	19.3/87.2	7.0	912	140	98	SuCS
29.10.99	00	19.6/87.0	7.0	912	140	98	SuCS
	03	19.9/86.7	7.0	912	140	98	SuCS
	06	20.5/86.0	7.0	912	140	98	SuCS
	Crossed Orissa coast near Paradip between 0430 and 0630 UTC						
	12	20.5/86.0					VSCS
	18	20.5/86.0					SCS
30.10.99	00	20.5/86.0					SCS
	03	20.5/86.0					CS
	06	20.5/86.0					CS
	12	20.5/86.0					CS
	18	20.5/86.0					DD
31.10.99	00	20.5/86.0					DD
	03	21.0/87.0					D


INSAT1 ASIA MER 26-OCT-99 03:00Z VIS VIS IR INSAT1D VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI


INSAT1 ASIA MER 27-OCT-99 03:00Z VIS VIS IR INSAT1D VIS ST VIS GR LINEAR
IMDPS IMD NEW DELHI

12

FIG. 2.7.2



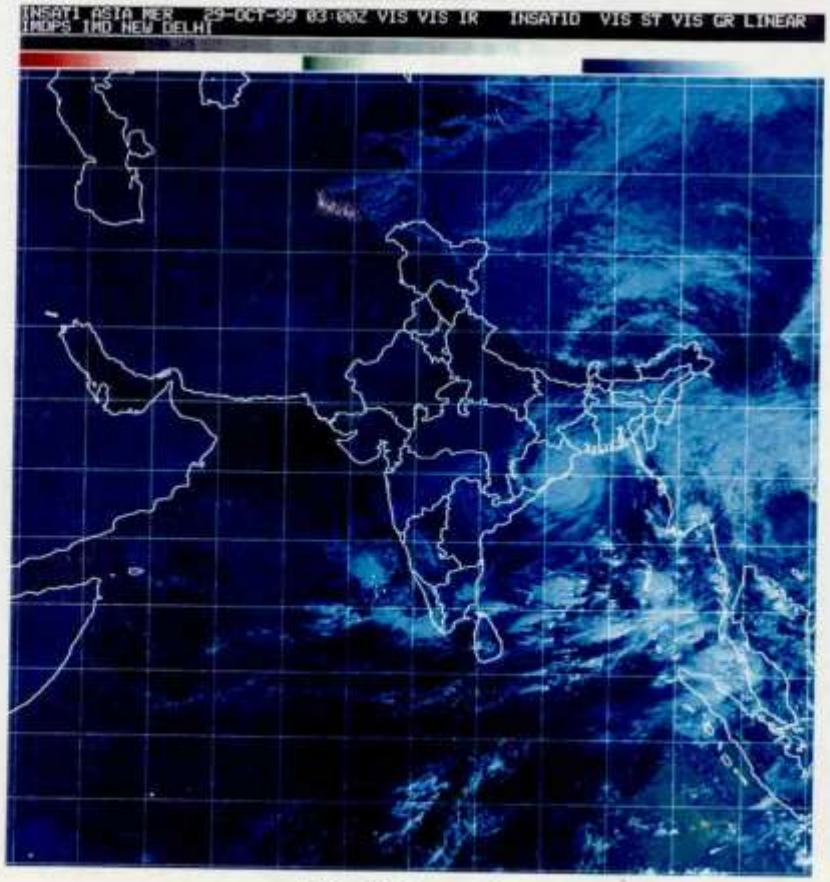


FIG. 2.7.2 contd.

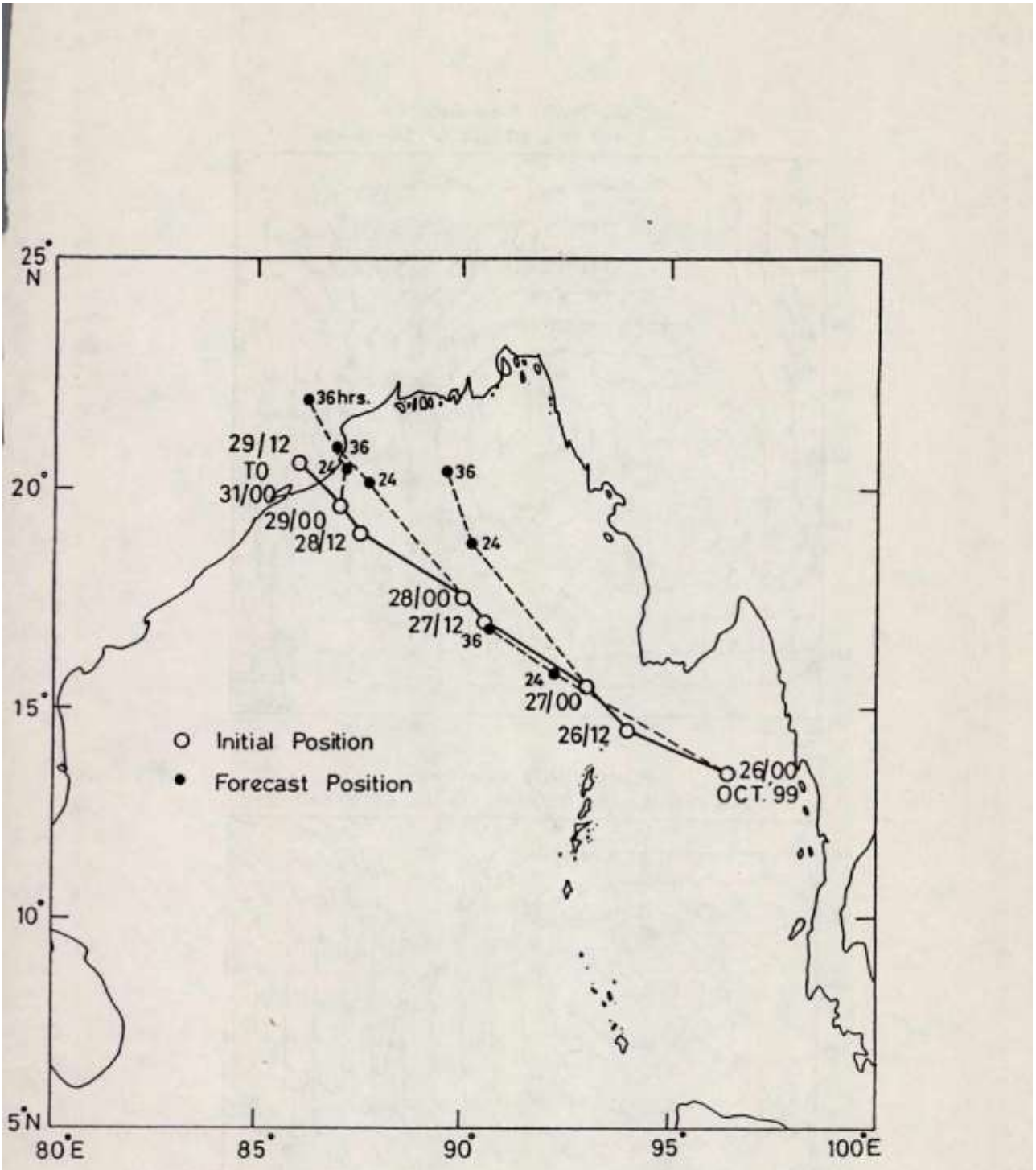
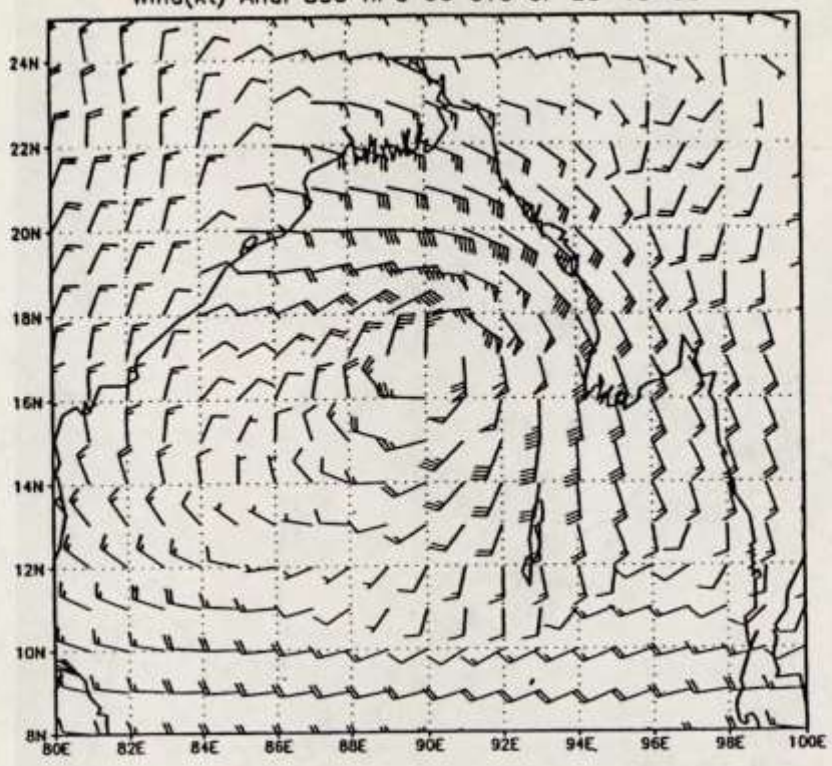


FIG.2.7.3 . TRACK PREDICTION BY IMD QLM

RSMC (IMD) New Delhi

Wind(kt) Anal 850 hPa 00 UTC OF 28-10-99



RSMC (IMD) New Delhi

24H Fcst Wind(kt) 850 hPa 00 UTC OF 29-10-99

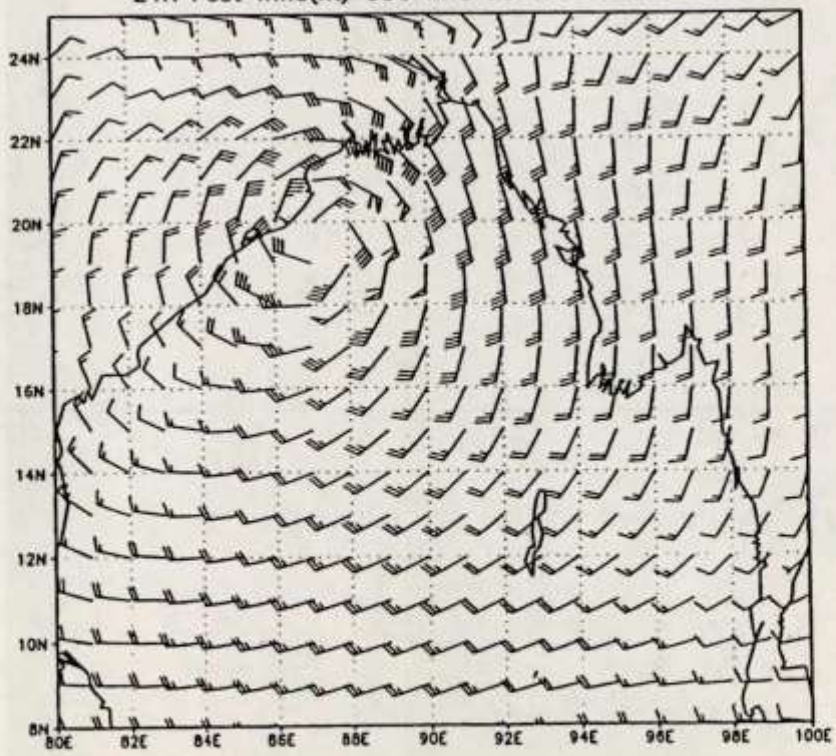
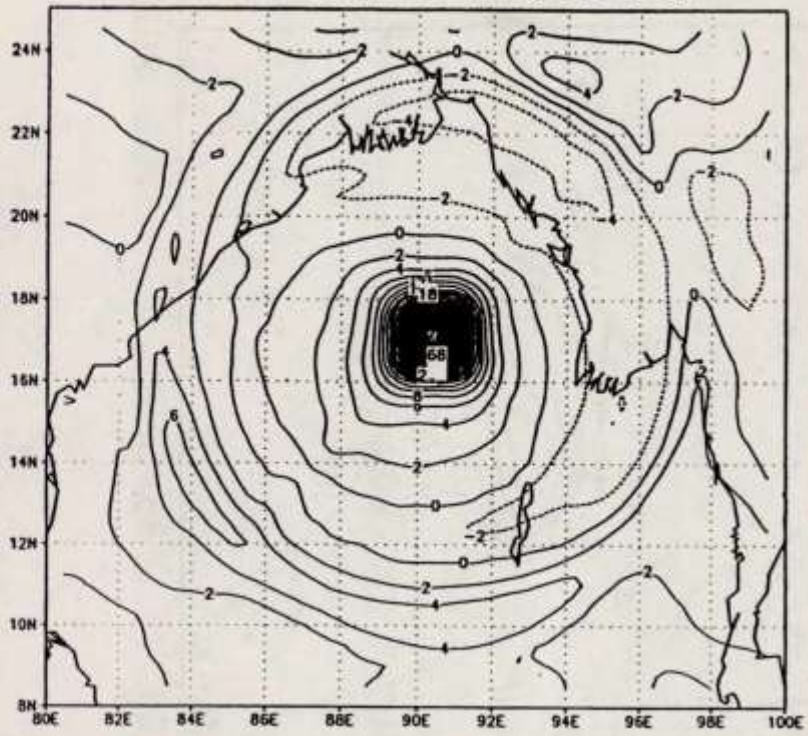


FIG. 2.7.4

RSMC (IMD) New Delhi

· Rel Vort Anal 850 hPa 00 UTC OF 28-10-99



RSMC (IMD) New Delhi

24H fcst Rel Vort 850 hPa 00 UTC OF 29-10-99

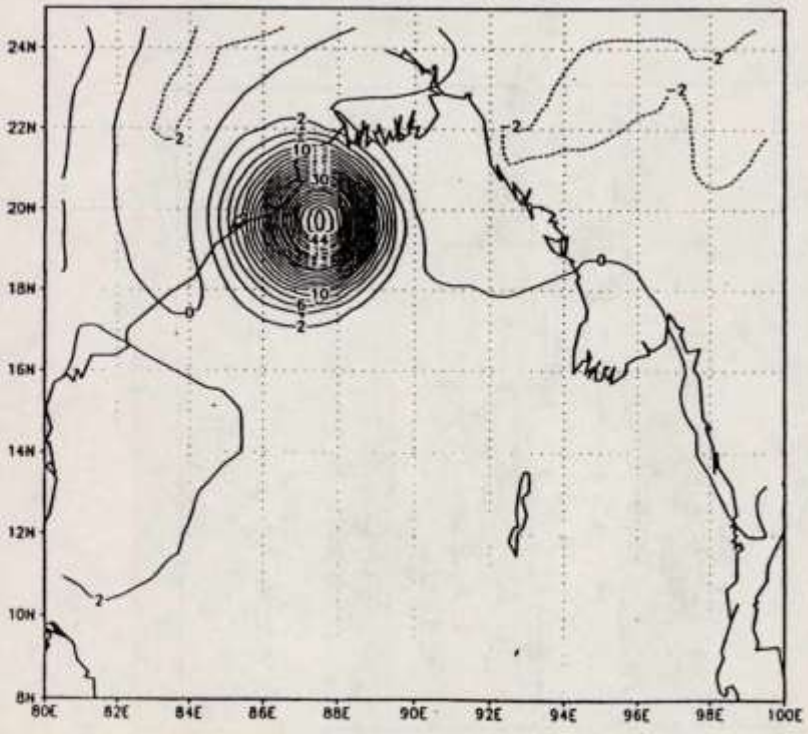


FIG. 2.7.5

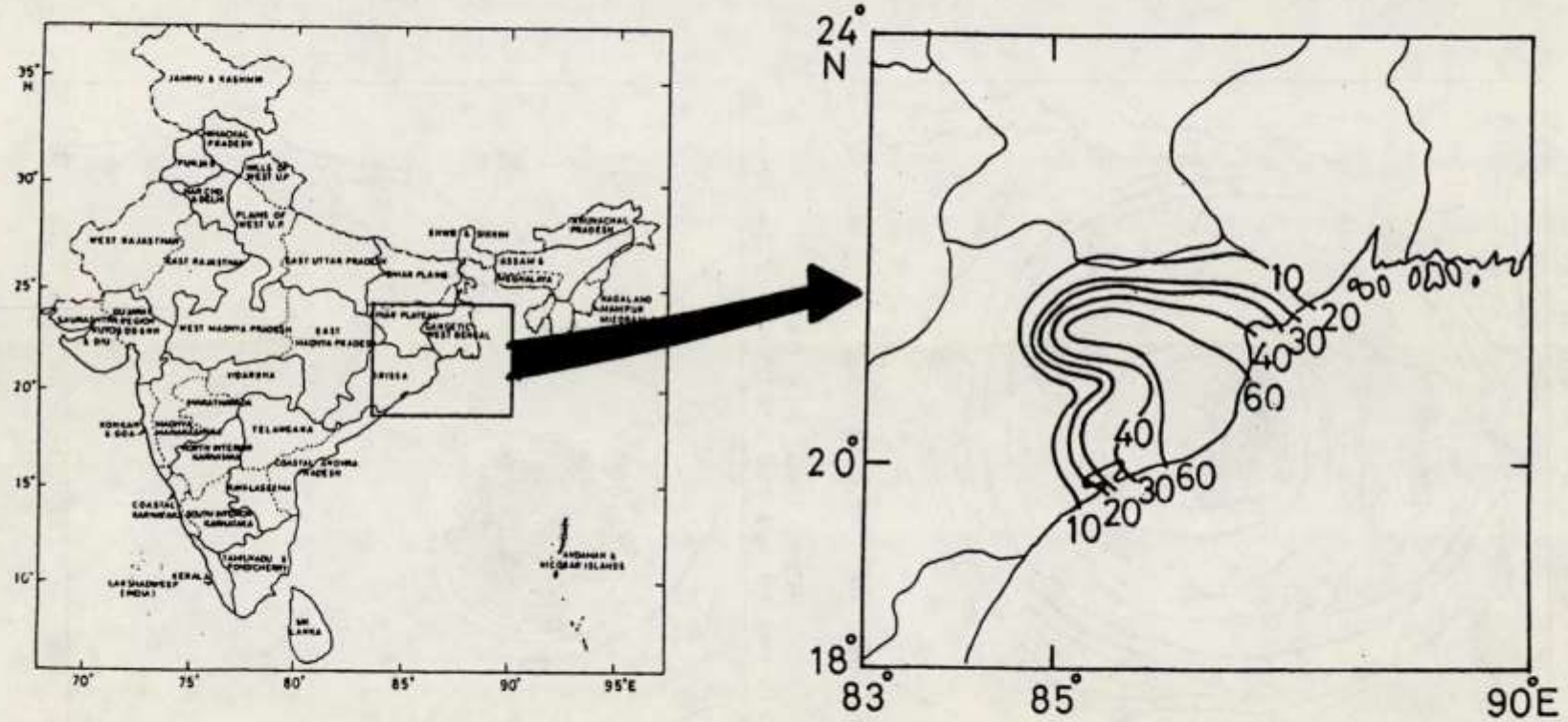

24°
N
20°
18°
83°
85°
90°E
10
20
30
40
60
40
60
10
20
30
70°
75°
80°
85°
90°
95°E
35°
N
30°
25°
20°
15°
10°

FIG. 2.7.6

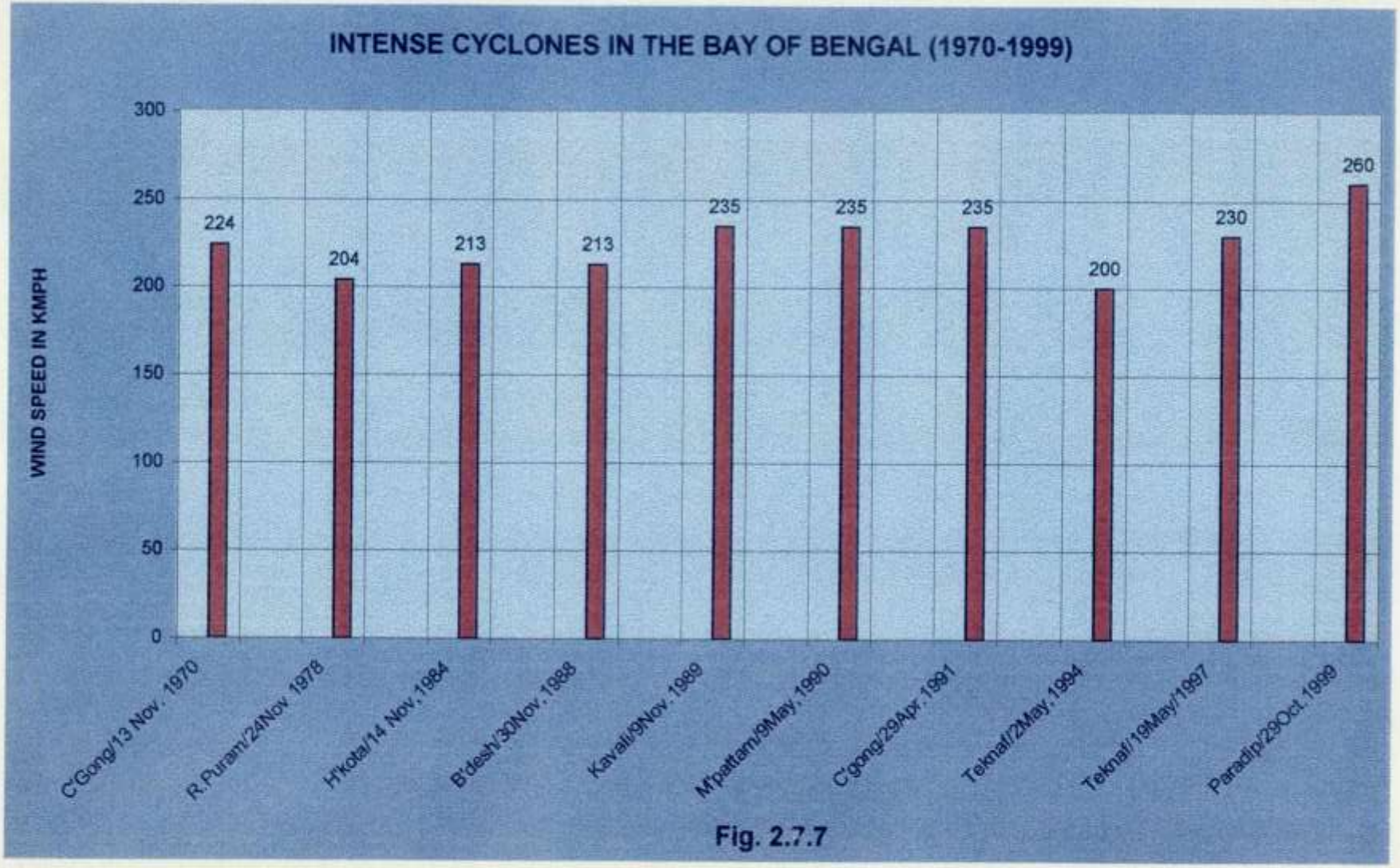

INTENSE CYCLONES IN THE BAY OF BENGAL (1970-1999)
WIND SPEED IN KMPH
300
250
200
150
100
50
0
224
204
213
213
235
235
235
200
230
260
C'Gong/13 Nov. 1970
R.Puram/24Nov. 1978
H'kota/14 Nov.1984
B'desh/30Nov. 1988
Kavali/9Nov. 1989
M'pattam/9May,1990
C'gong/29Apr. 1991
Teknaf/2May,1994
Teknaf/19May/1997
Paradip/29Oct.1999

Fig. 2.7.7

2.8 Depression over Bay of Bengal (8 - 10 December 1999)

This system developed in-situ over southeast Bay of Bengal on 8 December. Moving westwards it dissipated over southwest Bay of Bengal on 10 December.

The first 4 days of December 1999 witnessed the development of an active equatorial trough in the North Indian Ocean from west Arabian Sea to south Andaman Sea. On 6th morning deep convection extended upto north Andaman sea covering Gulf of Thailand. By 7th December an area of deep convection from 5^0 to 15^0 North latitude covering Bay Islands and areas to its east and west got separated from the deep convection over gulf of Thailand. It moved west wards, got organised over northern parts of Southeast Bay of Bengal by the morning of 8 December. By the afternoon of 8 December a depression formed over Southeast Bay of Bengal near lat. 10.5^0 N /long. 87.5^0 E. The system moved westwards till 091200UTC. Thereafter it moved Northwest and weakened into a low pressure area at 101130 UTC over western parts of south west Bay of Bengal .

The track of the system is given in Fig. 2.8.1. The best track positions and other parameters are included in Table 2.8.1 A few INSAT cloud imagery are shown in Fig. 2.8.2 .

Weather realized :

This system affected Tamilnadu as a low pressure upto 15th and caused isolated heavy rainfall in coastal districts .

Damage:

No damage to life and property was reported.

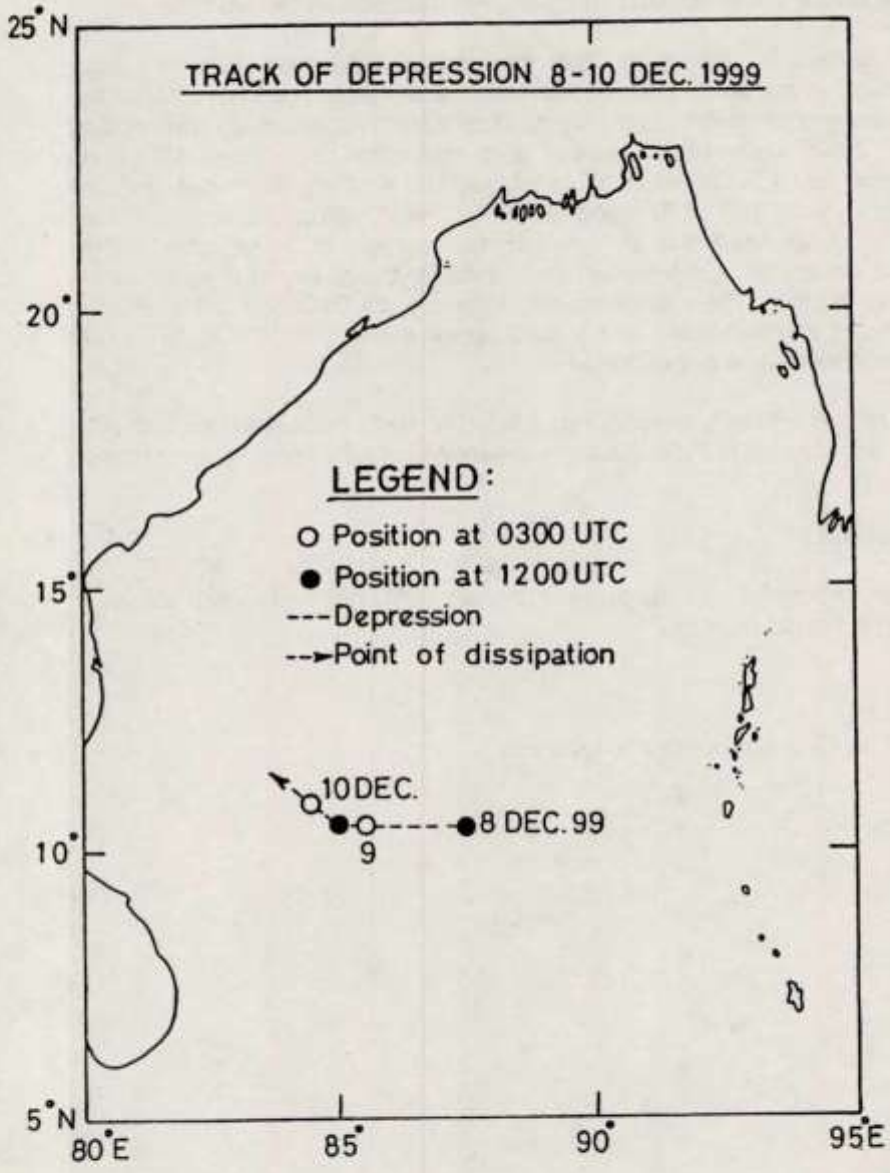
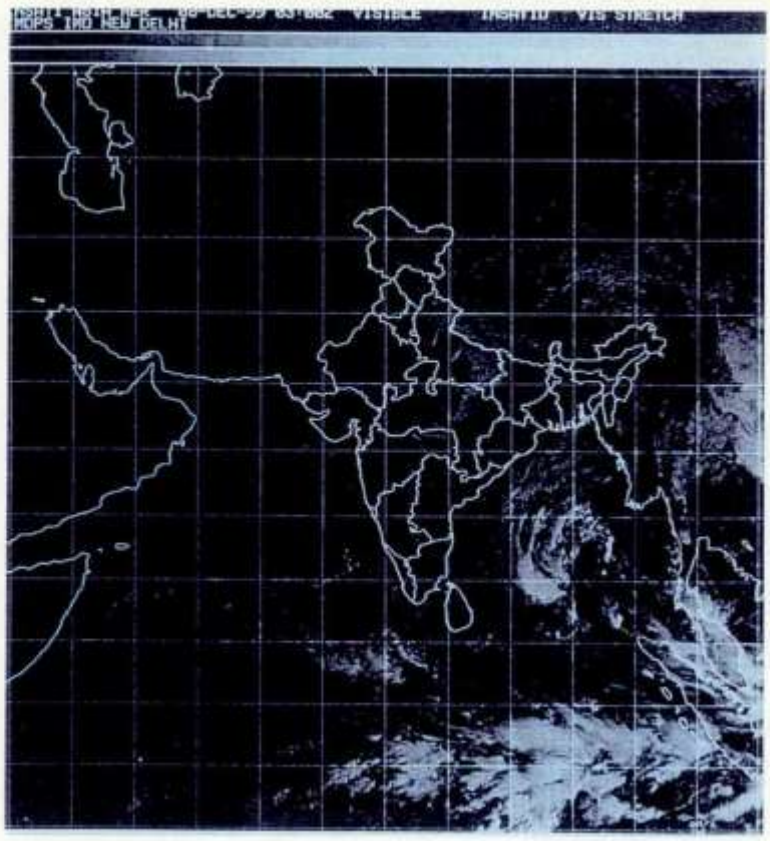

TRACK OF DEPRESSION 8-10 DEC. 1999
25°N
20°
15°
10°
5°N
80°E
85°
90°
95°E
LEGEND:
O Position at 0300 UTC
● Position at 1200 UTC
---Depression
-->Point of dissipation
10 DEC.
9
8 DEC. 99

FIG. 2.8.1

Table 2.8.1

Best track position and other parameters for the Bay of Bengal Depression (8- 10 December 1999)

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
08.12.99	0600	9.5/88.5	1.0	1000	15	...	L
	0900	9.5/88.0	1.0	1000	15	...	L
	1130	10.5/87.5	1.5	998	25	2	D
	1500	10.5/87.5	1.5	998	25	2	D
	1800	10.5/87.0	1.5	998	25	2	D
	2100	10.5/87.0	1.5	998	25	2	D
09.12.99	0300	10.5/85.5	1.5	998	25	2	D
	0600	10.5/85.0	1.5	998	25	2	D
	0900	10.5/85.0	1.5	998	25	2	D
	1200	10.5/85.0	1.5	998	25	2	D
	1800	10.5/85.0	1.5	998	25	2	D
	2100	10.5/85.0	1.5	998	25	2	D
10.12.99	0000	11.0/84.5	1.5	998	25	2	D
	0300	11.0/84.5	1.5	998	25	2	D
	0600	11.0/84.0	1.5	998	25	2	D
	0900	11.0/84.0	1.5	998	25	2	D



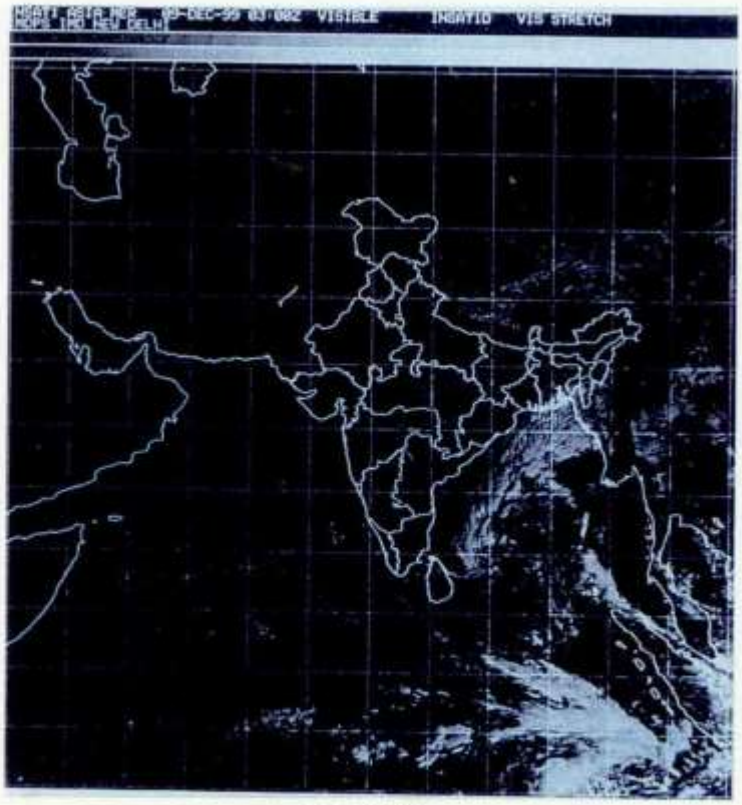


FIG. 2.8.2

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 Limited Area Forecast Model.

The errors in the predicted positions from Persistence, Climatology and CLIPER for the tropical cyclones in North Indian Ocean during 1999 are given in table 3.1. Compared among themselves, in the 12 hours as well as in 24 hours forecast, both Climatological and CLIPER performed better in two cases each. This was also the case in 36 hours forecast. In 48 hours forecast Climatology performed better than other two. This was also the case in 24 hour predictions except for Bay of Bengal Cyclone in February 1999. 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 1999, the Limited Area Model (LAM) 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 for different initial conditions have been included in sections 2.2 , 2.6 and 2.7. 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. The composite forecast errors in respect of the three cyclonic storms are as follows :

24 hours forecast:

Mean position error : 172 Km
Vector errors
(Difference of the vector lengths
from Day (0) to Day (1) observed and
Day (0) to Day (1) forecast positions)

Mean	: - 85 Km(slow bias)
RMS	: 136 Km
RMS deviation angle	: 29^0

48 hours forecasts:
Mean position error : 283 Km
Vector errors
(Difference of the vector lengths
from Day (0) to Day 2 observed and
Day (0) to Day 2 forecast positions)

Mean : +17 Km
RMS : 197 Km
RMS deviation angle : 19^0

Recently, IMD has implemented another Limited Area Model adopted from NCEP (USA) based on Quasi- Lagrangian Model (QLM) for hurricane prediction. The model is being tested for tropical cyclone track prediction over Indian Seas. The composite forecast errors in respect of the three cyclonic storms are as below :

24 hours mean forecast error :124 km
48 hour mean forecast error : 243 km.

Table 3.1

Forecast position errors for tropical cyclones in the Bay of Bengal and the Arabian Sea in 1999 based on Climatology (C), Persistence(P) and CLIPPER(CLIP) Models.

Date	12 Hours			24 Hours			36 Hours			48 Hours		
	P	C	CLIP	P	C	CLIP	P	C	CLIP	P	C	CLIP
01-03 Feb,1999	273	060	106	682	236	481	885	290	652	-	-61	249
16-19 May,1999	162	058	050	225	247	116	380	170	104	488	-	092
15-19 Oct ,1999	075	071	060	208	097	126	318	136	200	576	065	283
25-31 oct,1999	168	109	118	247	240	147	404	405	237	483	711	315

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Damage to coconut trees in Orissa during
29 October 1999 Super Cyclonic Storm