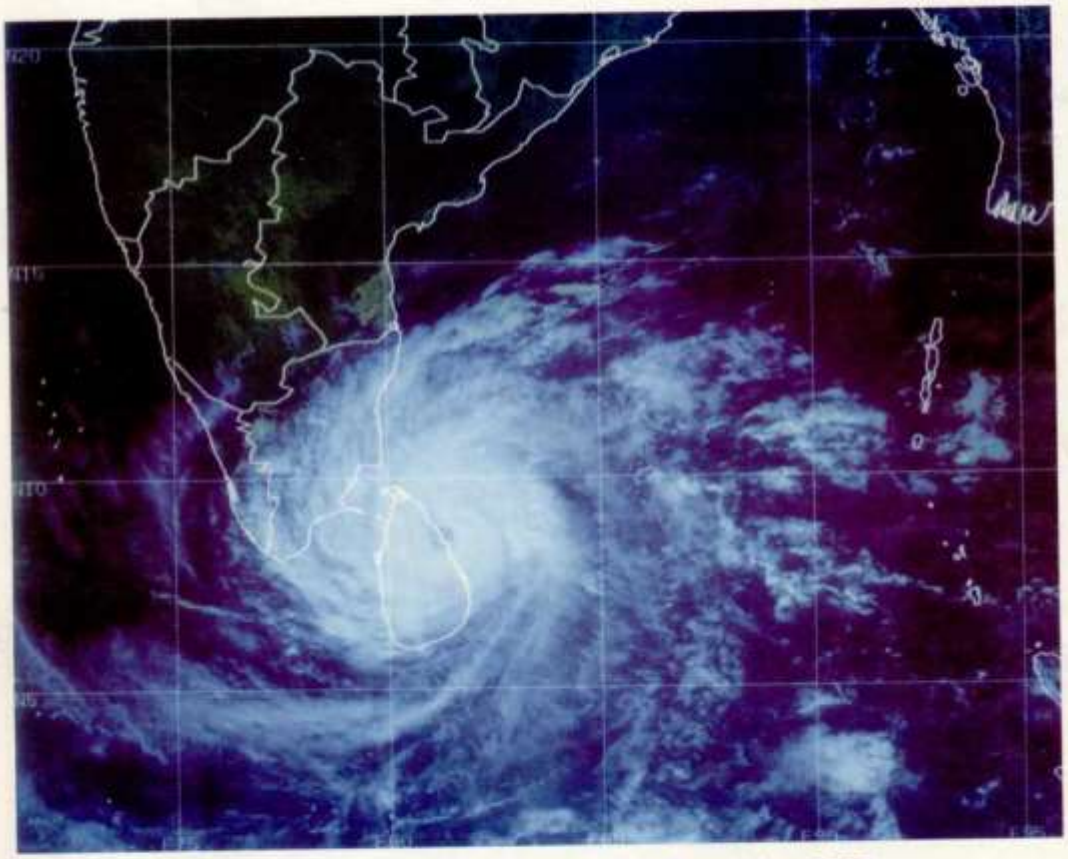
भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 2000



Very Severe Cyclonic Storm of 26 December 2000

REGIONAL SPECIALISED METEOROLOGICAL CENTRE-TROPICAL CYCLONES

NEW DELHI

FEBRUARY 2001

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

2000

RSMC-TROPICAL CYCLONES NEW DELHI
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CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 2000

CONTENTS

* * *

INTRODUCTION

The North Indian Ocean witnessed a decrease in the number of tropical disturbances during 2000 (5 cyclones and one depression, Fig.1.1) as compared to 1999 (4 cyclones & 4 depressions). The significant feature of the year was the development of a very severe cyclonic storm in the Bay of Bengal that first made landfall over Sri Lanka and later over India. The cyclonic activity was absent in the pre-monsoon months of April and May and also during the monsoon months of June, July and September. No cyclo-genesis took place in the Arabian Sea during this year. Though the sea surface temperatures were near normal over the Arabian Sea , it was the lack of suitable upper air wind and vorticity patterns that prevented the cyclogenetic activity in this region. Two of the five cyclones that developed over the Bay of Bengal weakened over the sea itself. Two cyclones crossed Indian coasts. Only one cyclone each crossed Bangladesh and Sri Lanka coast.

The convective activity over the central Bay of Bengal was generally subdued during the month of October though it was pronounced in the south Bay of Bengal. This is evident from the mean Outgoing Longwave Radiation (OLR) field derived from INSAT-1D IR data (Fig. 1.2) that shows that one convective maxima was located over Sumatra and another over the Gulf of Thailand extending into neighbouring land areas. The position was no different in the subsequent months of November and December in which the convective maxima shifted relatively southwards. In comparison to this higher OLR upwelled from central and north Bay of Bengal in 1998 in which two cyclones formed in quick succession in the month of November.

The Regional Specialised Meteorological Centre (RSMC) –Tropical Cyclones New Delhi mobilised all of 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 classification of cyclonic disturbances followed in the report is as given below:

S.N.	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 118 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 above 119 kt (above 221 kmph)

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

List of cyclonic disturbances during 2000 in chronological order

1.	Cyclonic storm over the Bay of Bengal (27 – 30 March)
2.	Depression over the Bay of Bengal (23 – 24 August)
3.	Cyclonic Storm over the Bay of Bengal (15- 19 October)
4.	Cyclonic Storm over the Bay of Bengal (25 – 28 October)
5.	Very Severe Cyclonic Storm over the Bay of Bengal (26 –30 November)
6.	Very Severe Cyclonic Storm over the Bay of Bengal (23 - 28 December)

Some Characteristics of cyclonic disturbances which attained cyclonic storm or higher intensity during 2000

Cyclonic Storm	Date, Time (UTC) & lat. (N /) / long .(E) of formation	Date, Time (UTC) & lat./long of landfall.	Estimated lowest central pressure, Date &Time (UTC) & lat./long	Estimated maximum wind speed (kt) ,Date & Time & lat. & long.	Maximum T. No. attained
Cyclonic Storm over the Bay of Bengal 27-30 March	27.3.2000 at 1200 UTC & near 7.5°/90.0°	Dissipated over sea on 30.3.2000 after 1200 UTC	998 hPa on 29.3.2000 & at1200 & near 14.0°/88.5°	45 Kt on 29.3.2000 at 1800 UTC & 15..0°/89.5°	3.0
Cyclonic Storm over the Bay of Bengal 15–19 October	15.10.2000 at 0300 UTC & near 14.5°/88.5°	Weakened into a low pressure area over sea on 19.10.2000 at 0300 UTC	996 hPa on 17.10.2000 at 0900 UTC & near 14.0°/84.0°	35 Kt on 16.10.2000 at 0300 UTC & near 14.5°/86.0°	2.5
Cyclonic Storm Over Bay of Bengal 25-28 October	25.10.2000 at 0900 UTC & near 13.5° /93.0°	Crossed Bangladesh coast on 28.10.2000 between 0100 and 0300 UTC near Mongla near 23.0°/89.0°	998 hPa on 27.10.2000 at 1800 UTC & near 20.5°/88.5°	35 Kt on 27.10.2000 at 1800 UTC & near 20.5°/88.5°	2.5
Very Severe Cyclonic Storm over Bay of Bengal 26-30 November	26.11.2000 at 1800 UTC& near 9.0°/90.5°	Crossed Tamil Nadu coast on 29.11.2000 around 1130 UTC near Cuddalore	958 hPa on 28.11.200 at 1800 UTC near 11.5°/82.0°	102 Kt on 28.11.2000 at 1500 UTC & near 11.5°/82.0°	5.5
Very Severe Cyclonic Storm over Bay of Bengal 23-28 December	24.12.2000 at 1200 UTC& near 8.0°N/83.5° E	First crossing near Trincomalee in Sri Lanka on 26.12 .2000 around 1200 UTC Second Crossing near Tuticorin in south Tamil Nadu on 28.12 2000 around 2200 UTC	970 hPa on 26.12.2000 at1200 UTC near 8.5°N/ 81.0° E	90 Kt on 26.12 2000 at 1200 UTC near 8.5° N/ 81.0° E	5.0

Statistical data relating to cyclonic disturbances in the North Indian Ocean during 2000

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

S.No.	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Life Time (days)
1.	CS			↔										0.75
2.	D*								↔					-
3.	CS										↔			1.00
4.	CS										↔			0.25
5.	VSCS											↔		2.38
6.	VSCS												↔	3.00

* One disturbance did not intensify even to the stage of T-2.0 .

Average Lifetime =	1.23 (days)

2. Frequency distribution of different intensity classes

CI	≥2.0	≥2.5	≥3.0	≥5.0	≥6.0	≥7.0
No. Of Disturbances	5	5	5	2	-	--
No. of days with Cyclone Intensity(≥2.5)	-	7.38	5.0	0.63	-	--

Note: CI = Current Intensity on Dvorak's Scale

3. Basin-wise distribution of disturbances

Bay of Bengal	5
Arabian Sea	NIL

Activities of RSMC-Tropical Cyclones New Delhi

Area of responsibility:

The area of responsibility of RSMC-Tropical Cyclones New Delhi covers sea areas of north Indian ocean to the north of 5° N / 10° N between 45° E to 100° E and includes the Member Countries of WMO/ESCAP Panel on Tropical Cyclones viz., Bangladesh, India, Maldives, Myanmar, Sultanate of Oman, Pakistan, Sri Lanka and Thailand . The Centre issues Tropical Weather Outlooks and Tropical Cyclone Advisories on tropical cyclones when they form and develop over the north Indian Ocean.

Limited Area Model

A Quasi-Lagrangian Model (QLM) for cyclone track prediction has been implemented at RSMC New Delhi. The QLM is a multilevel primitive equation fine-mesh model cast in the sigma coordinate system ($\sigma = p/p_s$; pressure divided by surface pressure). The model has a limited area domain using a cartesian grid. The horizontal grid spacing is 40 km and the integration domain consists of 111x111 grid points in a 4400x4400 km^2 domain that is centred on the initial position of the cyclone. The QLM uses 16 layers in the vertical. The model incorporates physical processes. Radiation and turbulent processes, which have only marginal impact in the development, are currently excluded to minimize computational time. The numerical integration of the model is carried out by using the so called quasi-Lagrangian method.

The model provides track forecasts out to 36 hours at present. The initial analysis and lateral boundary conditions are generated from operational analysis and forecasts produced by the global spectral model of National Centre for Medium Range Weather Forecasting (NCMRWF), New Delhi.

Tropical Weather Outlook

Tropical Weather Outlook is issued daily at 06 UTC for use by the Member Countries of WMO/ESCAP Panel. This contains description of synoptic systems over North Indian Ocean and sub-tropical ridge position at 200 hPa level. In addition, a special weather outlook is also issued at 18 UTC in situations where a tropical depression is expected to attain the cyclone intensity. These bulletins were transmitted through the Global Telecommunication System (GTS). This year, five special 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 METAREA VIII are: (i) India, (ii) Kenya, (iii) Mauritius, and (iv) La Reunion.

Tropical Cyclone Advisories

As per one of the recommendations of the Twenty Sixth Session of the WMO/ESCAP Panel on Tropical cyclones held at Male Maldives, 2-8 March 1999, issue of 3 hourly tropical cyclone advisories for the benefit of the Member Countries of the Panel was continued during the year 2000 also.

These bulletins contain 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 Activities

A new HRPT station has been established at New Delhi to receive and process data from existing and newly launched NOAA satellites. A Primary Data Utilisation Centre (PDUS) station has been established at New Delhi to receive processed data from METEOSAT-5 satellite located over Indian Ocean. This equipment is operational at New Delhi since February 2000. Under Indo-US co-operation scheme a data centre has been established to facilitate the exchange of data and products. India will be launching by the end of 2001, one METSAT satellite which will have only Meteorological payloads, unlike INSAT which is a multipurpose satellite system.

Satellite bulletins were produced at every three hour interval based on the interpretation of INSAT cloud imagery. In the event of cyclonic storm, INSAT pictures were also taken at hourly interval . The bulletins contain 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 are also included in Tropical Cyclones Advisories.

TRACKS OF CYCLONIC STORMS AND DEPRESSIONS DURING JANUARY-DECEMBER, 2000

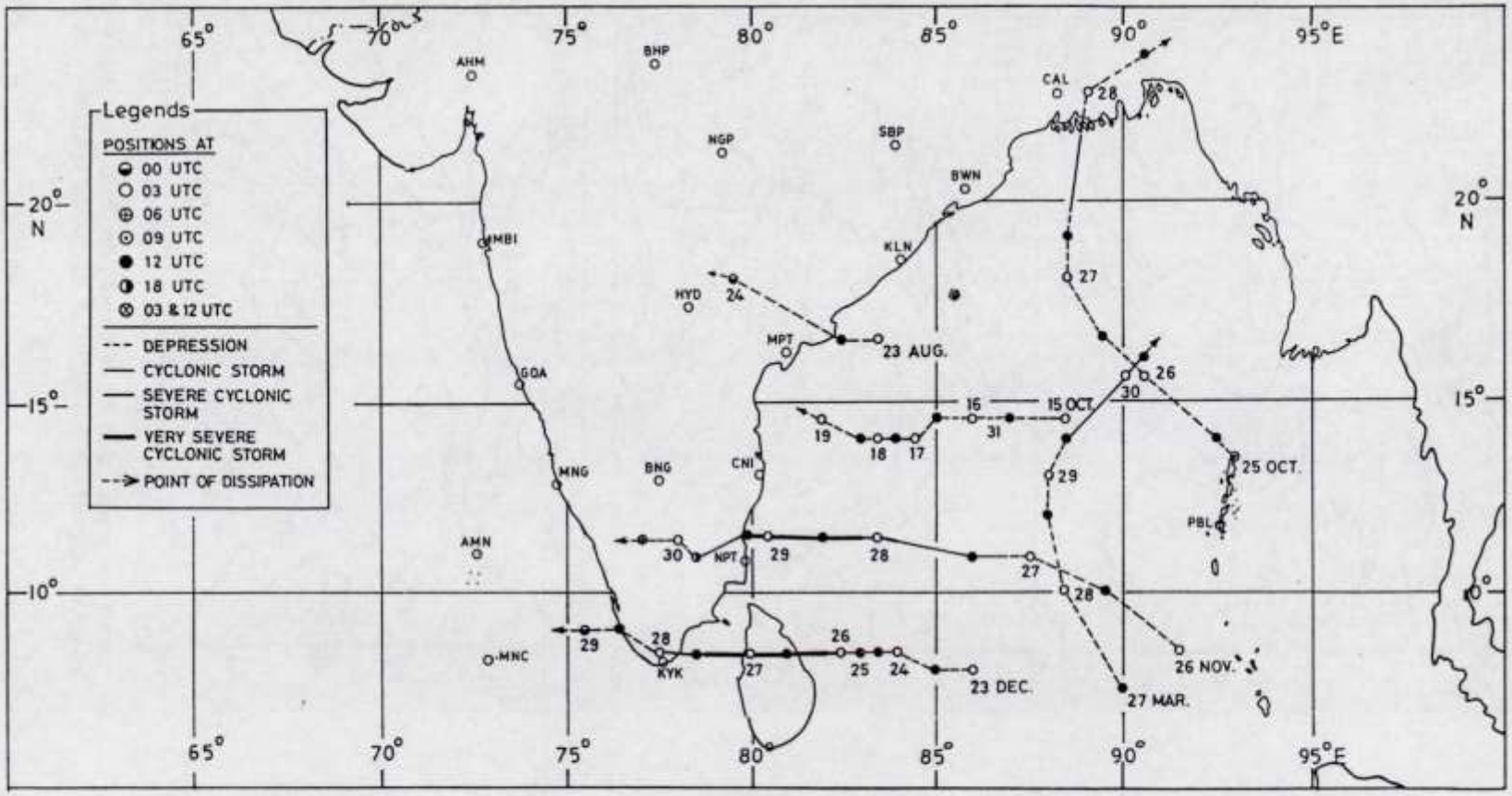
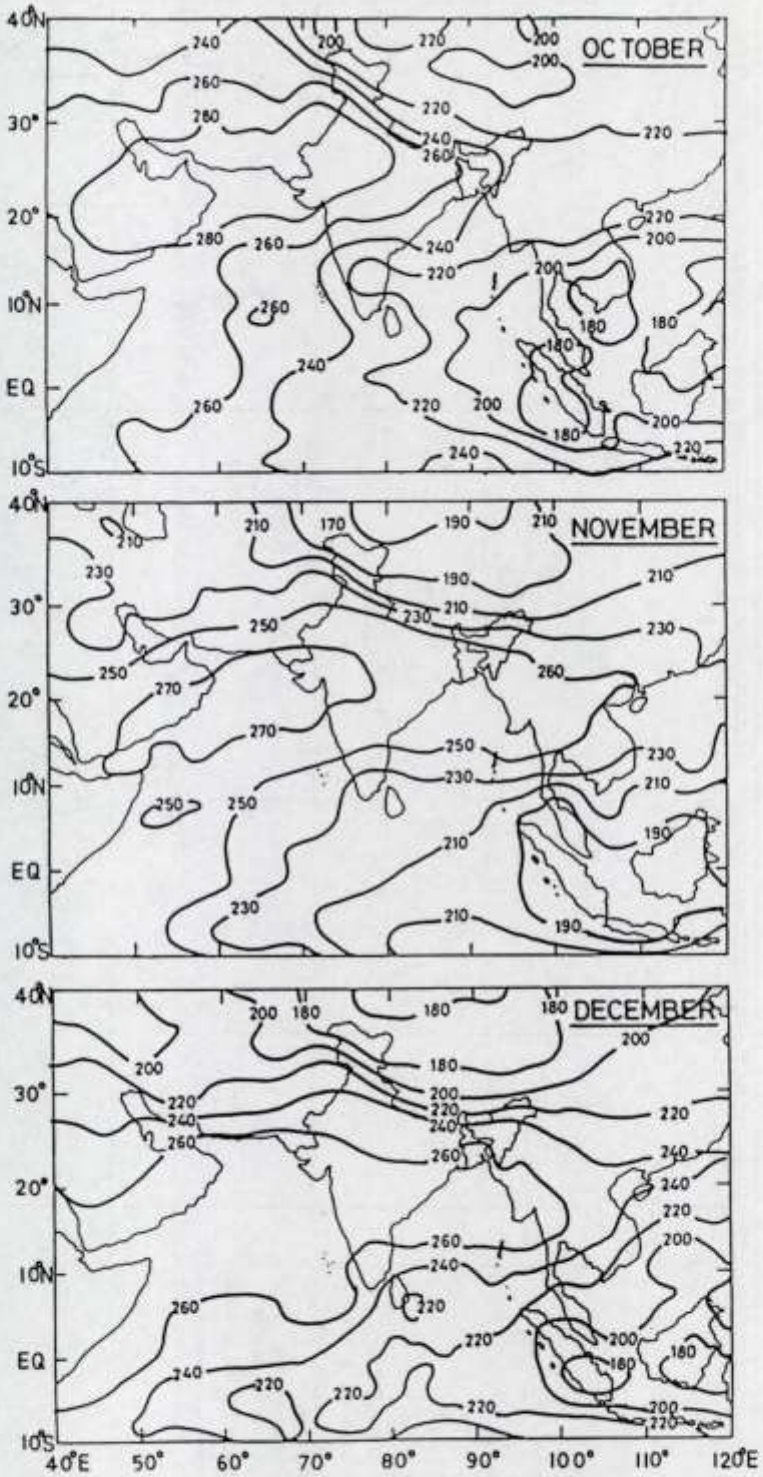


Fig 1.1



MEAN OUTGOING LONG WAVE RADIATION (OLR) from INSAT-ID IN WATTS/SQ. METER DURING POST MONSOON SEASON OF 2000

Fig 1.2

CHAPTER 2
BRIEF DESCRIPTION OF THE SYSTEMS

2.1 Cyclonic Storm over the Bay of Bengal (27-30 March, 2000) (BOB 00 01 03 27 30)

It was an unusual development in which a depression formed over south-east Bay of Bengal on 27 March. While moving initially northwestwards and later northward it intensified into a cyclonic storm over east central Bay of Bengal on 29 March. The development could not be sustained and the cyclonic storm weakend into a depression and later dissipated over east central Bay of Bengal on 30 March.

The third week of March 2000 witnessed enhanced convective activity in the equatorial Bay of Bengal. The maximum cloud zone associated with it drifted northward and reached the latitude belt 5-10 degree north in the subsequent week. In this active equatorial trough a low pressure area formed over south-east Bay of Bengal on 27 March that concentrated into a depression at 271200 UTC near Lat. 7.5° N / Long. 90.0° E.

It was still an innocuous system that moved in a north-westerly direction and lay centred at 280300 UTC near Lat. 10.0° N / Long. 88.5° E. A ship VVKG (7.3° N/82.6° E) reported wind of 310°/30 kts and pressure 1010.3 hPa at 280300 UTC The movement of the system slowed down as it intensified into a deep depression and lay centred at 290300 UTC near Lat. 13.0° N / Long. 88.0° E. A ship SHIP (11.1° N / 82.5° E) reported wind of 020°/25 Kts and pressure of 1008.5 hPa. Thereafter the system changed its course and started moving in a north-easterly direction. It continued to intensify further and reached the minimal cyclone intensity (T-2.5) at 291200 UTC when it was centred near Lat. 14.0° N / Long.88.5° E. At 300300 UTC the ship SHIP (15.1° N / 83.0° E) reported wind of 020° / 20 kts and pressure of 1008.7 hPa. At this stage the system came under the influence of strong upper air westerly flow and got sheared off. It weakened and dissipated over east central Bay of Bengal on the afternoon of 30 March.

Development of a cyclonic storm in the North Indian Ocean in the month of March is rare. In the history of the cyclonic storms in the Bay of Bengal (since 1877) cyclonic storms had developed earlier in March in the year 1907, 1924, 1925 and 1928. Except the cyclone of the year 1907 which crossed Sri Lanka coast, all others dissipated over the sea.

The track of the system is given in Fig. 2.1.1.The best track positions and other parameters have been included in Table 2.1.1. A few INSAT cloud pictures have been included in Fig. 2.1.2

Weather Realised

In association with the system widespread rainfall occurred in Andaman and Nicobar Islands. Realised cumulative rainfall for the period 27-31 March was 23 cm at Hut Bay (43364), 18 cm at Port Blair (43333) and 15 cm at Car Nicobar (43367).

Damage

No damage to life and property was reported.

TRACK OF CYCLONIC STORM OF BAY OF BENGAL 27-30 MARCH 2000

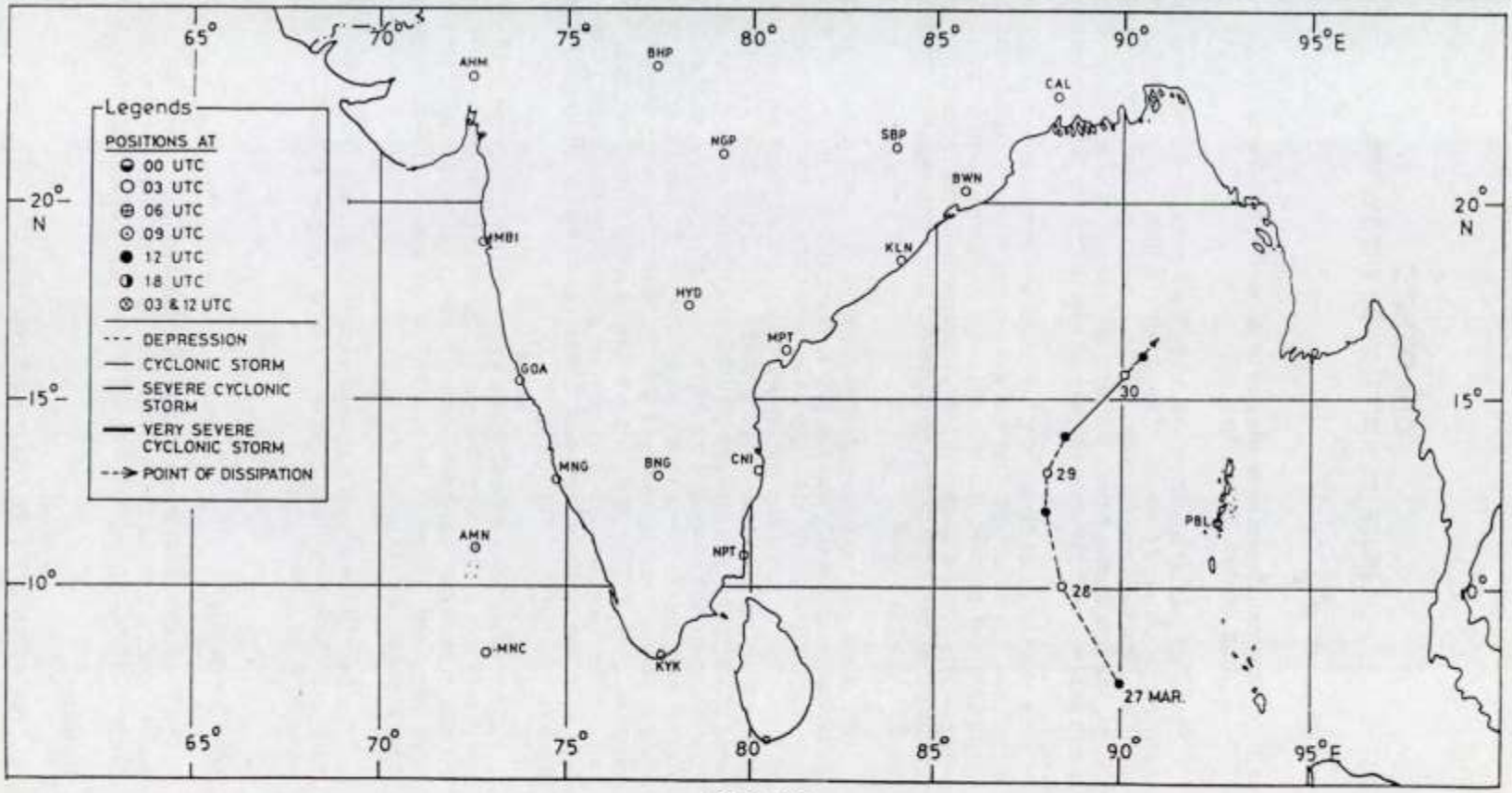
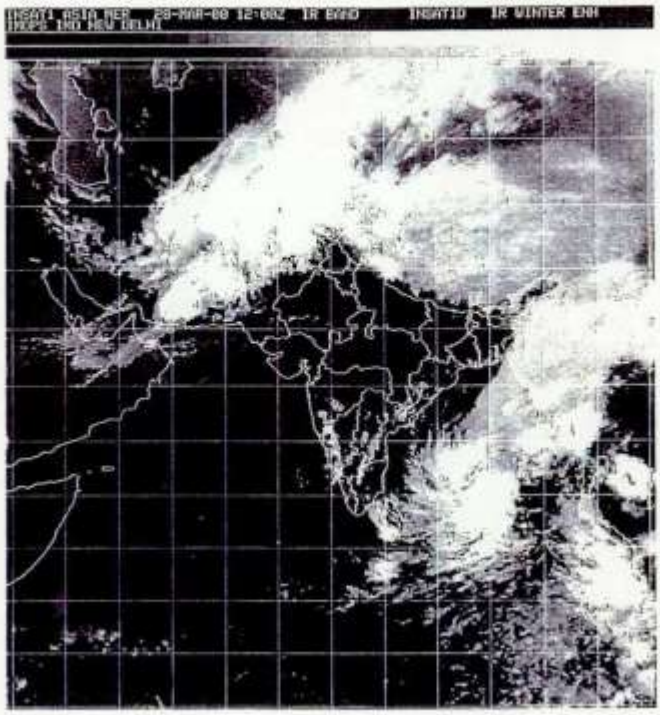


FIG 2.1.1

Table 2.1.1
Best track positions and other parameters for the Bay of Bengal cyclonic storm (27-30 March, 2000)

Date	Time (UTC)	Centre Lat. °N / Long .°E	C. I NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the centre (hPa)	Grade
27.3.2000	12	7.5/90.0	1.5	1004	25	4	D
	18	8.5/89.0	1.5	1006	25	4	D
28.3.200	00	9.5/89.0	1.5	1004	25	4	D
	03	10.0/88.5	1.5	1006	25	4	D
	12	12.0/88.0	1.5	1004	25	4	D
	18	12.0/88.0	1.5	1004	25	4	D
29.3.2000	00	12.5/88.0	1.5	1004	25	4	D
	03	13.0/88.0	2.0	1002	30	6	DD
	06	13.5/88.0	2.0	1002	30	6	DD
	12	14.0/88.5	2.5	998	35	8	CS
	15	14.5/89.0	2.5	1000	35	8	CS
	18	15.0/89.5	2.5	1000	35	8	CS
	21	15.0/89.5	3.0	1000	45	10	CS
30.3.2000	00	15.0/89.5	3.0	998	45	10	CS
	03	15.5/90.0	3.0	998	45	10	CS
	06	15.5/90.0	2.5	1000	35	8	CS
	09	15.0/90.0	2.0	1000	30	6	DD
	12	16.0/90.5	1.5	1002	25	4	D
	System weakened over east central Bay of Bengal in the afternoon of 30 March 2000						


INSAT1 ASIA MER 28-MAR-00 12:00Z IR BAND INSAT1D IR WINTER ENH
IMDPS IMD NEW DELHI

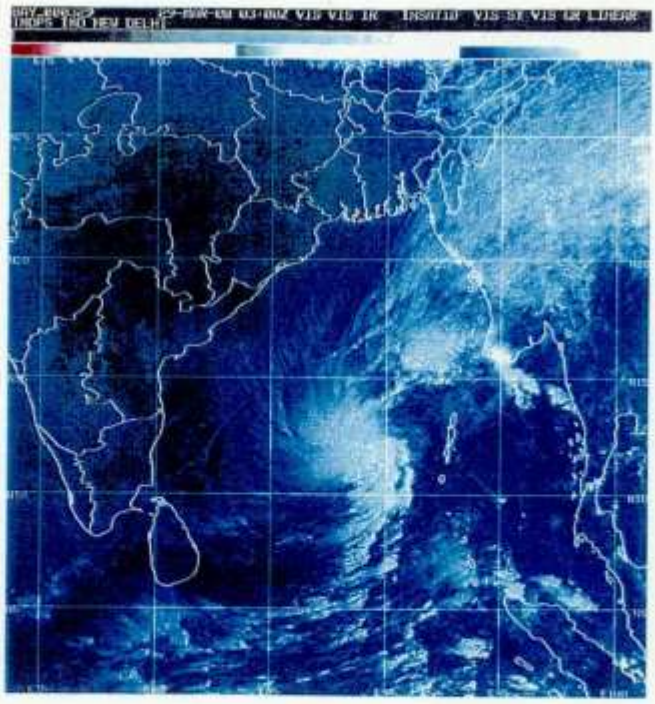

IMDPS IMD NEW DELHI

Fig 2.1.2

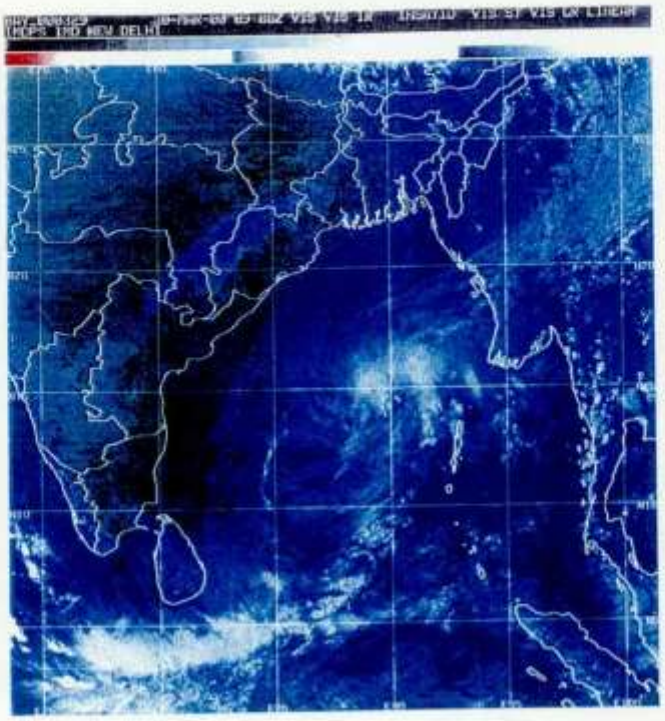


Fig 2.1.2 (Contd.)

2.2 Depression over Bay of Bengal (23-24 August, 2000)

No monsoon depression formed over the Bay of Bengal in the first two months of the south-west monsoon season. Season's first depression formed on 23 August over west-central Bay. It crossed Andhra Pradesh coast north of Machilipatnam and led to an intense rainstorm leading to floods that submerged many areas even in Hyderabad City.

Initial cyclogenesis took place on 22 August when a well marked low pressure area developed over west central Bay that concentrated into a depression in the morning of 23 August over west-central Bay of Bengal close to Andhra Pradesh coast with its centre near Lat. 16.5 N/ Long. 83.5 E. It crossed Andhra Pradesh coast near Kakinada (43189) by the midnight of 23 August and weakened into a well marked low pressure area over Telengana region of Andhra Pradesh and neighbourhood. Continuing to move in a north-westerly direction the well marked low pressure area dissipated over south Gujarat coast and neighbourhood on 28 August.

The track of the system is given in Fig. 2.2.1. The best track positions and other parameters have been included in Table 2.2.1. A few INSAT cloud pictures have been included in Fig. 2.2.2. The Satellite pictures did not show cloud organisation normally associated with a monsoon depression.

Weather Realised

Under the influence of this depression heavy to very heavy rainfall occurred in Rayalaseema. Isolated heavy rainfall also occurred in rest Andhra Pradesh, Marathawada and Madhya Maharashtra. Hyderabad recorded exceptionally heavy rainfall of 24 cm on 24 August.

Damage

In association with the depression, heavy rains were reported from districts in the central parts of Andhra Pradesh State of India. Hydrabad city received exceptionally heavy rain of 24 cm. In the above districts 131 deaths have been reported due to wall collapse, drowning, etc. As per the preliminary estimates, about 8651 houses were fully damaged, 27026 houses partly damaged in 2886 villages/ towns . 98079 people were evacuated and kept in 189 relief camps. About 5368 cattle were reported as lost and 2389 roads of Panchayati Raj, R & B and National High Ways were damaged over a distance of 7435 km disrupting traffic. 1578 minor irregation and Panchayati Raj tanks breached. An estimated 1,77,987 hectares paddy and other crops were damaged in the affected districts. Due to heavy rains 902 power transformers were damaged. 28 sub-stations 787 distribution transformers were damaged. 33 KV lines numbering 225 and 11 KV lines numbering 6000 are damaged. Preliminary estimate of a loss of Rs. 776.75 crores was reported by the government of Andhra Pradesh.

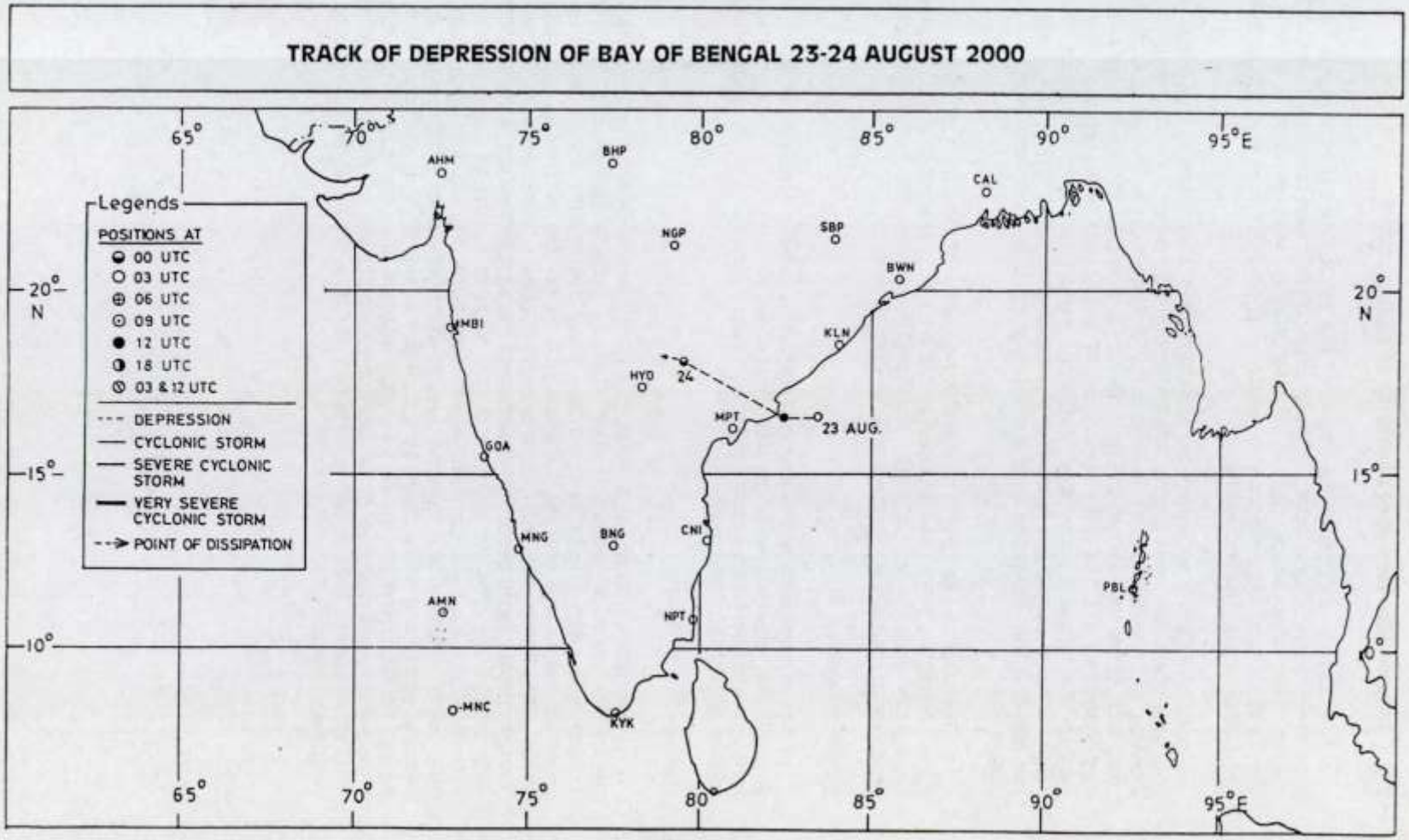
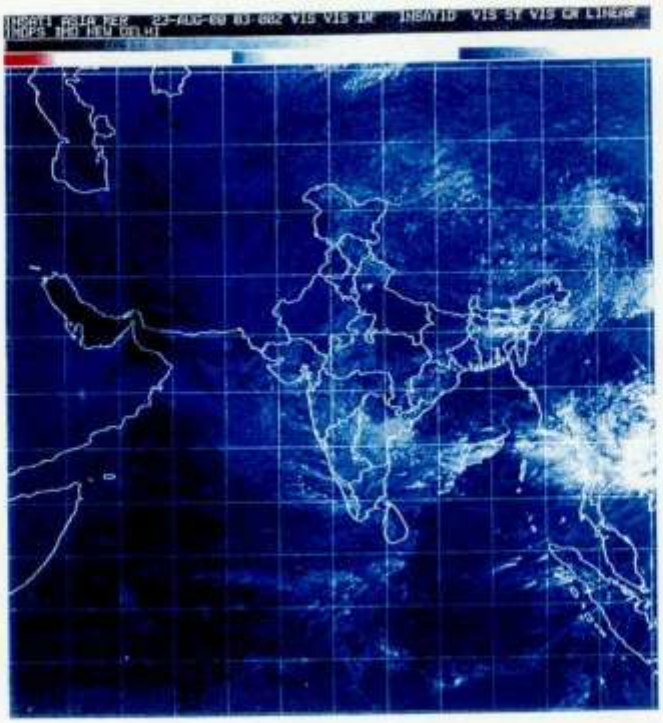

TRACK OF DEPRESSION OF BAY OF BENGAL 23-24 AUGUST 2000
Legends
POSITIONS AT
00 UTC
03 UTC
06 UTC
09 UTC
12 UTC
18 UTC
03 & 12 UTC
DEPRESSION
CYCLONIC STORM
SEVERE CYCLONIC STORM
VERY SEVERE CYCLONIC STORM
POINT OF DISSIPATION
65°
70°
75°
80°
85°
90°
95°E
20° N
15°
10°
AHM
BHP
CAL
NGP
SBP
BWN
MBI
KLN
HYD
24
MPT
23 AUG.
GOA
MNG
BNG
CNI
PBL
AMN
NPT
MNC
KYK

Fig 2.2.1

Table 2.2.1
Best track and other parameters for the Bay of Bengal Depression (23-24 August, 2000)

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 (hPa)	Grade
23.8.2000	03	16.5/83.5	1.5	994	25	4	D
	06	16.5/83.0	1.5	996	25	4	D
	12	16.5/82.5	1.5	994	25	4	D
	18	17.5/82.0	1.5	996	25	4	D
24.8.2000	00	18.0/79.5	1.5	996	25	4.	D



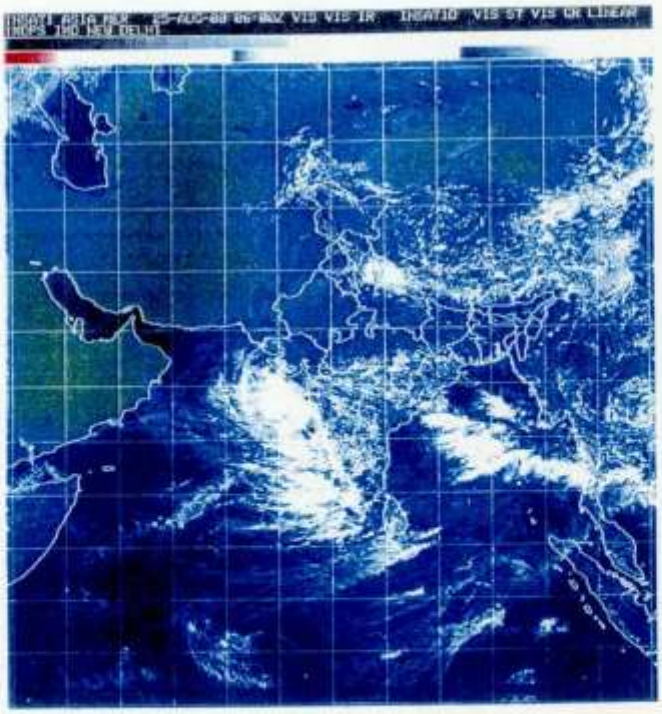


Fig 2.2.2

2.3 Cyclonic Storm over the Bay of Bengal (15-19 October, 2000) (BOB 00 02 10 15 19)

A depression formed over eastern parts of west central Bay of Bengal on 15 October. Moving in a westerly direction it intensified into a cyclonic storm over central parts of west central Bay of Bengal on 17 October. However, it weakend over the sea itself on 19 October without making landfall.

The monsoon shear zone was active over the south Bay of Bengal in the beginning of October 2000. It shifted northward towards the end of second week of October. In this active shear zone a low pressure area formed ' in- situ' over central and adjoining south Bay of Bengal on 12 October. It persisted, moved westward and became well marked over east central Bay of Bengal on 14 October and concentrated into a depression at 150000 UTC that lay centred near Lat 14.5^0 N / Long 88.5^0 E.

The INSAT imagery showed a shear pattern in which deep layer cluster was seen to the west of the low level circulation centre in the visible satellite imagery. In the infrared cloud imagery the low level circulation centre was not seen. The subsequent satellite imagery confirmed that this circulation centre had come closer to the dense convection. It was upgraded to the stage of a deep depression at 151800 UTC near Lat 14.5^0 N/ Long 86.5^0 E. A Ship ATJW at 13.2^0 N/ 84.8^0 E reported wind 230^0/35 kts and pressure 1000.2 hPa at 160600 UTC. Another ship VTZJ (11.4^0 N/ 91.7^0 E) reported wind 240^0/08 kts. After 161200 UTC the system took a west-south-westerly course and intensified into a cyclonic storm at 170000 UTC near Lat 14.0^0 N /Long 84.5^0 E. A ship VWXG at 13.5^0 N/ 84.3^0 E reported wind of 210^0/30 Kts and pressure of 997.2 hPa at 170600 UTC. A Buoy at lat.13.9^0 N/ long.83.2^0 E reported wind of 033^0 / 20 Kts. The system continued to display the shear band pattern. As the vertical wind shear over the system increased, it weakened over the sea itself during next 3 days.

The track of the system is given in Fig 2.3.1. The best track positions and other parameters have been included in Table 2.3.1. Tracks predicted for various initial positions are included in Fig. 2.3.2. Mean sea level pressure and wind analysis at 850 hPa at 180000 UTC, 24-hr and 36-hr forecast position (black dot) of the storm and wind field as obtained from the Quasi-Lagrangian Model (QLM) is shown in Fig. 2.3.3. A few INSAT cloud pictures have been included in Fig. 2.3.4. A few radar pictures from Cyclone Detection Radar (CDR) Machilipatnam are included in Fig. 2.3.5.

Weather Realised

Under the influence of this system widespread rainfall with isolated heavy rain occurred over coastal areas of Andhra Pradesh and Orissa.

Damage

As the system weakened over the sea itself, No damage to life and property was reported.

TRACK OF CYCLONIC STORM OF BAY OF BENGAL 15-19 OOCTOBER 2000

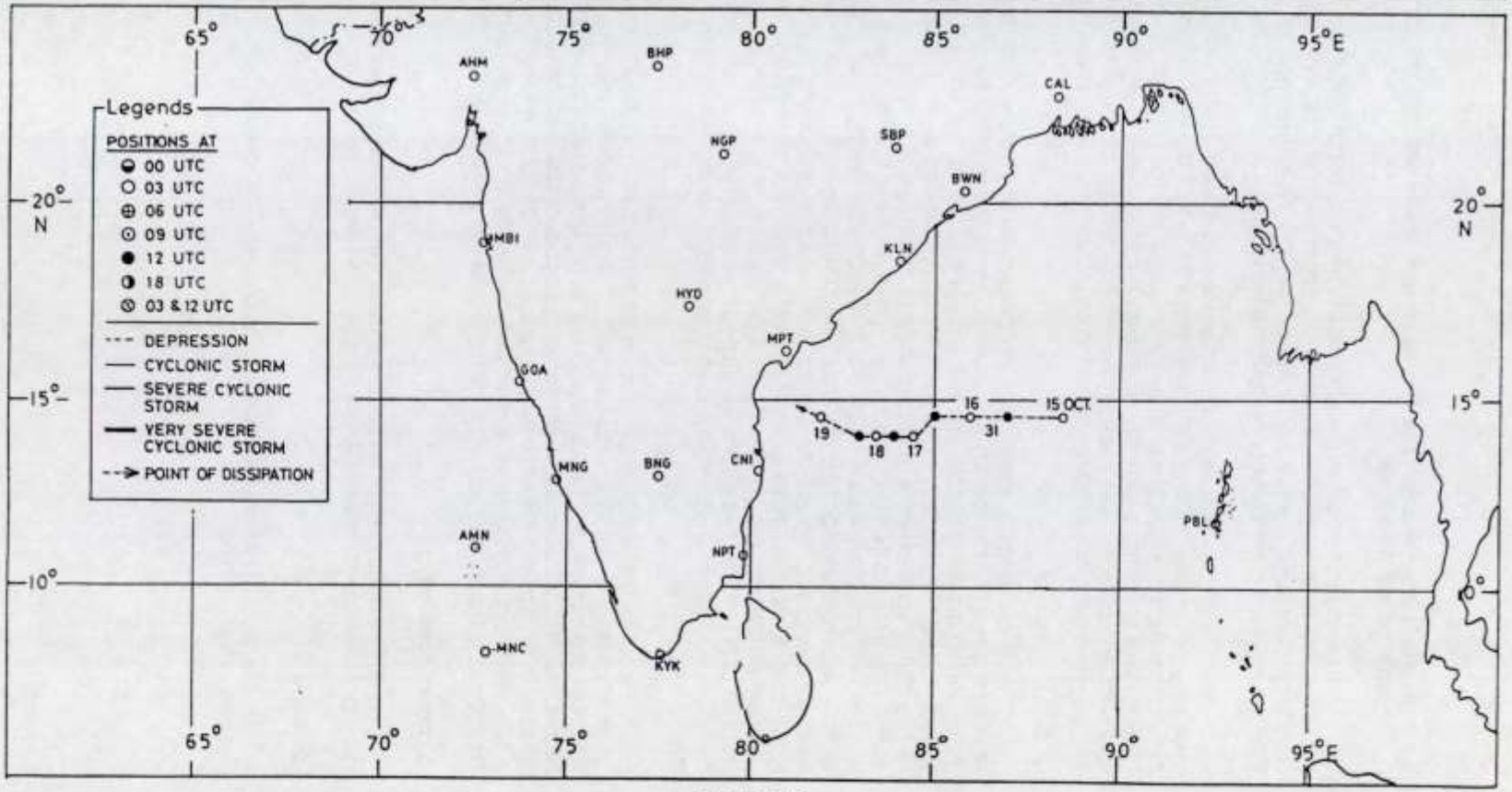


Fig 2.3.1

Table 2.3.1
Best track and other parameters for the Bay of Bengal Cyclonic storm (15-19 October, 2000)

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 (hPa)	Grade
15.10.2000	00	14.5/88.5	1.5	1004	25	4	D
	03	14.5/88.5	1.5	1004	25	4	D
	06	14.5/88.0	1.5	1002	25	4	D
	12	14.5/87.0	1.5	1000	25	4	D
	18	14.5/86.5	2.0	1002	30	6	DD
16.10.2000	00	14.5/86.3	2.0	1000	30	6	DD
	03	14.5/86.0	2.0	1000	30	8	DD
	06	14.5/85.5	2.0	1000	30	8	DD
	12	14.5 /85.0	2.0	998	30	8	DD
	18	14.0/85.0	2.0	1000	30	8	DD
17.10.2000	00	14.0/84.5	2.5	998	35	8	CS
	03	14.0/84.5	2.5	998	35	8	CS
	06	14.0/84.5	2.5	996	35	10	CS
	09	14.0/84.0	2.5	996	35	10	CS
	12	14.0/84.0	2.5	996	35	8	CS
	15	14.0/84.0	2.5	998	35	8	CS
	18	14.0/84.0	2.5	998	35	8	CS
	21	14.0/84.0	2.5	998	35	8	CS
18.10.2000	00	14.5/83.5	2.5	998	35	8	CS
	03	14.0/83.5	2.0	1000	30	6	DD
	06	14.0/83.5	2.0	1000	30	6	DD
	12	14.0/83.0	2.0	998	30	6	DD
	18	14.5/82.5	1.5	1000	25	4	D
19.10.2000	03	14.5/82.0	1.5	1004	25	4	D
	06	14.5/82.0	1.5	1004	25	4	D
		Weakened into a low pressure area over sea					

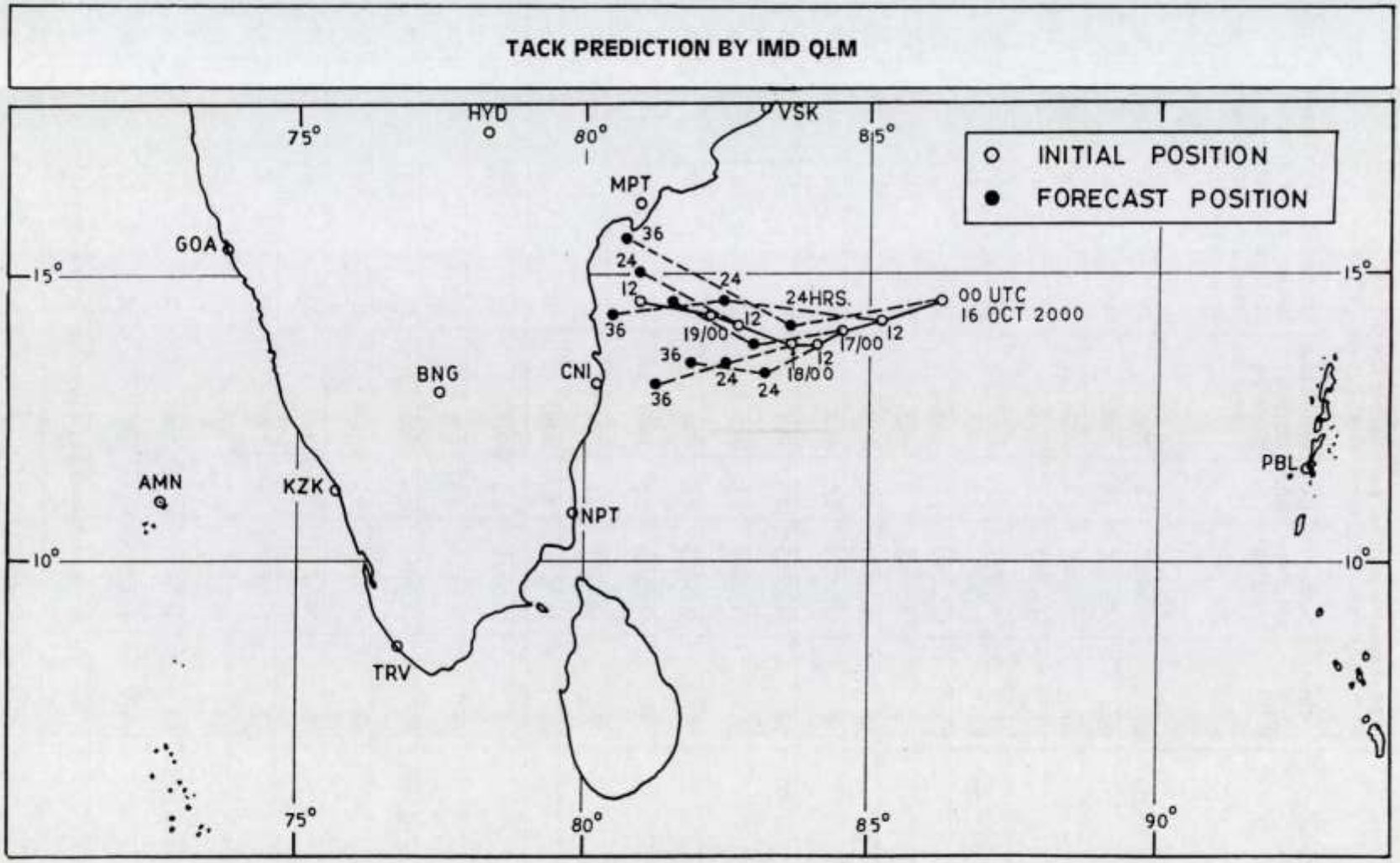
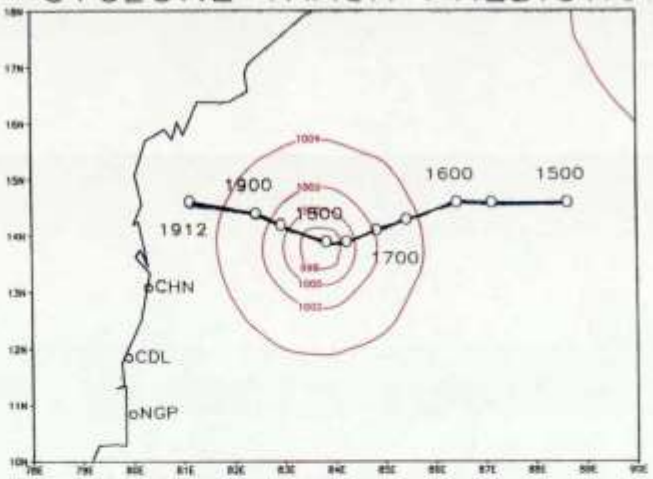
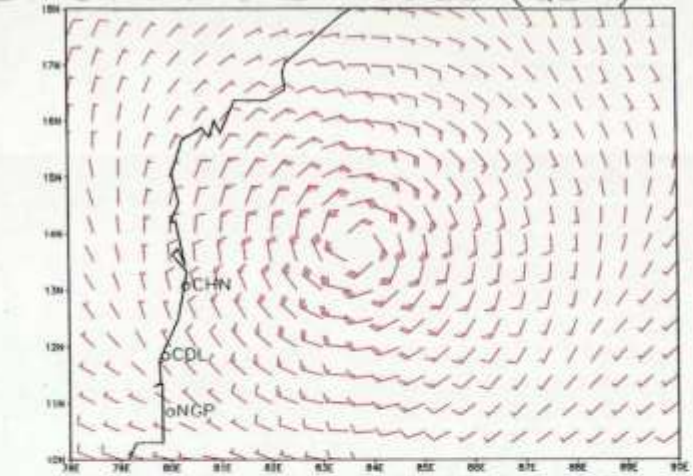

TACK PREDICTION BY IMD QLM
INITIAL POSITION
FORECAST POSITION
HYD
VSK
MPT
GOA
BNG
CNI
AMN
KZK
NPT
TRV
PBL
24HRS.
00 UTC
16 OCT 2000
19/00
17/00
18/00
75°
80°
85°
90°
15°
10°

Fig 2.3.2

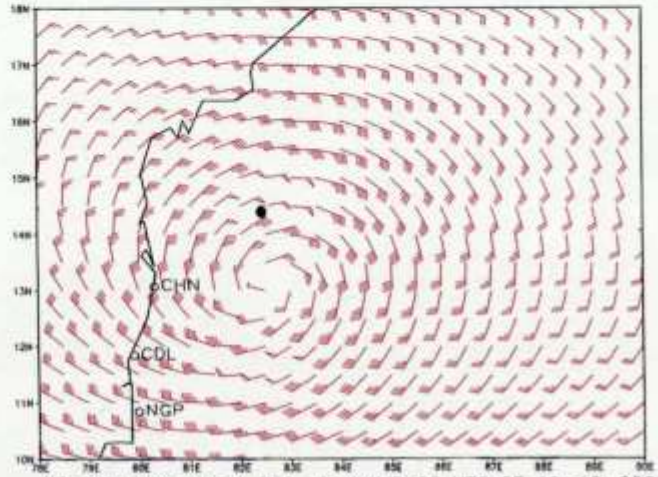
CYCLONE TRACK PREDICTION BY DYNAMICAL MODEL (QLM)



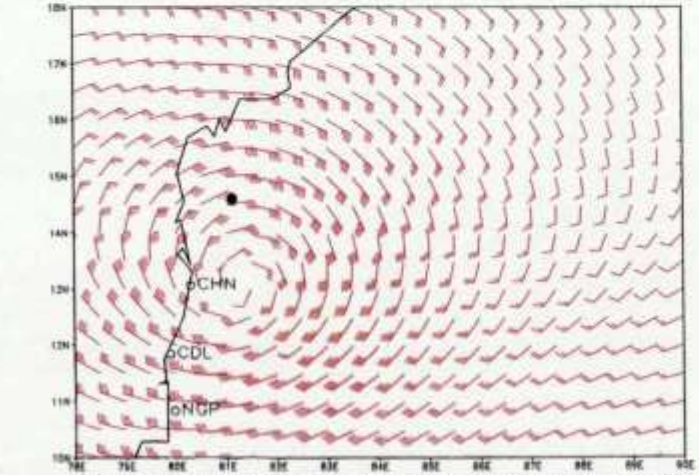
(a) MSLP ANAL 00 UTC OF 18-10-2000
(O—O: Observed track)



(b) WIND ANAL 850 hPa 00 UTC OF 18-10-2000



(c) 24H FCST WINDS 850 hPa VALID 00 UTC OF 19-10-2000
(Heavy dot shows verifying position)



(d) 36H FCST WINDS 850 hPa VALID 12 UTC OF 19-10-2000
(Heavy dot shows verifying position)

Fig 2.3.3

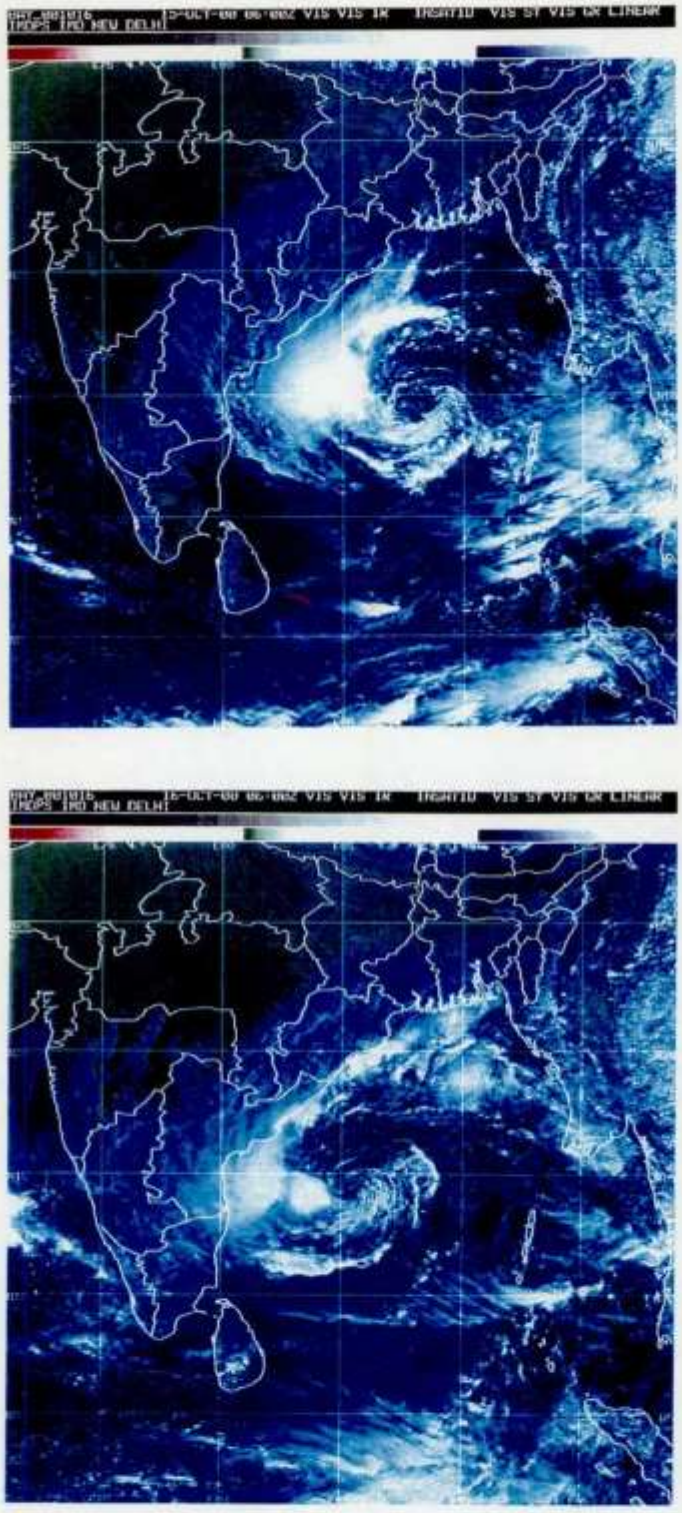
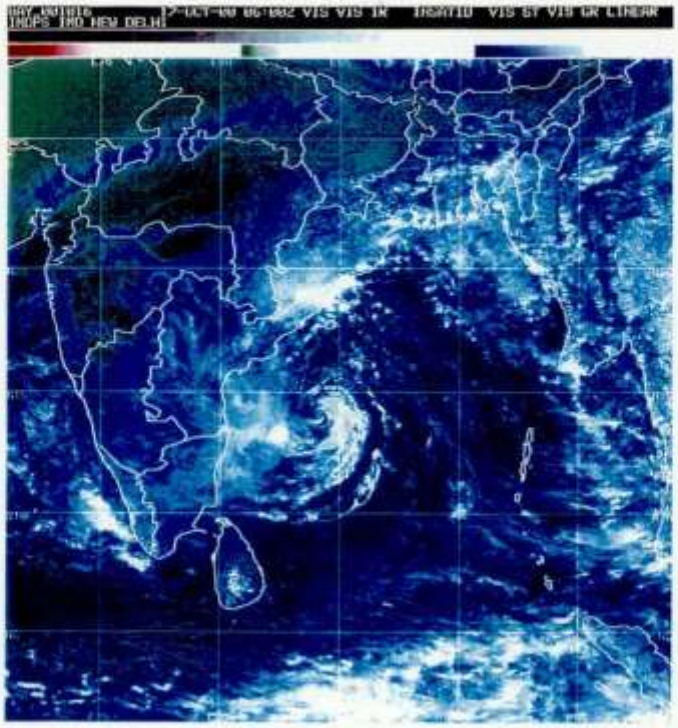


Fig 2.3.4



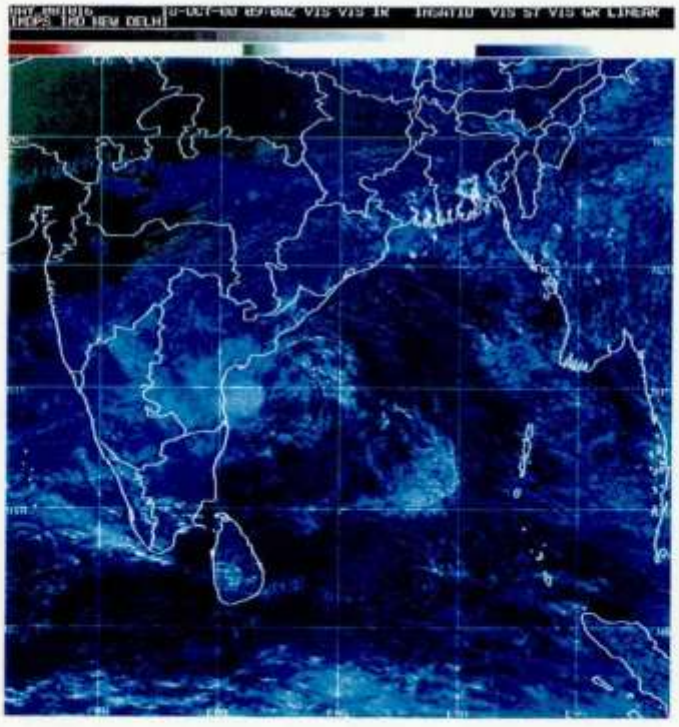
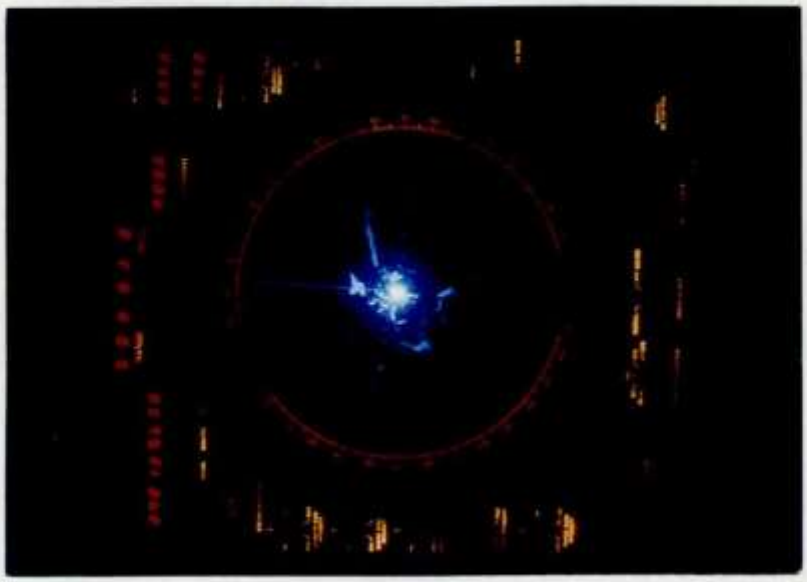
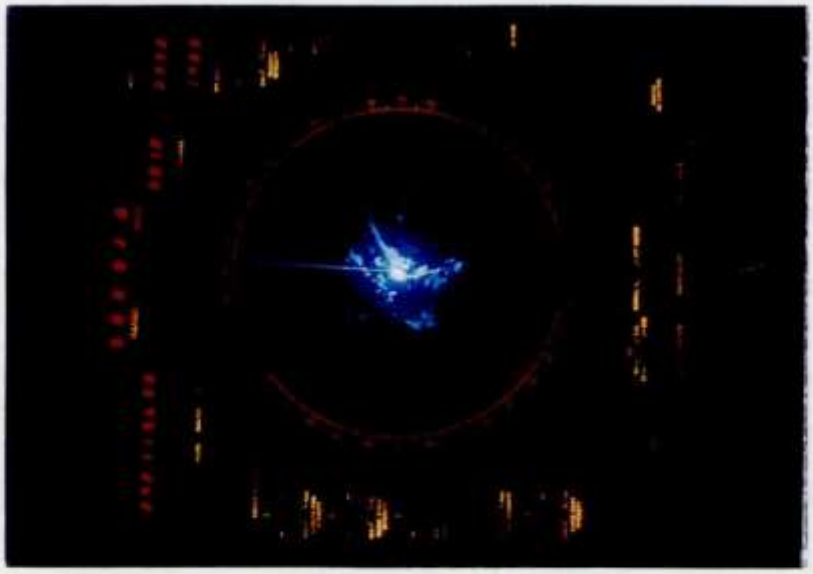


Fig 2.3.4(Contd.)

Machilipatnam 18.10.2000



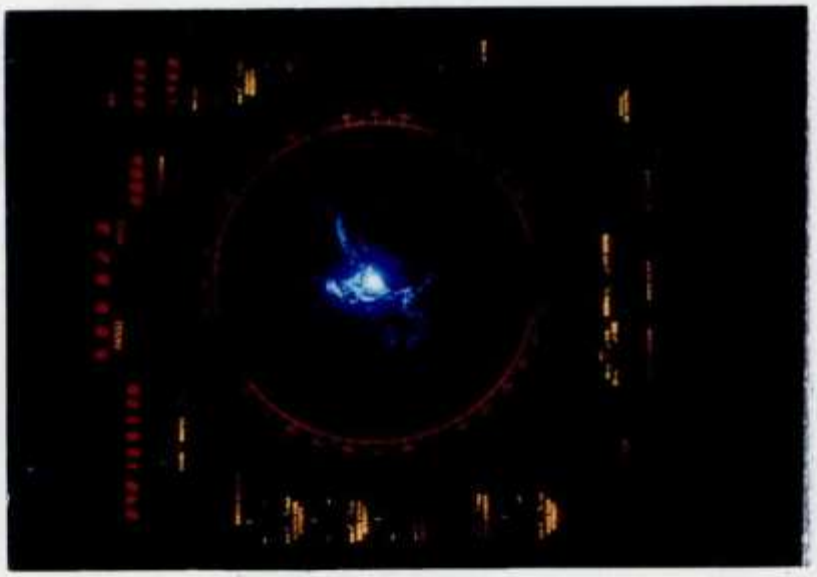
1200 UTC



1300 UTC

Fig 2.3.5

1400 UTC



1500 UTC

Fig 2.3.5 (Contd.)

2.4 Cyclonic Storm over the Bay of Bengal (25- 28 October, 2000) (BOB 00 03 10 25 28)

A depression developed in the East Central Bay of Bengal on 25 October. Moving initially in a northwesterly direction and later northward, it intensified into a cyclonic storm on 27 October. It eventually re-curved northeastwards and crossed Bangladesh coast in the morning of 28 October.

The seasonal trough was active between 10° N and 15° N latitudes in the Bay towards the end of October. In this active trough zone a low pressure area formed 'in -situ' over North Andaman Sea on 24 October that became well marked in the morning on 25 October. It concentrated into a depression over North Andaman Sea and adjoining East Central and Southeast Bay of Bengal at 250900 UTC near lat. 13.5° N / Long. 93.0° E.

The system initially moved in a north-westerly direction. The amount of intense convection in the inner area of the depression increased in the afternoon of 26 October. The system became a deep depression at 270300 UTC when it was centred near Lat. 18.0° N / Long. 88.5° E. . At this stage the buoy at 12.2° N / 90.8° E reported wind 184°/12 kt and pressure 1010.2 hPa . Another buoy at 18.5° N/ 87.5° E indicated wind 360°/13 kt and pressure 1002.1 hPa. The third bouy at 14.0° N /83.2° E reported wind 010° / 06 kt and pressure 1008.1 hPa . These observations were found very useful as they enabled the analyst to draw 4 isobars, at 2 hPa interval, around the system centre. The northern buoy continued to provide valuable data as the storm moved further northward. There was another surge of deep convection in the inner area in the afternoon on 27 October and a comma cloud system could be seen at night in the satellite imagery. The system further intensified into a cyclonic storm at 271800 UTC near Lat 20.5° N / Long 88.5° E. The cyclonic storm eventually re-curved north-eastward and crossed Bangladesh coast around 280300 UTC near Mongla (lat. 23.0° N / long. 89.0° E). It rapidly weakened into a low pressure area over north Bangladesh.

The track of the system is given in Fig 2.4.1. The best track positions and other parameters have been included in Table 2.4.1. A few INSAT cloud pictures have been included in Fig. 2.4.2.

Weather Realised

In association with the system widespread rainfall occurred in Andaman and Nicobar Islands. Fairly widespread rainfall with isolated heavy falls also occurred over north-east India.

Damage

[Source: Government of Meghalaya]

The system severely affected six of the seven districts of the state of Meghalaya in India. It caused extensive damage to infra-structure, standing crops and plantation. Hundreds of houses were damaged rendering thousands of people homeless. It also caused loss of a large number of livestock. The preliminary estimate of total damage was of the order of Rs. 60 crores.

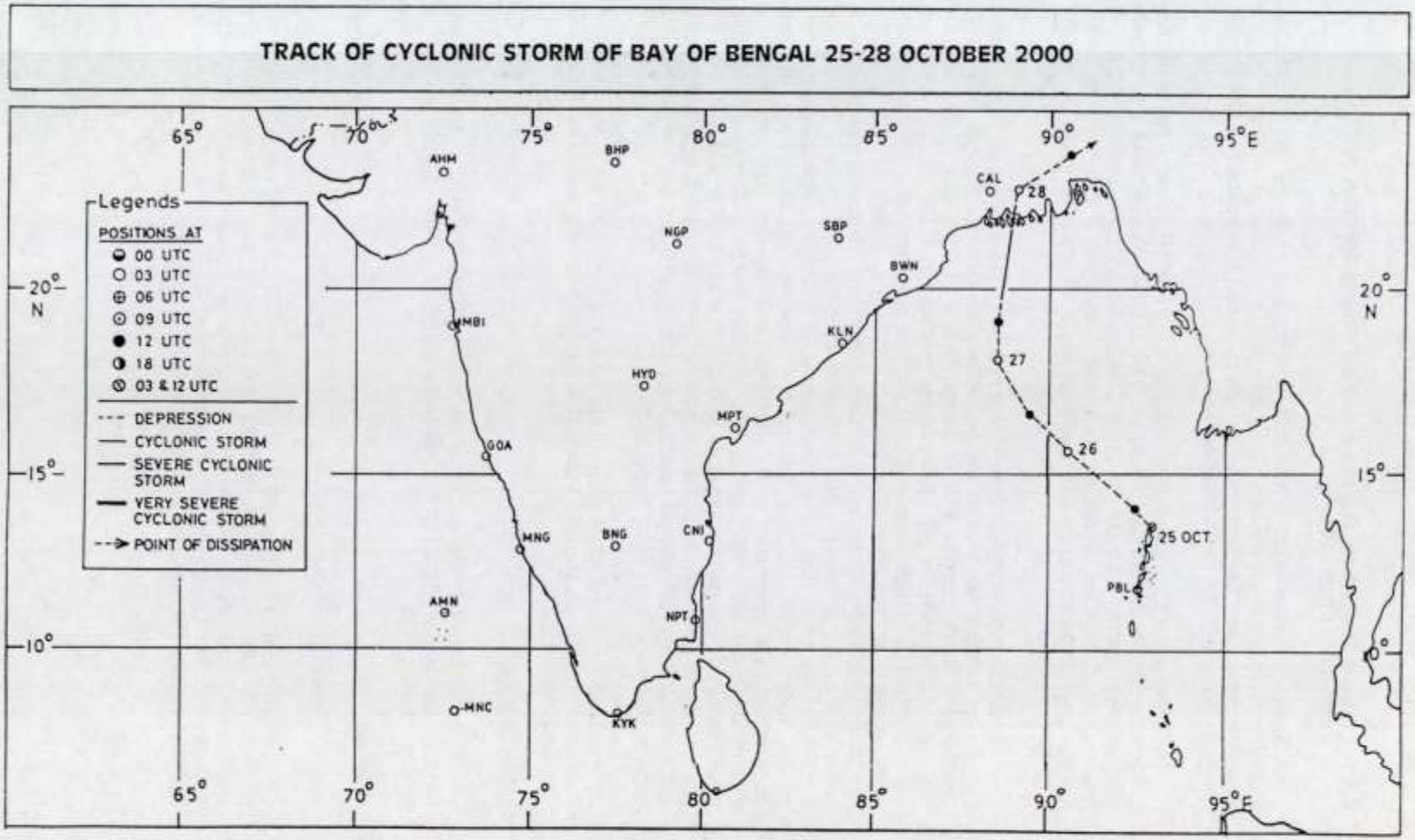
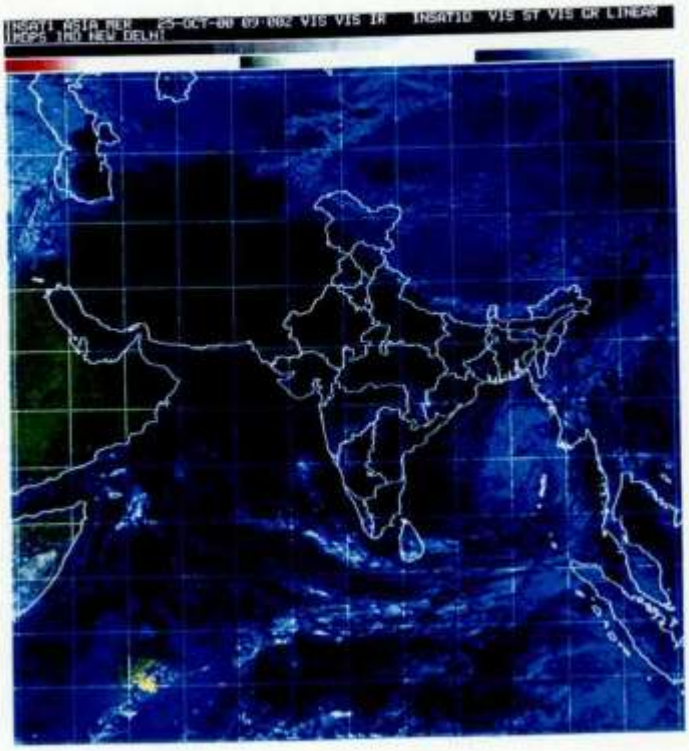

TRACK OF CYCLONIC STORM OF BAY OF BENGAL 25-28 OCTOBER 2000
Legends
POSITIONS AT
00 UTC
03 UTC
06 UTC
09 UTC
12 UTC
18 UTC
03 & 12 UTC
DEPRESSION
CYCLONIC STORM
SEVERE CYCLONIC STORM
VERY SEVERE CYCLONIC STORM
POINT OF DISSIPATION
65°
70°
75°
80°
85°
90°
95°E
20° N
15°
10°
AHM
BHP
CAL
NGP
SBP
BWN
MBI
KLN
HYD
MPT
GOA
MNG
BNG
CNI
AMN
NPT
MNC
KYK
PBL
28
27
26
25 OCT

Fig 2.4.1

Table 2.4.1
Best track and other parameters for the Bay of Bengal Cyclonic storm (25-28 October, 2000)

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 (hPa)	Grade
25.10.2000	09	13.5/93.0	1.5	1002	25	4	D
	12	14.0/92.5	1.5	1002	25	4	D
	18	14.5/92.0	1.5	1002	25	4	D
26.10.2000	00	15.0/91.5	1.5	1002	25	4	D
	03	15.5/90.5	1.5	1004	25	4	D
	06	16.5/90.5	1.5	1002	25	4	D
	12	16.5/89.5	1.5	1002	25	4	D
	18	17.0/89.0	1.5	1004	25	4	D
27.10.2000	00	17.5/88.5	1.5	1002	25	4	D
	03	18.0/88.5	2.0	1002	30	6	DD
	06	18.5/88.5	2.0	1002	30	6	DD
	12	19.0/88.5	2.0	1000	30	6	DD
	18	20.5/88.5	2.5	998	35	8	CS
	21	21.0/88.5	2.5	998	35	8	CS
28.10.2000	00	21.5/89.0	2.5	998	35	8	CS
	Crossed Bangladesh coast near Mongla between 01 UTC & 03 UTC						
	03	22.5/89.0	-	-	30	6	DD
	06	23.0/89.5	-	-	30	6	DD
	12	23.5/90.5	-	-	25	4	D
	18	24.0/93.0	-	-	25	4	D
29.10.2000	00	24.0/94.0	-	-	25	4	D
	Weakend into a well marked Low Pressure area over Bangladesh and adjoining Assam & Meghalaya.						


INSAT ASIA MER 25-OCT-00 07:00Z VIS VIS IR INSAT1D VIS ST VIS GK LINEAR
HOPS IMD NEW DELHI

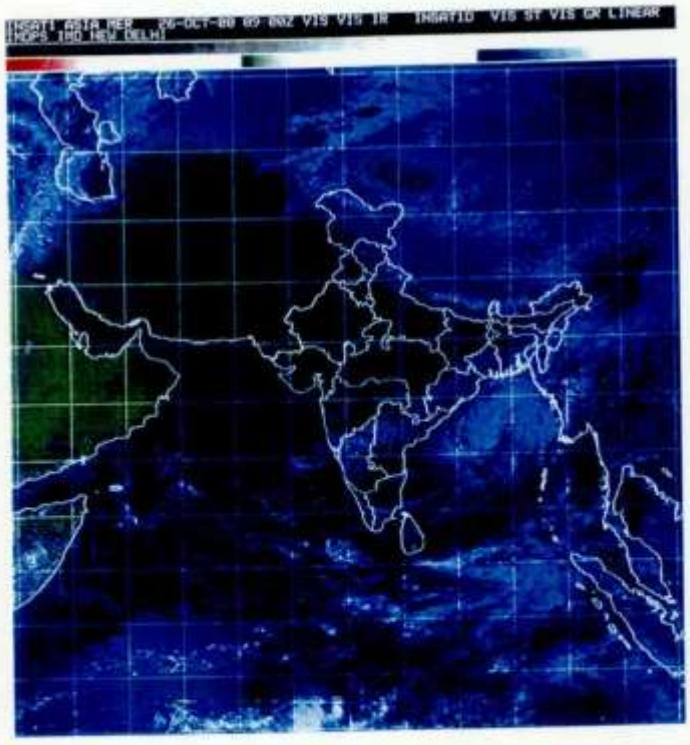

INSAT ASIA MER 26-OCT-00 07:00Z VIS VIS IR INSAT1D VIS ST VIS GK LINEAR
HOPS IMD NEW DELHI

Fig 2.4.2

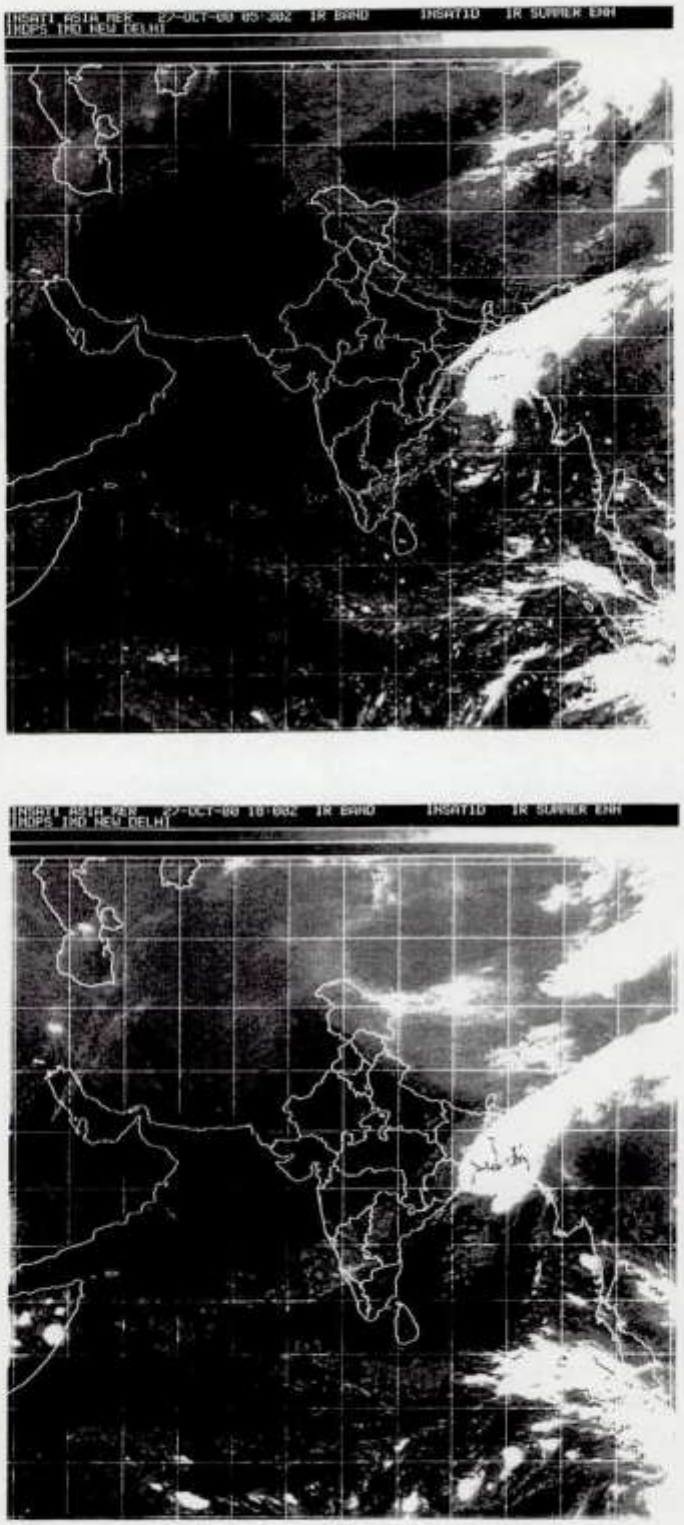


Fig 2.4.2 (Contd.)

2.5 Very Severe Cyclonic Storm over the Bay of Bengal (26- 30 November, 2000) (BOB 00 04 11 26 30)

A depression formed in the south-east Bay of Bengal on 26 November that initially moved northwestwards and intensified into a cyclonic storm on 27 November. While moving almost westwards later, the system further intensified into a very severe cyclonic storm on 28 November when it was located more than 300 km away from north Tamil Nadu coast. However, it weakend before crossing the coast near Cuddalore and activated the north-east monsoon rainfall in some areas of Tamil Nadu for about two days.

An upper air cyclonic circulation lay over South Andaman Sea on 24 November. It culminated into a low pressure on 25 November when the satellite picture showed increase in the extent and depth of convection. A solid cloud cluster indicating central dense overcast (CDO) with embedded low level circulation centre was seen in the visible satellite imagery at 260300 UTC which indicated that a depression had formed near lat.8.5 ^{0} N / long. 91.5^{0}E.

The depression moved north-north-westward and intensified into a deep depression. A buoy at lat. 12.1^0 N / long.90.7^0 E reported north-easterly wind of about 25 knots at 261500 UTC. The system acquired the stage of cyclonic storm at 270900 UTC when it lay centred near lat. 11.0^0 N / long. 86.5^0 E. The CDO pattern continued on 27 November and became more marked with outflow seen in all quadrants. The easterly surge strengthened the convergence in the inflow band from the north. The system was upgraded to the stage of a severe cyclonic storm at 280000 UTC near lat.11.5 ^{0}N / long. 84.0^{0}E.

The system further intensified into a very severe cyclonic storm at 280600 UTC near lat.11.5 ^{0} N/ long. 83.0^0 E. The cyclone came within the range of Cyclone Detection Radars (CDR) at Chennai and Karaikal at 280800 UTC. CDR Karaikal reported open 'eye' at 280800 UTC and closed elliptical 'eye' from 281100 UTC. CDR Chennai reported 'open eye' from 281400 UTC onwards with 'eye' wall 20 km . The eye in the satellite imagery got warmed up to – 16^0 C with surrounding cold convection with cloud top temperature in the range of –70^0 C to –75^0 C. Around this time CDR Karaikal reported closed circular 'eye' near lat.11.4 ^{0} N/ long. 81.6^{0}E and CDR Chennai reported 'eye' near lat.11.5 ^{0} N / long. 81.5^{0}E with eyewall 20 km wide. Thereafter the cyclone weakened as it interacted with the land.

The cyclone crossed the coast south of Cuddalore (43329) at 291130 UTC as a very severe cyclonic storm uprooting big trees at various places in and around Pondicherry and Cuddalore areas, Cuddalore Observatory reported surface pressure of 983.1 hPa. The touring officer indicated that this cyclone crossed just south of Cuddalore. Thus the central pressure is estimated as 978 hPa at the time of landfall . However, the winds experienced over the coastal areas were reported to be of the order of 110-120 Kmph.

This cyclone after land fall drifted south-westwards and weakened into a depression at 300300 UTC near Kodaikanal (43339) in south Tamil Nadu. Thereafter, it emerged into east Arabian Sea on 1 December as a low pressure system and weakened later.

From the information gathered from the affected people in the coastal areas, it was learnt that lull period lasted for a maximum of 45 minutes indicating prevalence of 'eye' which was , however, not seen in the satellite and radar images at that time.

The track of the system is given in Fig 2.5.1. The best track positions and other parameters have been included in Table 2.5.1.

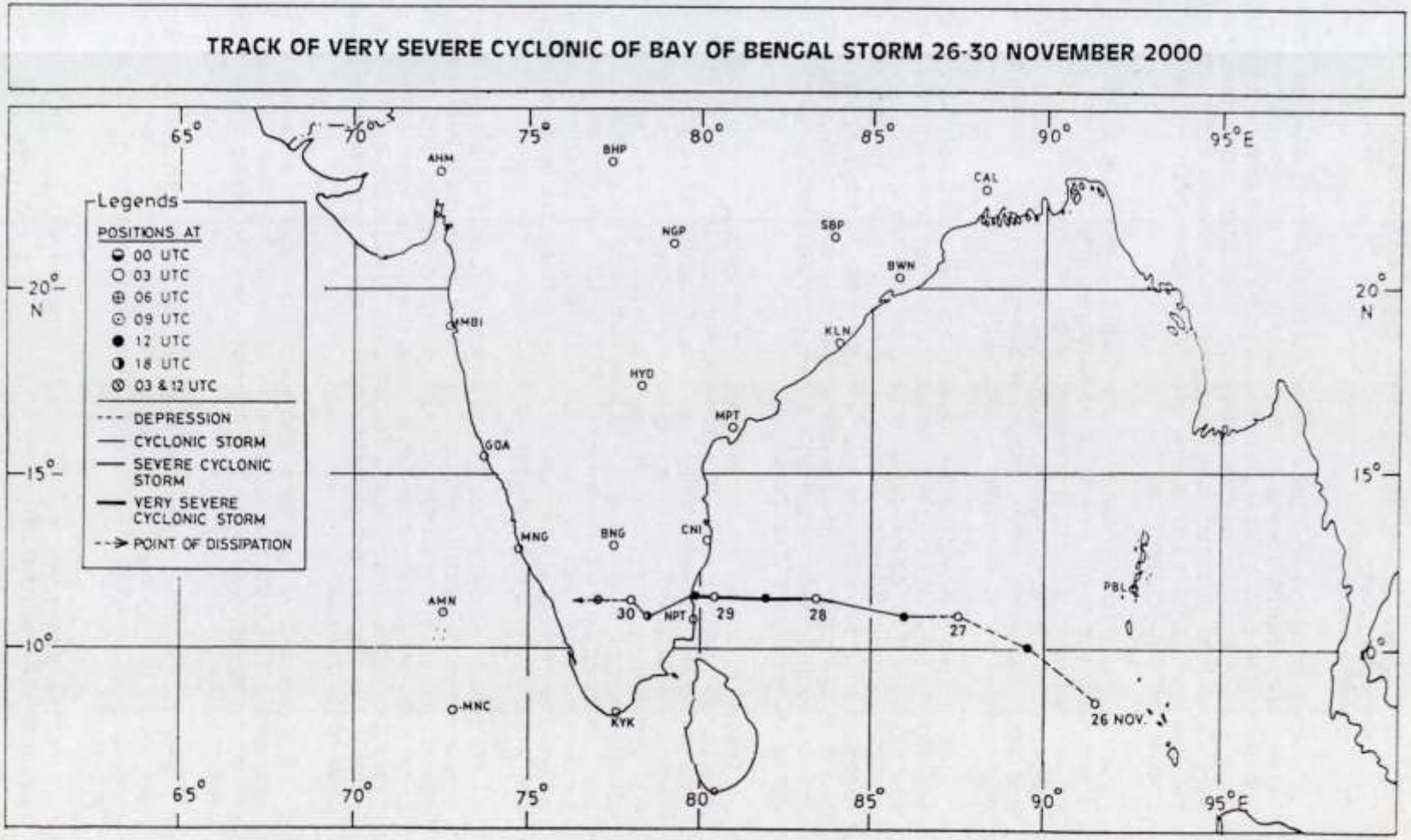

TRACK OF VERY SEVERE CYCLONIC OF BAY OF BENGAL STORM 26-30 NOVEMBER 2000
Legends
POSITIONS AT
00 UTC
03 UTC
06 UTC
09 UTC
12 UTC
18 UTC
03 & 12 UTC
DEPRESSION
CYCLONIC STORM
SEVERE CYCLONIC STORM
VERY SEVERE CYCLONIC STORM
POINT OF DISSIPATION
65°
70°
75°
80°
85°
90°
95°E
20° N
15°
10°
AHM
BHP
CAL
NGP
SBP
BWN
MBI
KLN
HYD
MPT
GOA
MNG
BNG
CNI
PBL
AMN
30
NPT
29
28
27
26 NOV.
MNC
KYK

Fig 2.5.1

Table 2.5.1
Best track and other parameters for the Bay of Bengal Very Severe Cyclonic Storm (26-30 November, 2000)

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 (hPa)	Grade
26.11.2000	03	8.5 / 91.5	1.5	1004	25	4	D
	06	9.5/90.5	1.5	1004	25	4	D
	09	9.5/91.0	1.5	1004	25	4	D
	12	10.0/89.5	1.5	1004	25	4	D
	15	10.0/ 90.0	2.0	1004	30	6	DD
	18	10.0 / 90.0	2.0	1002	30	6	DD
27.11.2000	00	10.5/88.0	2.0	1002	30	6	DD
	03	11.0/87.5	2.0	1004	30	6	DD
	06	11.0/87.0	2.0	1002	30	8	DD
	09	11.0/86.5	2.5	998	35	10	CS
	12	11.0/86.0	3.0	998	45	10	CS
	15	11.0/85.5	3.0	998	45	10	CS
	18	11.0/85.0	3.0	998	45	10	CS
	21	11.0/84.5	3.0	998	45	10	CS
28.11.2000	00	11.5/84.0	3.5	992	55	15	SCS
	03	11.5/83.5	3.5	992	55	15	SCS
	06	11.5/83.0	4.0	986	65	20	VSCS
	09	11.5/82.5	4.0	986	65	20	VSCS
	12	11.5/82.0	4.5	978	77	30	VSCS

Table 2.5.1 (Continued)

Best track and other parameters for the Bay of Bengal Very Severe Cyclonic storm (26-30 November, 2000)

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 (hPa)	Grade
28.11.2000	15	11.5/81.8	5.0	968	90	40	VSCS
	18	11.5/81.5	5.5	958	102	52	VSCS
	21	11.5/81.2	5.5	958	102	52	VSCS
29.11.2000	00	11.5/81.0	5.0	968	90	40	VSCS
	03	11.5/80.5	5.0	966	90	40	VSCS
	06	11.5/80.5	4.5	976	77	30	VSCS
	09	11.5/80.0	4.5	976	77	30	VSCS
	Crossed Tamil Nadu coast near Cuddalore around 1130 UTC.						
	12	11.5/80.0	-	998	55	10	SCS
	18	11.0/78.5	-	998	45	10	CS
30.11.2000	03	11.5/78.0	-	1002	30	4	DD
	06	11.5/77.0	-	1004	25	2	D

Tracks predicted for various initial positions are included in Fig. 2.5.2. Mean sea level pressure and wind analysis at 850 hPa at 280000 UTC, 24-hr and 36-hr forecast position of the storm and wind field as obtained from the Quasi – Lagrangian Model (QLM) is shown in Fig. 2.5.3. A few INSAT cloud pictures have been included in Fig. 2.5.4. A few radar pictures of Cyclone Detection Radar (CDR) at Chennai are included in Fig. 2.5.5.

Weather Realised

The system produced comparatively very less rainfall activity. However, a few stations in the south-west and western sector of the storm received very heavy rainfall during the 24 hours periods of the order of 20 cm and above, the highest being 45 cm at Thozhudhur and 44 cm at Kilacheruvai in Cuddalore district.

Damage

Two states namely Tamil Nadu and Pondicherry were mainly affected by this system.

Tamil Nadu

The loss is mainly due to crop damage, uprooting of big trees and partial damages to more than one thousand Kuchha houses and fourteen brick houses due to strong wind. 10 persons lost their lives due to wall/ building collapse/ electrocution. Of these 7 were in Cuddalore district , two in Thiruvallure district and one in Nagapattinam district. Cuddalore district bore the brunt of cyclone fury where more than 30,000 trees were uprooted, more than thousand electric poles and four transformers had been damaged. Estimated loss in Cuddalore district is about 20 crores as per press report. Roofs of 1000 houses were blown off, 14 brick houses were washed away and 300 houses were surrounded by sea water. Sugarcane in 100 acres, 30,000 Plantain trees, 50,000 plantain saplings also got destroyed.

Pondicherry

Damage to paddy crops, plantains and coconut plantation were the major loss. About 40,000 Kutcha houses along the coastal belt were partially damaged due to strong wind. Two persons lost their lives. Total loss is estimated to be about 50 crores as per press report.

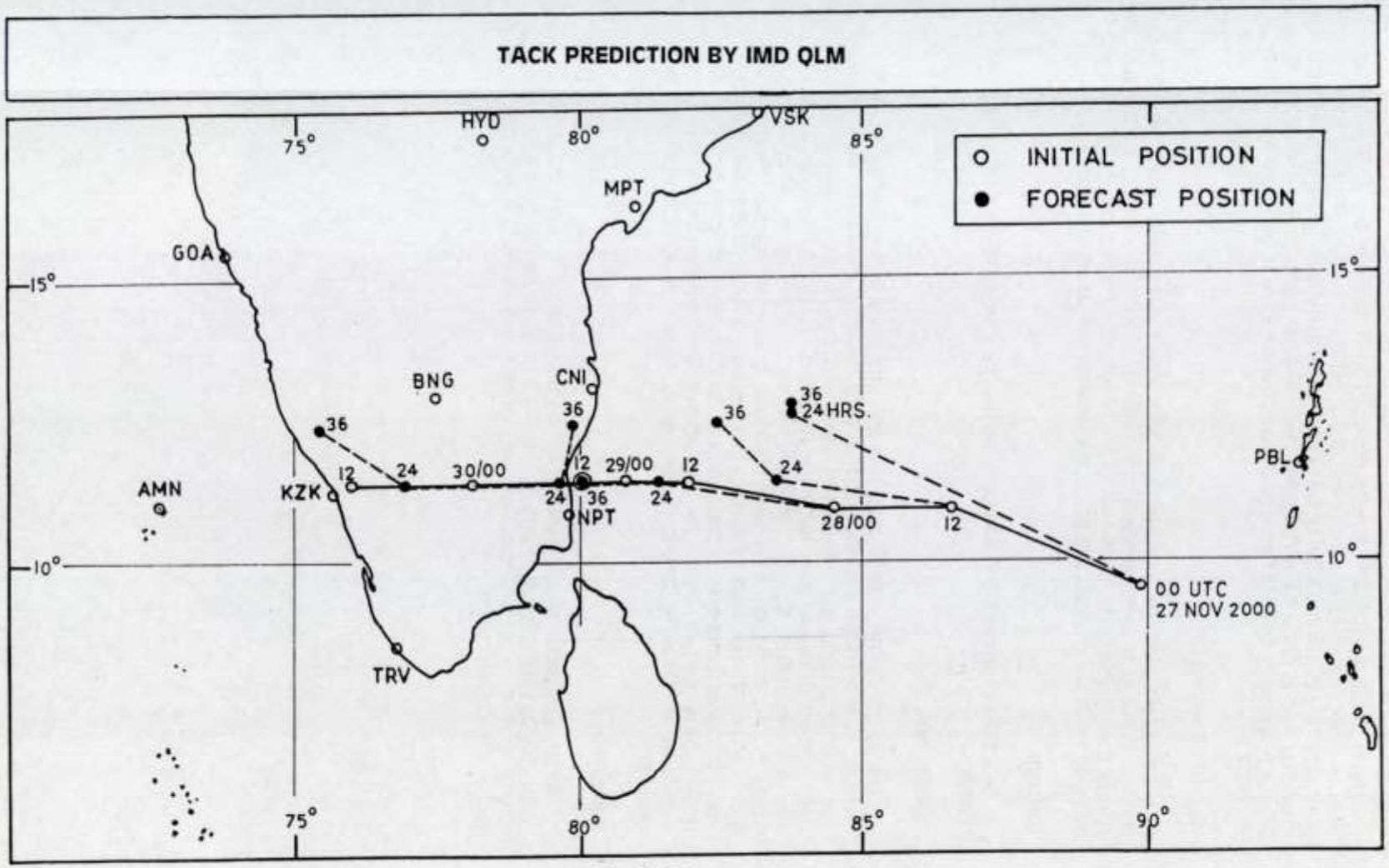
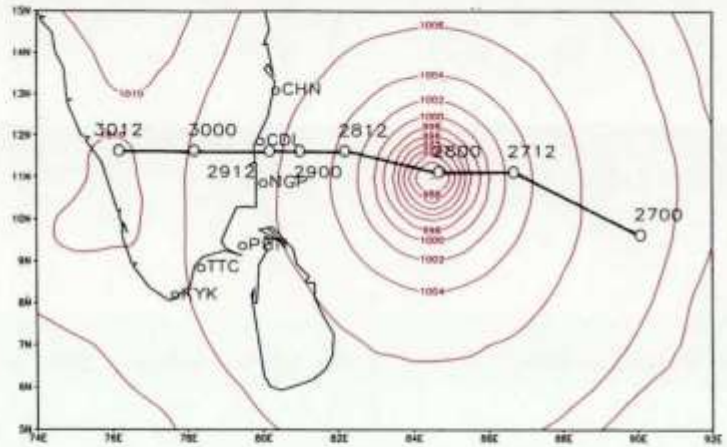
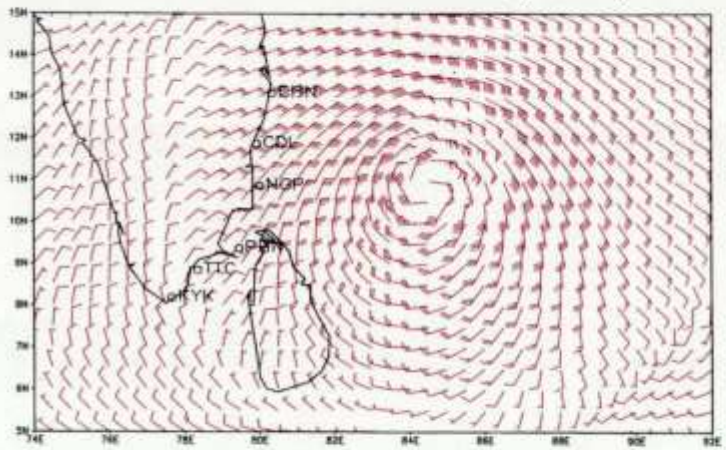

TACK PREDICTION BY IMD QLM
INITIAL POSITION
FORECAST POSITION
HYD
VSK
MPT
GOA
BNG
CNI
AMN
KZK
TRV
NPT
PBL
75°
80°
85°
90°
15°
10°
36
24
12
30/00
29/00
28/00
24HRS.
00 UTC
27 NOV 2000

Fig 2.5.2

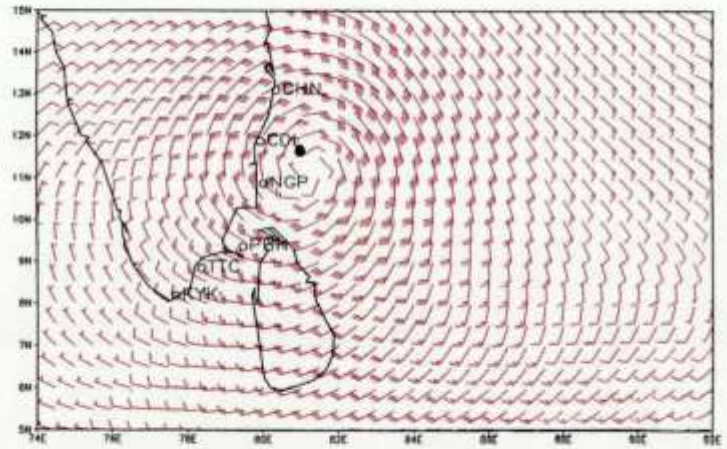
CYCLONE TRACK PREDICTION BY DYNAMICAL MODEL (QLM)



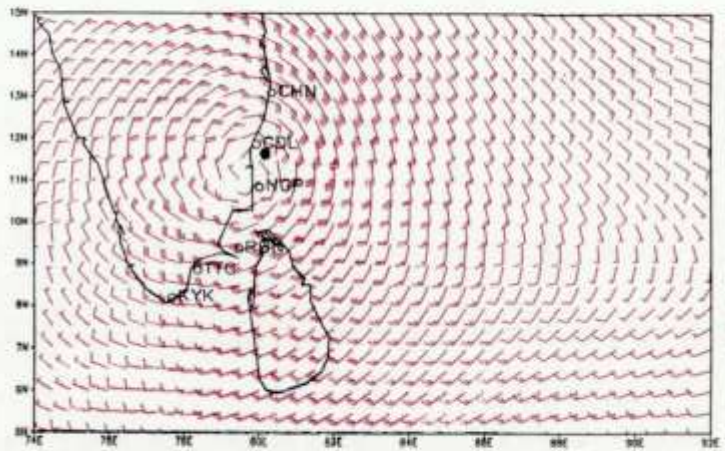
(a) MSLP ANAL 00 UTC OF 28-11-2000
(O—O: Observed track)



(b) WIND ANAL 850 hPa 00 UTC OF 28-11-2000



(c) 24H FCST WINDS 850 hPa VALID 00 UTC OF 29-11-2000
(Heavy dot shows verifying position)



(d) 36H FCST WINDS 850 hPa VALID 12 UTC OF 29-11-2000
(Heavy dot shows verifying position)

Fig 2.5.3

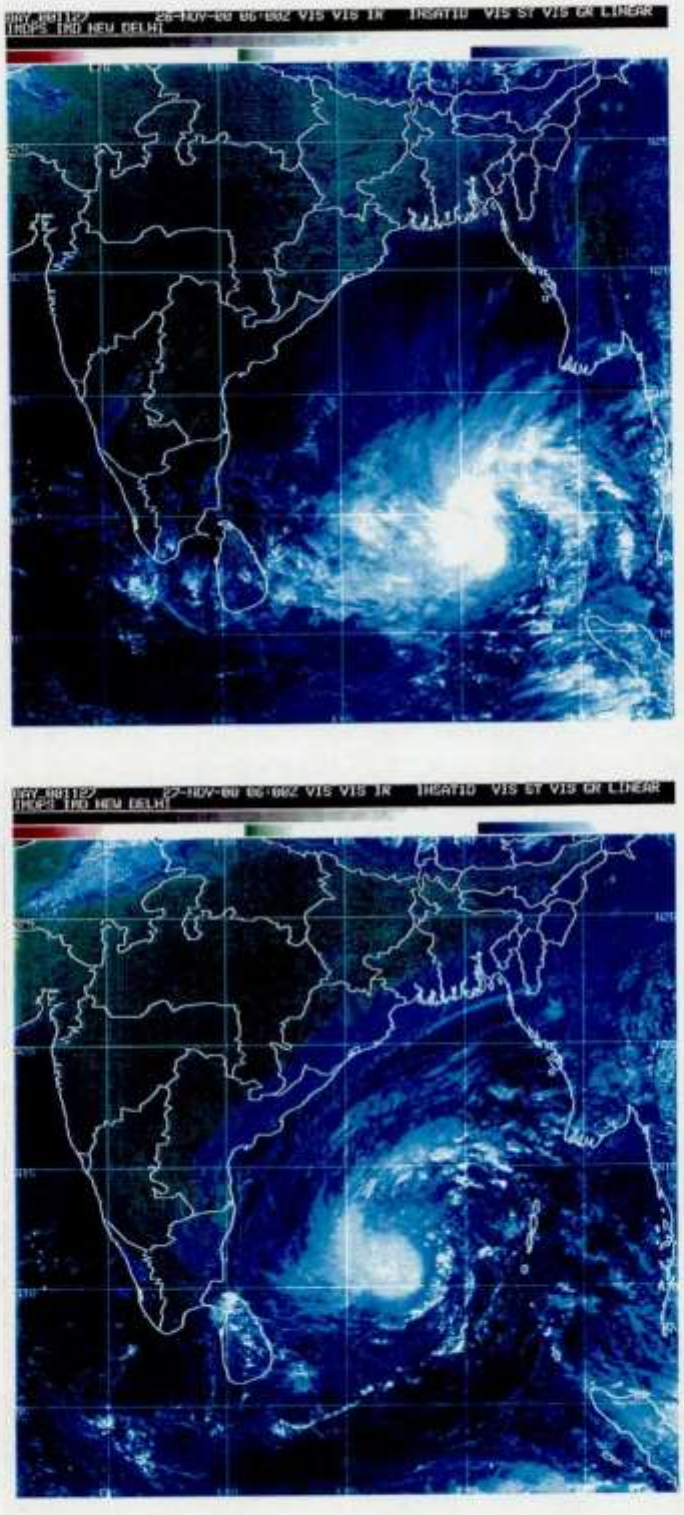
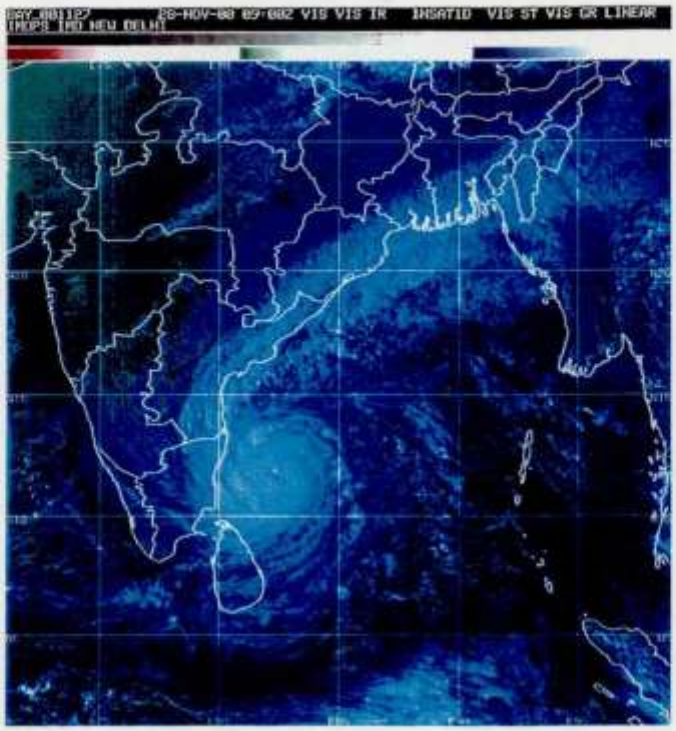


Fig 2.5.4



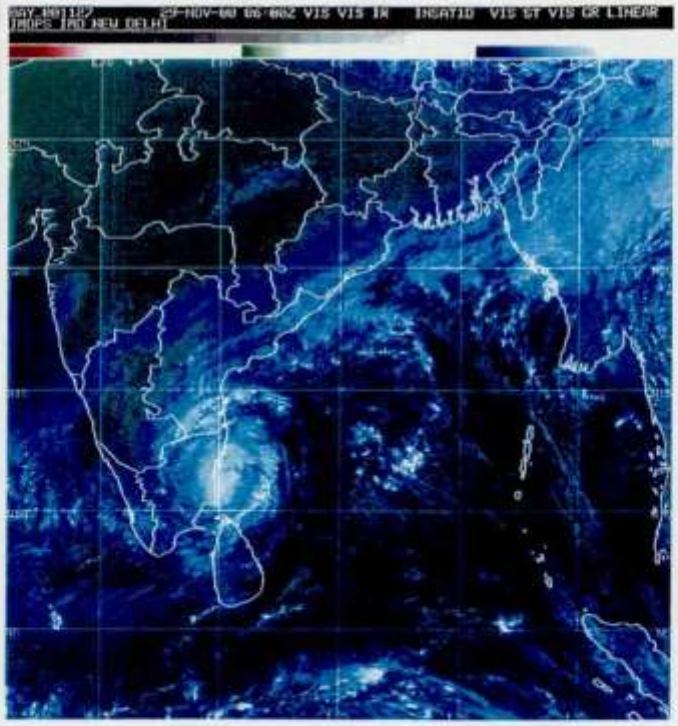
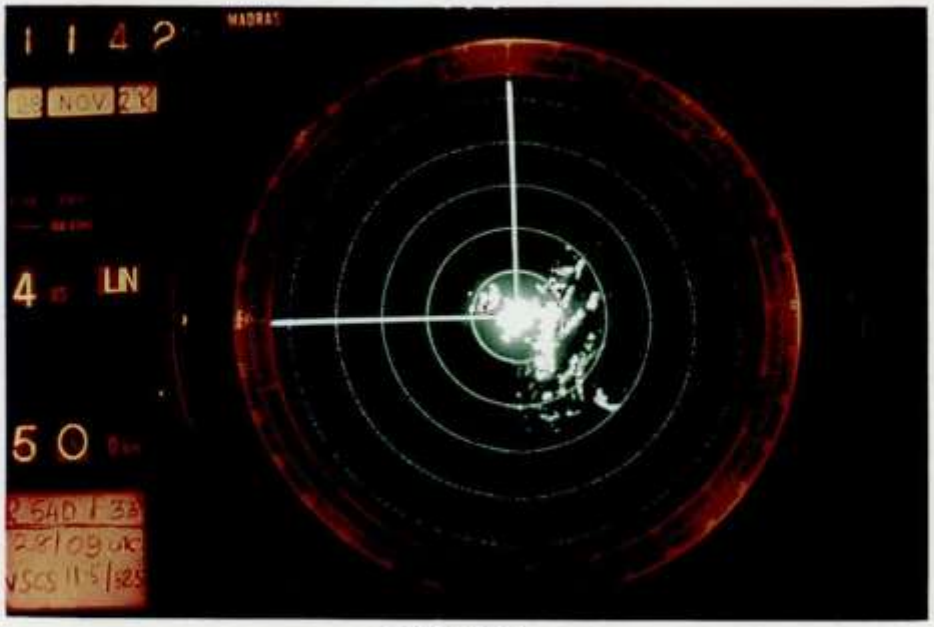
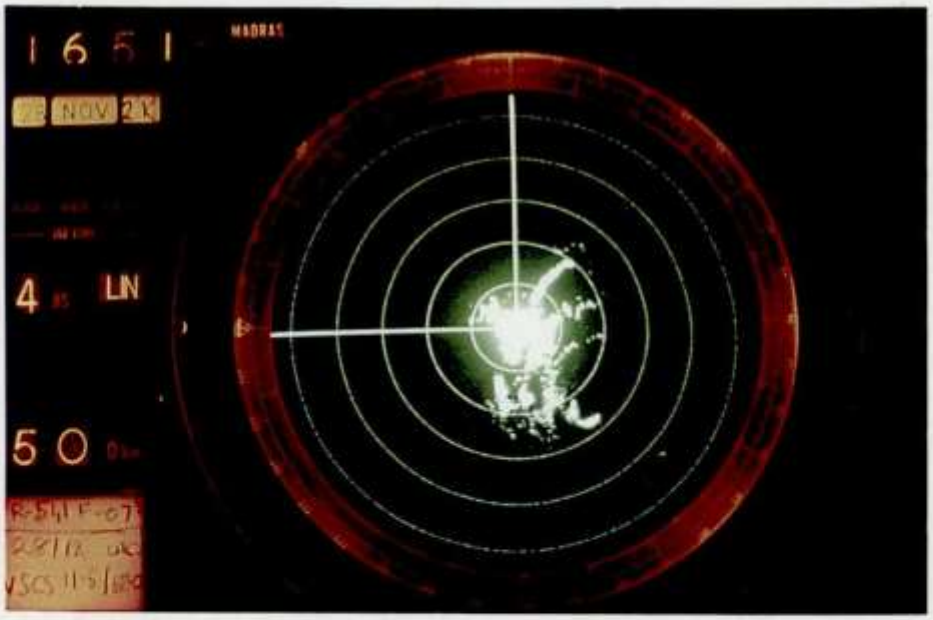


Fig 2.5.4(Contd.)

Chennai 28.11.2000

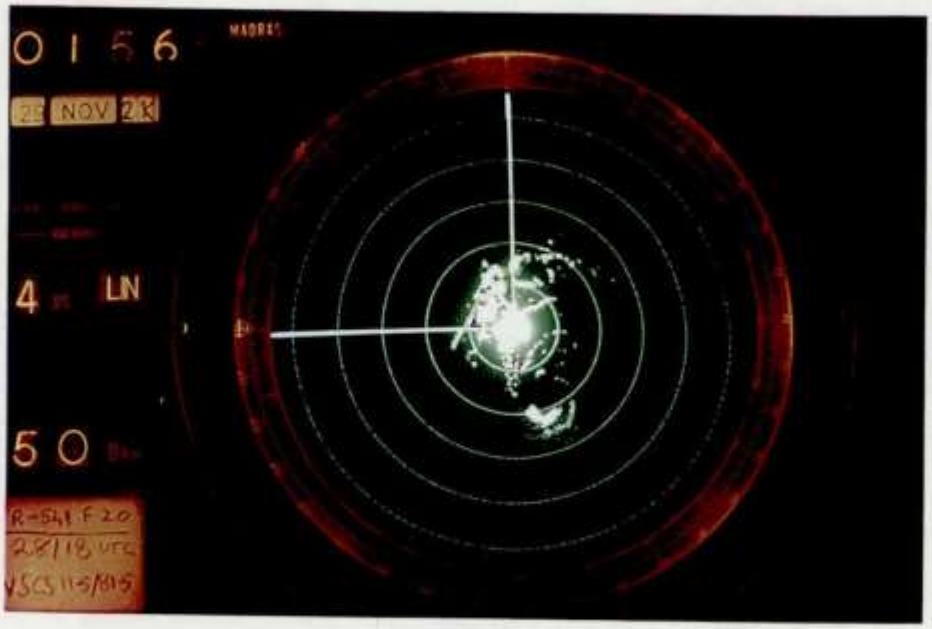


0900 UTC



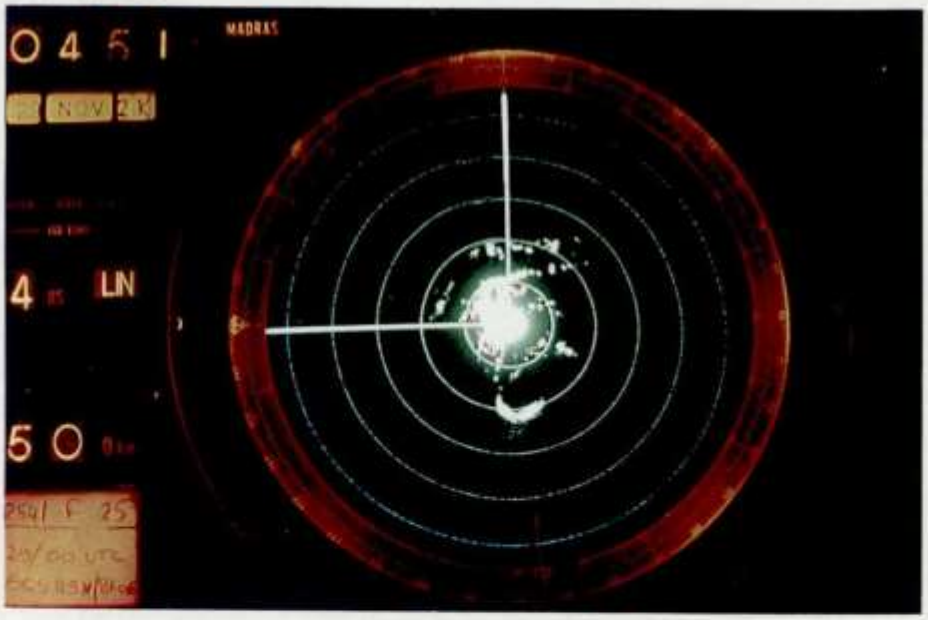
1200 UTC

Fig 2.5.5



1800 UTC

29.11.2000



0000 UTC

Fig 2.5.5 (Contd.)

2 .6 Very Severe Cyclonic Storm over the Bay of Bengal (23-28 Decembe,2000) (BOB 00 05 12 23 28)

Sri Lanka experienced the landfall of a very severe cyclonic storm 9 years after the strike of earlier cyclone of November 1992. But unlike the previous cyclone, it did not strengthen after emerging in the Gulf of Mannar. It was still able to deliver most needed rains in the southern state of Tamil Nadu .

A well marked low pressure area formed over south-west Bay of Bengal within the pre-existing active Northern Hemispherical Equatorial Trough on 22 December. A belt of strong easterly winds was seen extending westwards over the Bay of Bengal. A cloud vortex seen in the satellite imagery at 230300 UTC indicated formation of depression near lat. 8.0^0 N / long. 86.0^0 E about 500 km east-south-east of Trincomalee (43418) on the east coast of Sri Lanka.

The system moved very slowly westwards and intensified into a deep depression at 240000 near lat. 8.0^0 N / long. 84.0^0 E about 300 km east of Trincomalee. Moving almost in a north-westerly direction, the deep depression further intensified into a cyclonic storm at 250300 UTC near lat. 8.5^0 N / long 83.0^0 E when a central dense overcast pattern (CDO) started developing around the low level circulation centre. As the massive convective burst developed further in the CDO the system intensified into a severe cyclonic storm at 251800 UTC near lat. 8.5^0 N / long. 83.0^0 E. It moved westwards under the influence of upper tropospheric easterly flow south of the ridge at 200 hPa level which lay at about 15^0 N latitude over India and neighbourhood.

A broad banding 'eye' appeared at 260300 UTC when the system acquired the intensity of very severe cyclonic storm. The system came under the range of CDR Karaikal at 260600 UTC when it reported spiral band with partial eyewall. At 261000 UTC it reported open eye about 180^0, circular in shape. The system acquired the maximum intensity at 261200 UTC corresponding to T-5.0 with maximum sustained wind speed of 90 kts when it was centred near lat. 8.5^0 N / long. 81.0^0 E. The 'eye' was just on the east coast of Sri Lanka near Trincomalee. The system started interacting with land and the convective pattern weakened leading to weakening of the cyclone. It emerged in the Gulf of Mannar and unlike the November 1992 cyclone, it did not show any intensification as the fetch available was relatively small. A buoy at lat. 8.2^0 N / long. 78.6^0 E reported pressure of 1000.4 hPa at 2712000 UTC.

Continuing its westward course, it weakend further and made second landfall near Tuticorin (43379) between 272100 and 272200 UTC as a cyclonic storm. It further weakend into a depression at 281200 UTC near Alapuzha (43352). Moving westward it emerged in the Arabian Sea on 29 December. The system weakend into a low pressure area over east central Arabian Sea. It subsequently got linked up with the trough in mid tropospheric westerlies on 28 December. This synoptic situation gave rise to extensive light showers in parts of western and central India.

This system produced an excellent rainfall distribution in the drought hit State of Tamil Nadu on 3 days and improved the performance of the north-east monsoon further in the south peninsula.

The track of the system is given in Fig 2.6.1. The best track positions and other parameters have been included in Table 2.6.1.

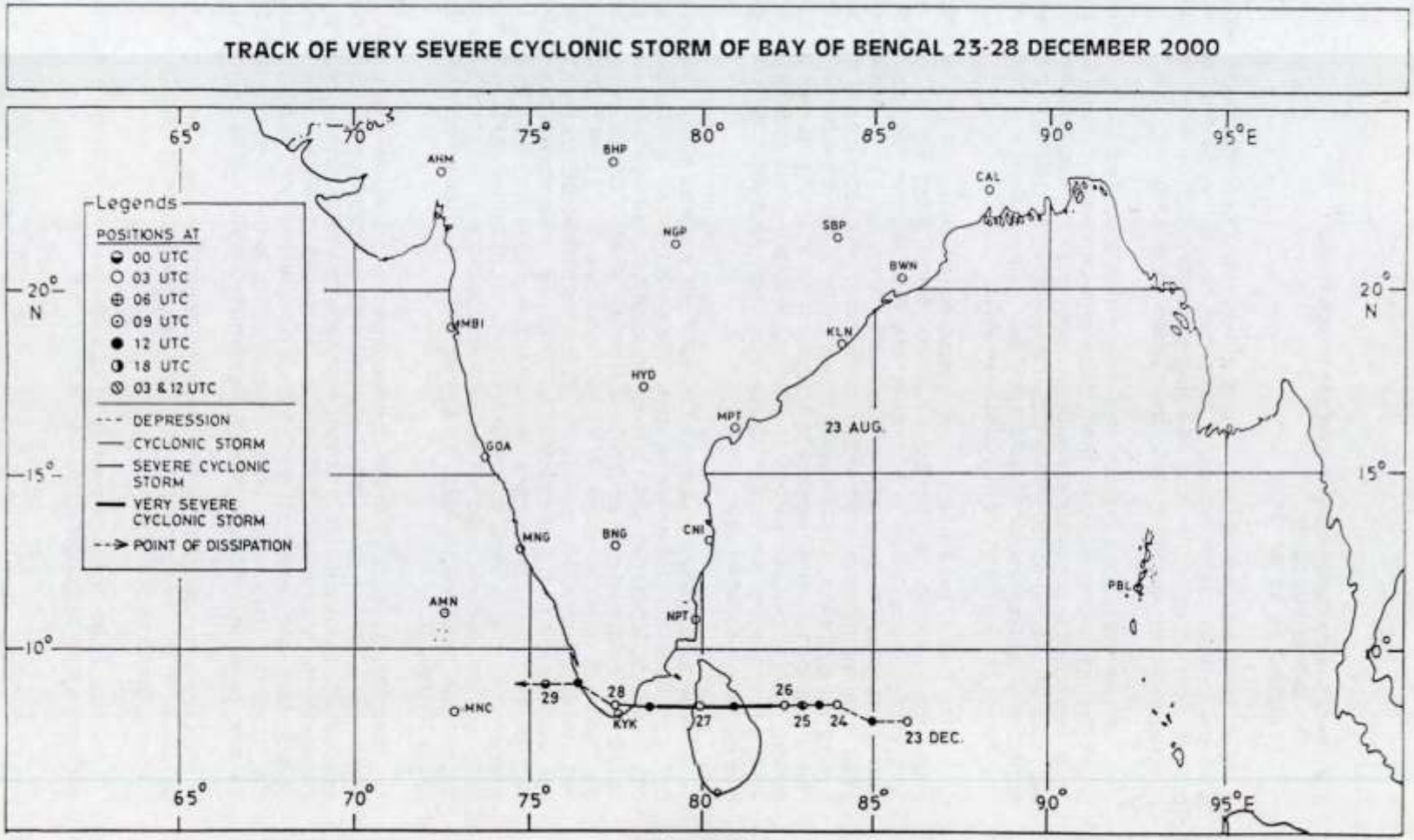

TRACK OF VERY SEVERE CYCLONIC STORM OF BAY OF BENGAL 23-28 DECEMBER 2000
Legends
POSITIONS AT
00 UTC
03 UTC
06 UTC
09 UTC
12 UTC
18 UTC
03 & 12 UTC
DEPRESSION
CYCLONIC STORM
SEVERE CYCLONIC STORM
VERY SEVERE CYCLONIC STORM
POINT OF DISSIPATION
65°
70°
75°
80°
85°
90°
95°E
20° N
15°
10°
AHM
BHP
CAL
NGP
SBP
BWN
MBI
KLN
HYD
MPT
23 AUG.
GOA
MNG
BNG
CNI
PBL
AMN
NPT
MNC
KYK
29
28
27
26
25
24
23 DEC.

Fig 2.6.1

Table 2.6.1

Best track and other parameters for the Bay of Bengal Very Severe Cyclonic Storm (23-28 December, 2000)

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 (hPa)	Grade
23.12.200	03	8.0/86.0	1.5	1006	25	4	D
	06	8.0/86.0	1.5	1006	25	4	D
	12	8.0/85.0	1.5	1006	25	4	D
	18	8.0/84.5	1.5	1006	25	4	D
24.12.200	00	8.0/84.0	2.0	1004	30	6	DD
	03	8.5/84.0	2.0	1004	30	6	DD
	06	8.5/84.0	2.0	1004	30	6	DD
	12	8.5/83.5	2.0	1004	30	6	DD
	18	8.5/83.5	2.0	1004	30	6	DD
2512.200	00	8.5/83.0	2.5	1004	30	6	DD
	03	8.5/83.0	2.5	1004	35	6	CS
	06	8.5/83.0	3.0	1000	45	10	CS
	12	8.5/83.0	3.5	994	55	16	CS
	18	8.5/83.0	4.0	990	65	20	SCS
26.12.2000	00	8.5/82.5	4.0	990	65	20	SCS
	03	8.5/82.5	4.0	990	65	20	VSCS
	06	8.5/82.0	4.5	982	77	30	VSCS
	09	8.5/81.5	4.5	982	77	28	VSCS
	12	8.5/81.0	5.0	970	90	40	VSCS
	First landfall near Trincomalee (43418) around 261200 UTC						
	15	8.5/81.0	5.0	970	90	40	VSCS
	18	8.5/81.0	4.5	982	77	30	VSCS

Table 2.6.1(Continued)
Best track and other parameters for the Bay of Bengal Very Severe Cyclonic storm (23-28 December, 2000)

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 (hPa)	Grade
26.12.2000	21	8.5/81.0	4.5	982	77	28	VSCS
27.12.2000	00	8.5/81.0	4.5	984	77	28	Vscs
	03	8.5/80.0	4.0	986	77	24	VSCS
	06	8.5/79.5	4.0	986	77	24	VSCS
	09	8.5/79.0	4.0	988	77	22	VSCS
	12	8.5/78.5	3.5	990	65	20	SCS
	15	8.5/78.5	3.5	996	55	16	SCS
	18	8.5/78.5	3.5	998	55	14	SCS
	21	8.5/78.0	3.0	1002	55	10	CS
	2nd landfall south of Tuticorin (43379) on early morning hours of 28 December						
28.12.2000	00	8.5/77.5	2.5	1004	35	8	CS
	03	8.5/77.5	2.5	1004	35	8	CS
	06	8.5/77.0	2.0	1004	30	6	DD
	12	9.0/76.5	1.5	1006	25	4	D
29.12.2000	00	9.0/75.5	1.0	1002	---	---	L

Tracks predicted for various initial positions are included in Fig. 2.6.2. Mean sea level pressure and wind analysis at 850 hPa at 270000 UTC, 24-hr and 36-hr forecast position of the storm and wind field as obtained from the Quasi–Lagrangian Model (QLM) is shown in Fig. 2.6.3. A few INSAT cloud pictures have been included in Fig. 2.6.4.

Weather

In association with the system widespread rainfall occurred in South Tamil Nadu, Rayalaseema, Pondicherry and Kerala. In association with this system the 24 hour rainfall was of the order of 10 cm and above, the highest being 18 cm at Nagapattinam and 13 cm at Ramanathapuram and Thanjavur each, 12 cm at Tiruvaarur.

Damage

[source : Govt. of Tamil Nadu]

Three districts of Tamil Nadu state were affected by the storm. In the Ramanathpuram district , 350 houses were reported damaged . The reported damages from the remaining two districts are as below:

Thirunelveli : Cattle head lost - 2, houses damaged - 162 (fully-16, partially 146)

Tuticorin : Cattle heads lost -3, houses damaged - 318 (fully 65, partially253), fishing boats lost-95, Loss to crops: Paddy crops-281hectares, betal -80 hectares and plantain- 650 hectares.

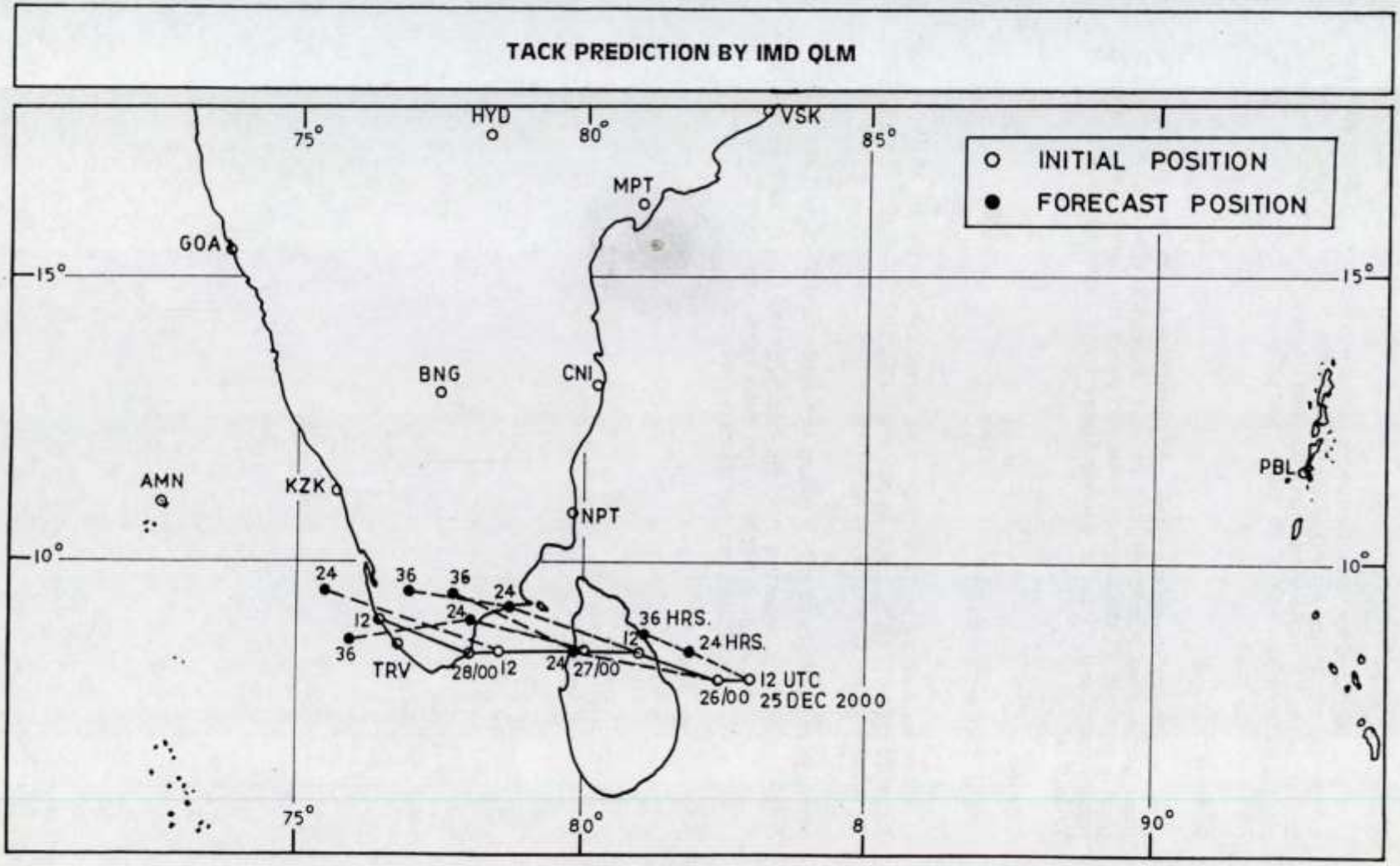
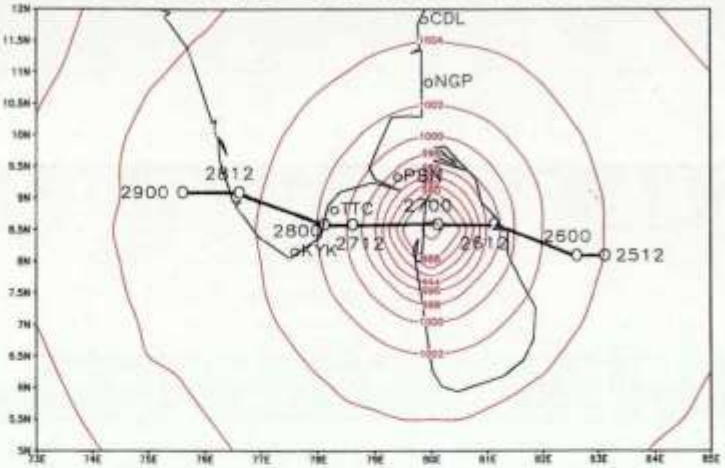
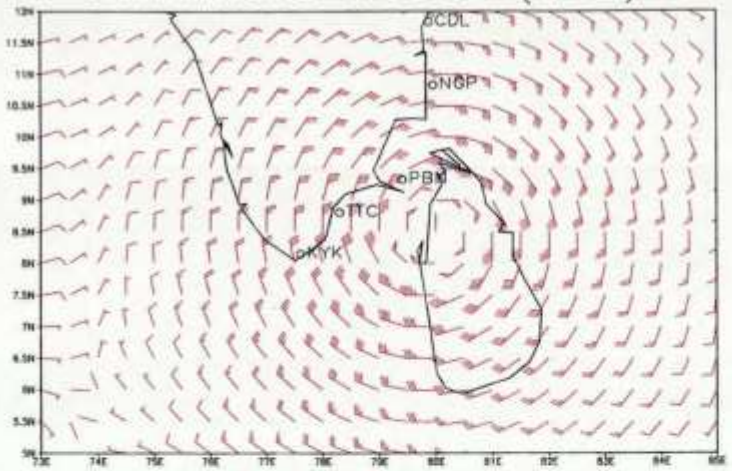

TACK PREDICTION BY IMD QLM
INITIAL POSITION
FORECAST POSITION
HYD
VSK
MPT
GOA
BNG
CNI
AMN
KZK
NPT
PBL
TRV
75°
80°
85°
90°
15°
10°
24
36
36
24
24
12
36
36 HRS.
24 HRS.
12
28/00
12
24
27/00
26/00
12 UTC
25 DEC 2000

Fig 2.6.2

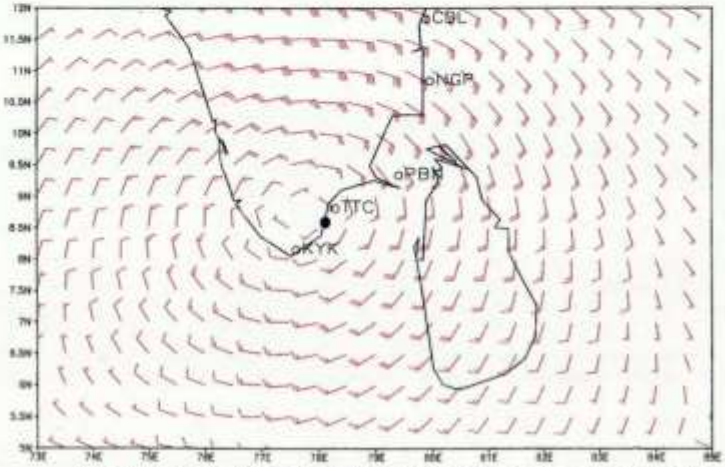
CYCLONE TRACK PREDICTION BY DYNAMICAL MODEL (QLM)



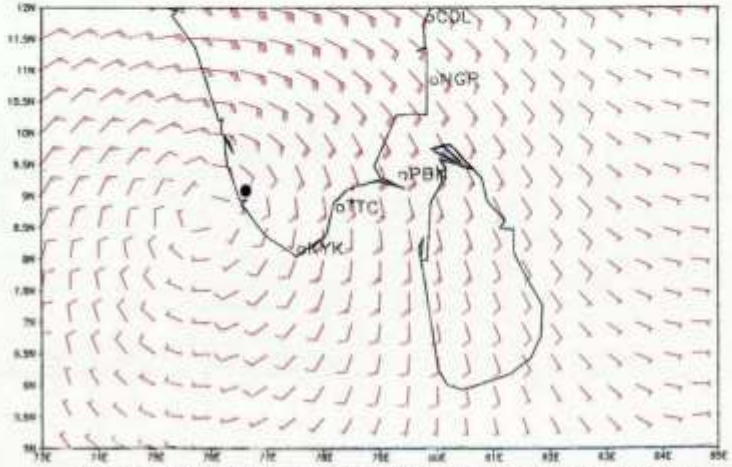
(a) MSLP ANAL 00 UTC OF 27-12-2000
(O—O: Observed track)



(b) WIND ANAL 850 hPa 00 UTC OF 27-12-2000

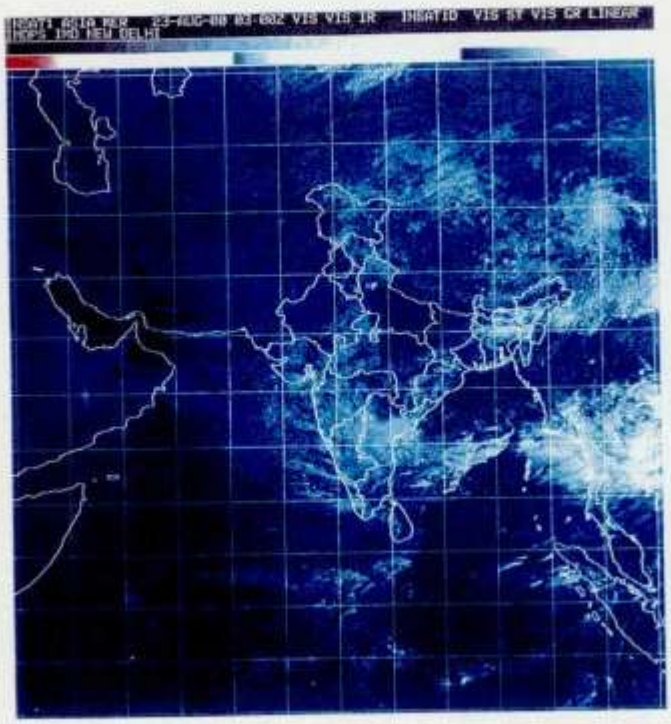


(c) 24H FCST WINDS 850 hPa VALID 00 UTC OF 28-12-2000
(Heavy dot shows verifying position)



(d) 36H FCST WINDS 850 hPa VALID 12 UTC OF 28-12-2000
(Heavy dot shows verifying position)

Fig 2.6.3



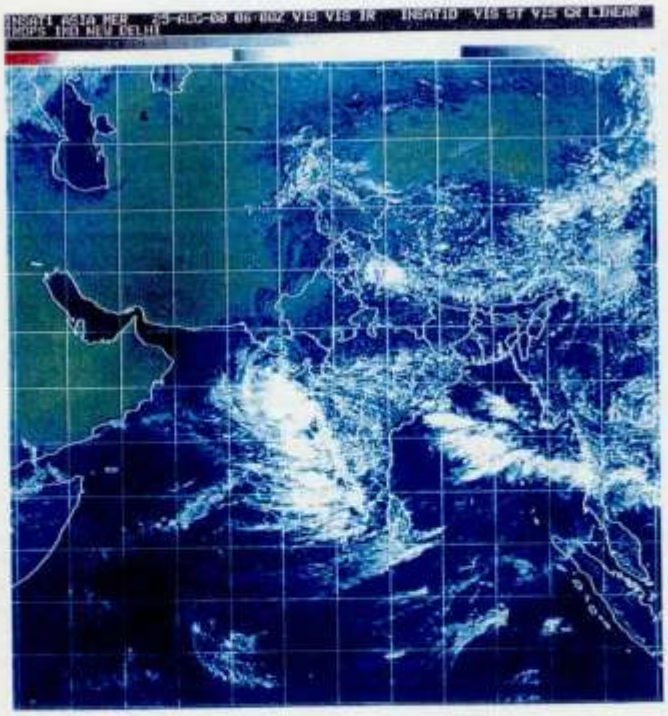
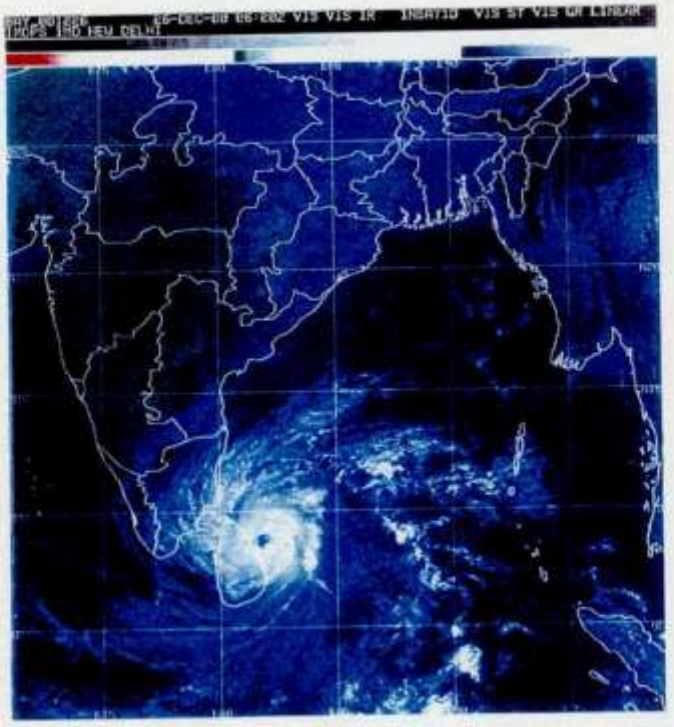


Fig 2.6.4



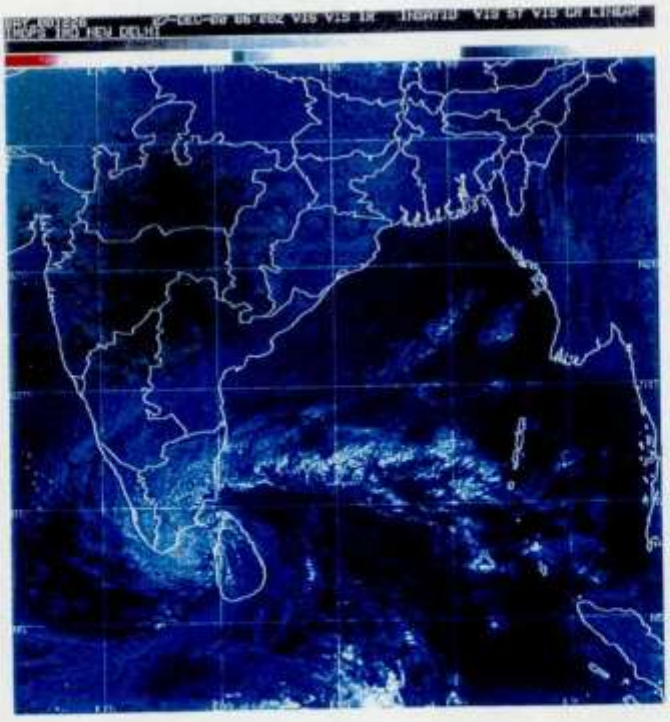


Fig 2.6.4(Contd.)

Chapter 3

Track Prediction

3.1 Track Prediction Models

3.1.1 The quasi-Lagrangian Model for cyclone track prediction

A quasi-Lagrangian model (QLM) for cyclone track prediction (originally developed by Dr. Mukut Mathur of NCEP Washington) has been implemented in RSMC New Delhi. The QLM is a multilevel primitive equation fine-mesh model cast in the sigma coordinate system ($\sigma = p/p_s$; pressure divided by surface pressure). The model has a limited area domain using a Cartesian grid. The horizontal grid spacing is 40 km and the integration domain consists of 111x111 grid points in a 4400x4400 km^2 domain that is centreed on the initial position of the cyclone. The QLM uses 16 layers in the vertical. The model incorporates physical processes which include surface frictional effects, sea-air exchange of sensible and latent heat, convective release of latent heat, divergence damping, horizontal diffusion, and isobaric condensation of water vapour. Radiation and turbulent processes, which have only marginal impact in the development, are currently excluded to minimize computational time. The numerical integration of the model is carried out by using the so called quasi-Lagrangian method.

The model provides track forecasts out to 36 hours at present. The initial analysis and latent boundary conditions are generated from operational analysis and forecasts produced by the global spectral model of NCMRWF, New Delhi.

The model makes use of an idealised vortex which is generated in the following manner.

3.1.1.1 The initial vortex

The prescription of idealised vortex is based on the storm's central pressure p_c, the pressure of the outer most closed isobar p_b and its distance R (size) from the centre. These parameters (p_c, p_b and R) together with the location of the storm centre are derived from synoptic analysis and satellite imagery information like T Number estimate.

The surface pressure $p_{sfc}(r)$ at a radius r in the idealised symmetric vortex is obtained from:

$$p_{sfc}(r) = p_{max} - [\Delta p \exp(-x^2)] / (1 + ax^2)^{1/2} \quad r < R \qquad (1)$$

$$p_{sfc}(r) = p_b \quad r \geq R$$

here $x = r/R$, a is a specified constant and the other two constants, p_{max} and Δp are evaluated from the conditions $p_{sfc}(0) = p_c$ and $p_{sfc}(R) = p_b$.

The large pressure gradients observed in intense cyclones cannot be prescribed well with the use of a coarse grid (40 km in the QLM). Therefore a lower limit has to be set to the central pressure, which is 970 hPa whenever a lower value occurs.

This has been arrived at based on past cases of model runs. In the rare cases when the reported storm size R is less than 170 km, R is reset to 170 km, because at least four grid points in the radial direction are required to capture a storm's basic structure.

The winds at pressure levels are specified as follows:

First, the wind $v_\theta(r)$ at 1000 hPa is obtained from the quadrant wind flow:

$$v_\theta^2/r + f_c v_\theta - \partial\phi/\partial r = 0 \quad (2)$$

Where f_c is the Coriolis parameter at the latitude of the storm centre, g is the acceleration due to gravity and geopotential ϕ at 1000 hPa is obtained from the approximate relation $\phi = 8[p_{sfc}(r) - 1000]$ (with p_{sfc} in hPa).

A set of horizontal and vertical functions is used to derive the winds at higher levels. The functions are chosen so that the wind structure resembles that typically observed in cyclonic storms. The horizontal grid spacing of the model (40 Km) is used in the radial direction. The wind v (r,p) at any radial distance r and at any standard pressure level p is obtained from:

$$v(r,p) = [F(p) - G(p)H(r)]\, v_\theta(r) \quad (3)$$

Where $F(p) = 0.5[1 + \tanh(\pi (p-Pa)/\Delta P_a)]$

$$G(p) = \mathrm{sech}[(p - P_a)/\Delta P_a]$$

$$H(R) = \mathrm{sech}[(r - R_a)/\Delta R_a]$$

The location of maximum cyclonic winds is controlled by the parameter a in Eq. (1); the rate of decrease of cyclonic winds in the vertical by Pa and ΔP_a; and the strength and location of anticyclonic winds in the higher atmosphere by R_a and ΔR_a.

Fixed values of $a = 100$, $P_a = 150$ hPa, $\Delta P_a = 200$ hPa, $R_a = 280$ km and $\Delta R_a = 200$ km are used in the QLM, although it might be more realistic to specify some of these parameters as functions of storm size and intensity. With the above specifications and the values of p_c, p_b and R corresponding to a mature cyclonic storm, the structure of the winds obtained from (3) consists of cyclonic winds everywhere in the lower levels with the maximum winds located at 2 to 3 grid intervals from the centre, cyclonic winds extending into the middle troposphere with a slight decrease in their strength, the cyclonic winds decreasing rapidly above the middle troposphere, and anticyclonic winds appearing in the upper troposphere.

The geo-potentials at interior grid points are obtained from the wind field with the use of gradient wind relation using the geo-potential at radius R as the boundary value, which in turn is evaluated as the mean geo-potential value at R from the initial analysis. Temperatures are derived hydro-statically from the geo-potential.

The vertical column at the vortex centre is specified to be nearly saturated. Somewhat lower values of RH are specified at R. The RH at intermediate grid points is interpolated linearly from the values at the centre and R. The rate of convective precipitation depends on RH distribution.

Since this rate is expected to be smaller in weaker storms, the RH values are reduced by a factor $B = 0.85 + 0.015(p_b - p_c)$ for an initial disturbance with $p_b - p_c < 10$ hPa. Prescription of near saturation values of RH is necessary to induce proper convection in the storm field, which has a significant contribution in its development and movement process.

The initial fields for QLM are obtained as follows. First, the analysis valid at the map time is carried out by updating the NCMRWF GCM forecast, 12H (for 12 UTC run) or 24H (for 00 UTC run) with current observations by optimum interpolation (OI) scheme.

The NCMRWF forecast fields are a set of spectral coefficients being the outputs of a T80 GCM on 18 sigma levels. The spectral coefficients are transformed to QLM grid and vertical interpolation carried out to get QLM sigma fields from GCM sigma levels. OI analysis is carried out directly on the QLM sigma levels.

A new version of the IMD's operational optimum interpolation scheme for objective analysis (used for generating initial fields for IMD LAM) has been developed to suit the QLM grid structure, which is quite different from the grid structure of LAM in horizontal and vertical both. The symmetric vortex as described in the preceding subsection, and the analysis are then merged using appropriate weighting functions (see below). The symmetric vortex fields are first projected on the QLM grid and then merged with the analysed fields. The following relation is used for the merging process:

$$X = w X_v + (1-w) X_a$$

Where X is one of the variables u, v, θ, q and p_{sfc} and the subscripts v and a denote a field in the vortex and analysis respectively. The weight w is given by:

$$w = \cos(\pi/2 \cdot r/R) \quad r < R;$$

$$w = 0 \text{ otherwise.}$$

3.1.1.2 Prescription of a steering current

A steering current, which is specified based on the current storm speed and direction is superimposed on the analyzed fields. The steering current is computed by constructing a dipole circulation.

The dipole winds and geopotential height fields (incremental heights calculated from dipole winds geostrophically) are added to the vortex fields at all levels.

Thus the two special attributes of the QLM are: (i) merging of an idealized vortex into the initial analysis to represent a storm in the QLM initial state; and (ii) imposition of a steering current over the vortex area with the use of a dipole. Full details of model can be seen in Mathur (1991).

3.1.2 Track forecast of cyclones during the year 2000

Track forecasts were made in respect of cyclonic storms formed during the year 2000 in Bay of Bengal. The model was run to produce track forecasts based on the initial conditions of each day (00H and 12 H map times) when the disturbance was in cyclonic storm stage. The mean sea level pressure analysis with observed track of the cyclone, the wind analysis and forecasts for 24H and 36H are presented in Figs.2.3.3, 2.5.3 and 2.6.3 (a-d) with initial conditions lay just prior to the day of landfall. The verifying position of the storm at the corresponding hour is shown by a heavy dot in panels c and d. It will be seen that the predicted centres are reasonably close to the observed positions in each case.

3.1.2.1 Track prediction errors

A quantitative assessment of the performance of forecast model was made by computation of track prediction errors. Two types of prediction errors have been attempted. Direct position errors (DPE) have been calculated by taking the geographical distance between the predicted position in each case of forecast and the corresponding observed position. The second type of error is the angular deviation between the observed and predicted track vectors starting from a given initial position of the storm.

While the former gives a measure of the absolute error of prediction, later provides an indication of the closeness of the predicted direction of movement and the observed direction.

Table-I contains the verification statistics of the mean position errors (km) and the angular deviation of the predicted track from the observed track (degree), in respect of each of the seven cases studied. The mean position errors for 24H forecast ranges between less than 100 km and a maximum of about 115 km. The 36 H forecast have these errors varying between around 119 km to as much as 237 km.

The angular deviations vary between about 5° to 25°. The overall average position errors for all the cases taken together (shown at the bottom of the Table) workout to 100 km (24H), and 173 km (36H) and angular deviation less than 20 degrees for both hours.

TABLE I
TRACK PREDICTION ERRORS

Year	Period	24 H		36 H	
		Mean position error (km)	Angular deviation between observed and predicted track vectors@ (rmse) (deg.)	Mean position error (km)	Angular deviation between observed and predicted track vectors@ (rmse) (deg.)
2000	15-19 OCT	105.0	25.8	237.1	23.8
	26-30 NOV	114.8	05.7	161.5	15.5
	23-28 DEC	80.4	12.3	119. 3	11.0
Mean (for 3 cases)		100.1	14.6	172.6	18.8

@ Observed track vector : Initial (at T_0) to observed (at $T_0 + 24H$ or $T_0 + 36H$) positions
Predicted track vector : Initial (at T_0) to predicted (at $T_0 + 24H$ or $T_0 + 36H$) positions

3.1.2.2 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 models for the tropical cyclones in North Indian Ocean during 2000 are given in table II below. Compared among themselves, in the 12 hour forecasts persistence performed better and it was followed by CLIPER. In 24 hour forecasts CLIPER performed better and it was followed by Persistence. In the case of 36 hour forecasts once again Persistence performed better and it was followed by CLIPER. In 48 hour forecasts CLIPER performed better. The performance of CLIPER forecasts was better in the cyclones of 15-19 October and 23-28 December. The performance of Persistence forecast was better in the cyclones of 25-28 October and 26-30 November. It was also better in the 36 hour forecasts of November cyclone.

Table II

Forecast position errors for tropical cyclones in the Bay of Bengal and the Arabian Sea in 2000 based on Climatology (C), Persistence(P) and CLIPER (CLIP) Models.

Date	12 Hours			24 Hours			36 Hours			48 Hours		
	P	C	CLIP	P	C	CLIP	P	C	CLIP	P	C	CLIP
27-30 Mar,2000	272	307	285	467	561	412	819	865	730	-	-	-
15-19 Oct,2000	56	56	28	73	143	60	100	295	105	250	332	-
25-28 Oct ,2000	84	172	110	206	363	184	-	-	-	-	-	-
26-30 Nov,2000	55	86	64	104	132	95	125	171	176	282	305	257
23-28 Dec,2000	140	123	113	190	121	114	288	199	84	386	250	281