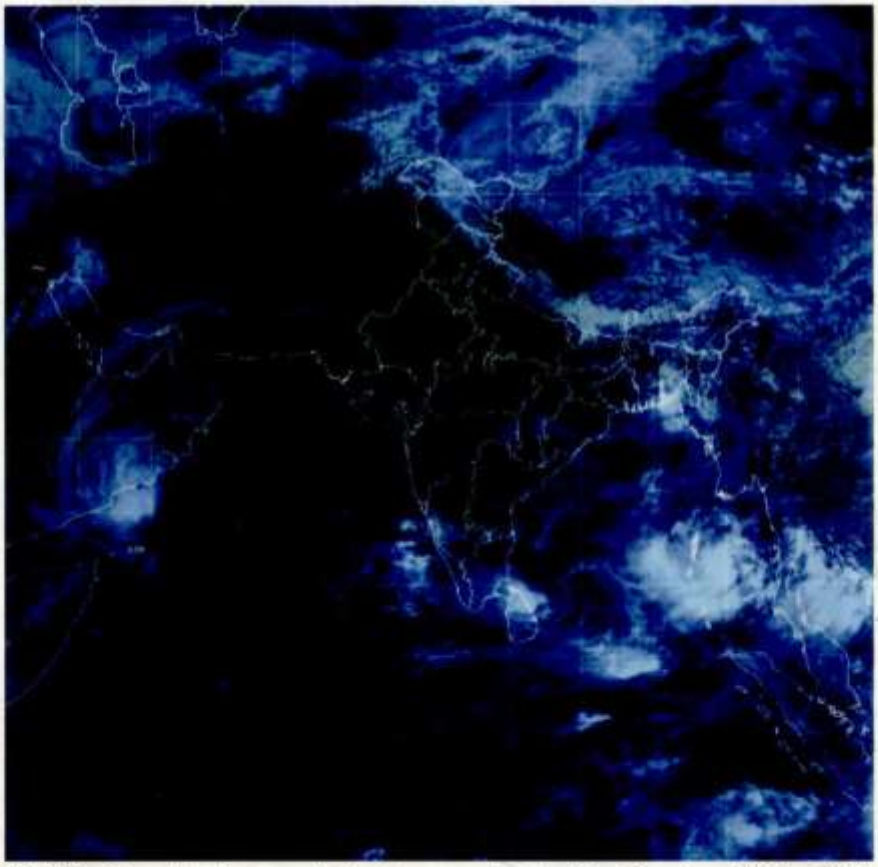
भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 2002



INSAT picture showing a cyclonic storm crossing Arabian Coast on 10 May, 2002.

RSMC-TROPICAL CYCLONES, NEW DELHI

JANUARY 2003

O/C
RSMC

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 2002

RSMC - TROPICAL CYCLONES NEW DELHI

JANUARY 2003

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 2002

CONTENTS

* * *

Activities of Regional Specialised Meteorological Centre -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 5^0 N / 10^0 N between 45^0 E to 100^0 E and includes the Member Countries of WMO/ESCAP Panel on Tropical Cyclones viz., Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand . The Centre issues Tropical Weather Outlook daily and Tropical Cyclone Advisories on tropical cyclones when they 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 (σ = p/ps; 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 covers an area of 4400x4400 km^2 which 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.

Global and Regional Spectral Model

A Global Spectral Model and a Regional Spectral Model based on the Florida State University has been installed in the computer system Origin-200. Successful test runs are conducted upto 72 hours forecast with ECMWF analysis data. Further test runs are being conducted with the analysis field of NCMRWF, New Delhi.

Storm Surge Modelling

RSMC New Delhi uses PC based storm surge model developed by IIT Delhi . The model is fully non-linear and is forced by wind stress and quadratic bottom friction following the method of numerical solution to the vertically integrated mass continuity and momentum equations. The method uses a conditionally stable semi-implicit finite difference scheme with staggered grid for numerical solution of the model equation. The bottom stress is computed from the depth-integrated current using quadratic equation. The bathymetry of the model is derived from Naval Hydrographic charts applying cubic spline technique.

Inputs to the model are pressure drop, radius of maximum winds, forecast landfall, speed and vector motion of the storm. At present six versions of the model are available for Indian coasts depending on the resolution and coastal segments. The model are Coarser Grid model for the entire east coast and west coast; Location specific refined model for Andhra coast, Orissa, West Bengal coasts, Tamil Nadu coast and Gujrat coasts. The resolution of coarser grid is 18-40 km in the east west (width 300 km) and 35.5 km in the north south direction. The refined model has the resolution of 2-15 km in the east west and 32.5 km in the north south direction. The time step of the model is 3 minutes. The coastal boundaries are taken as vertical side walls across which the normal transport vanishes. The normal current across the open sea boundaries is prescribed by a radiation type of condition. It is assumed that the motion in the sea area is generated from initial state of rest.

The model has been installed at RSMC, New Delhi. The validation exercises have shown that the performance of the model is reasonably good.

Doppler Radar

Doppler Weather Radars (DWR) have been installed and commissioned at Chennai and Kolkata. They are now operational. One DWR developed by Indian Space Research Organisation (ISRO) under IMD-ISRO collaboration has been installed at Shriharikota. This radar has also been commissioned recently and made operational.

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 17 UTC in situations where a tropical depression is expected to attain the cyclone intensity. These bulletins are 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 (N), which covers the entire North Indian Ocean. As a routine two GMDSS bulletins are broadcast at 0900 and 1800 UTC. During cyclone situation additional bulletins (up to 4) are also being issued for GMDSS broadcast depending on the requirement. In addition, coastal weather and warning bulletins are also issued to NAVTEX transmitting station located at Mumbai and Chennai.

Tropical Cyclone Advisories

Tropical cyclone advisories are issued at 3 hourly interval. These bulletins contain the current position of the cyclone, 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 54 cyclone advisories were issued.

Satellite Activities

Under Indo-US co-operative scheme a data centre has been established to facilitate the exchange of data and products. India has launched an exclusive Meteorological Geo-stationary Satellite now named KALPANA-I, in September 2002 over the Indian Ocean purely for the meteorological purposes and provides imagery in VIS, IR, and WV channels. In addition another Geo-stationary satellite under INSAT series (INSAT-3A) is to be launched shortly with the meteorological payloads identical to those of INSAT-2E.

Satellite bulletins are being produced at three hourly intervals based on the interpretation of INSAT cloud imagery. In the event of a cyclonic storm, INSAT pictures are also taken at hourly intervals. 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 Cyclone Advisories.

INTRODUCTION

The North Indian Ocean witnessed development of four cyclonic storms and two depressions in the year 2002 (Fig. 1.1) which is same as that of the last year. Out of the four cyclones, three developed in the Bay of Bengal and only one in the Arabian Sea. The cyclone of 10 May caused extensive damage in Oman and 9 People lost their lives. No damage to life and property was caused due to cyclones in other Panel member countries other than India. Even in India the damage to life and property was much less compared to some other years in the recent past. Except for the severe cyclonic Storm over Bay of Bengal in the month of November, the remaining three cyclones were marginal ones. Two cyclones that developed over the Bay of Bengal weakened over the sea itself.

Like the previous two years, convective activity was generally subdued over the Bay of Bengal during the month of October except over a part of southwest Bay of Bengal. This is evident from the mean Outgoing Long - wave Radiation (OLR) field (Fig. 1.2) . In the month of November convection maxima was located over central parts of south Bay of Bengal. During December by the time convection maxima shifted to the south of 5° N. the region of main convection had already shifted to the south of equator. For the season as a whole, the convection maxima was located over the sea area south of 5° N .

The Regional Specialised Meteorological Centre (RSMC–Tropical Cyclones New Delhi 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 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 2002 in chronological order

1.	Cyclonic Storm over the Arabian Sea (06-10 May)
2.	Deep Depression over the Bay of Bengal (11-12 May)
3.	Depression over the Bay of Bengal (22-23 October)
4.	Severe Cyclonic Storm over the Bay of Bengal (10-12 November)
5.	Cyclonic Storm over the Bay of Bengal (23-28 November)
6.	Cyclonic Storm over the Bay of Bengal (21- 25 December)

Some Characteristics of cyclonic disturbances which attained cyclonic storm or higher intensity during 2002

Cyclonic Storm	Date, Time (UTC) & lat. (N /) / long .(E) of genesis	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 Arabian sea 06-10 May	6 May at 0300 UTC near 11.0^0 /67.0^0	Crossed Arabian coast near Salalah Port (Oman) at 0900 UTC on 10 May	994 hPa at 1200 UTC on 9 May near 15.0^0 /57.0^0	35 kt on 9 May at 0600 UTC	2.5
Severe cyclonic Storm iver the Bay of Bengal 10-12, November	10 November at 0300 UTC near 12.0^0 / 82.5^0	Crossed West Bengal coast south of Kolkata near Sagar Island on 12 November at 0900 UTC	990 hPa at 0600 UTC on 12 November near 21.0^0 /87.5^0	55 kt on 12 November at 0600 UTC near 21.0^0 /87.5^0	3.5
Cyclonic Storm over the Bay of Bengal 23-28 November	23 November at 0300 UTC near 10.0^0 /87.0^0	Weakened into a well marked low pressure area over extreme eastern parts of southeast Bay of Bengal on 29 November at 0300 UTC	1000 hPa on 24.11.2002 at 0900 UTC near 14.0^0 /87.5^0	35 kt on 24.11.2002 at 0900 UTC near 14.0^0 /87.5^0	2.5
Cyclonic Storm over the Bay of Bengal 21-25 December	21December at 0300 UTC near 4.0^0 /77.0^0	The system weakened into a low pressure area over the southwest and adjoining southeast Bay of Bengal on 25 December at 1500 UTC	1000 hPa on 24.12.2002 at 1200 UTC near 6.0^0 /82.0^0	35 kt on 24.12.2002 at 0300 UTC near 5.50^0 /81.5^0	2.5

Statistical data relating to cyclonic disturbances in the North Indian Ocean during 2002

1. Synoptic class distribution of Cyclonic Disturbances (CI ≥ 1.5)

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

Average Lifetime	**3.60 (days)**

2. Frequency distribution of different intensity classes

CI No.	≥2.0	≥2.5	≥3.0	≥4.0	≥5.0	≥6.0	≥7.0
No. Of Disturbances	5	4	1	-	-	-	-
No. of days with Cyclone Intensity	10.17	5.75	0.63	-	-	-	-

3. Basin-wise distribution of disturbances

Bay of Bengal	5
Arabian Sea	1

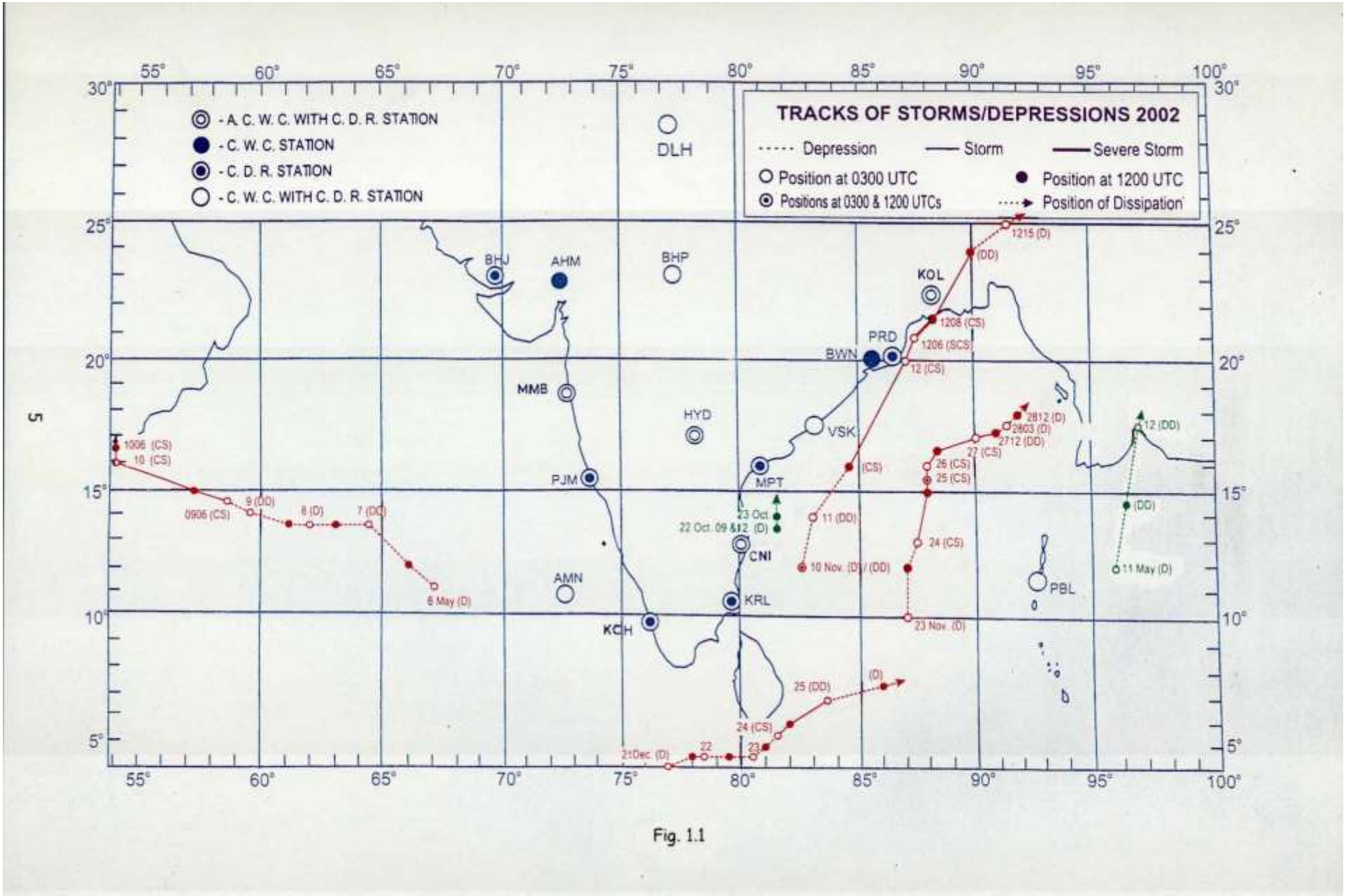

TRACKS OF STORMS/DEPRESSIONS 2002
Depression
Storm
Severe Storm
Position at 0300 UTC
Position at 1200 UTC
Positions at 0300 & 1200 UTCs
Position of Dissipation
- A. C. W. C. WITH C. D. R. STATION
- C. W. C. STATION
- C. D. R. STATION
- C. W. C. WITH C. D. R. STATION
DLH
BHJ
AHM
BHP
KOL
PRD
BWN
MMB
HYD
VSK
PJM
MPT
CNI
AMN
KRL
KCH
PBL
1215 (D)
(DD)
1208 (CS)
1206 (SCS)
12 (CS)
2812 (D)
2803 (D)
2712 (DD)
27 (CS)
26 (CS)
25 (CS)
12 (DD)
1006 (CS)
10 (CS)
0906 (CS)
9 (DD)
8 (D)
7 (DD)
6 May (D)
23 Oct
22 Oct. 09 &12 (D)
11 (DD)
10 Nov. (D) / (DD)
24 (CS)
23 Nov. (D)
11 May (D)
25 (DD)
24 (CS)
21 Dec. (D)
22
23
55°
60°
65°
70°
75°
80°
85°
90°
95°
100°
30°
25°
20°
15°
10°
5°

Fig. 1.1

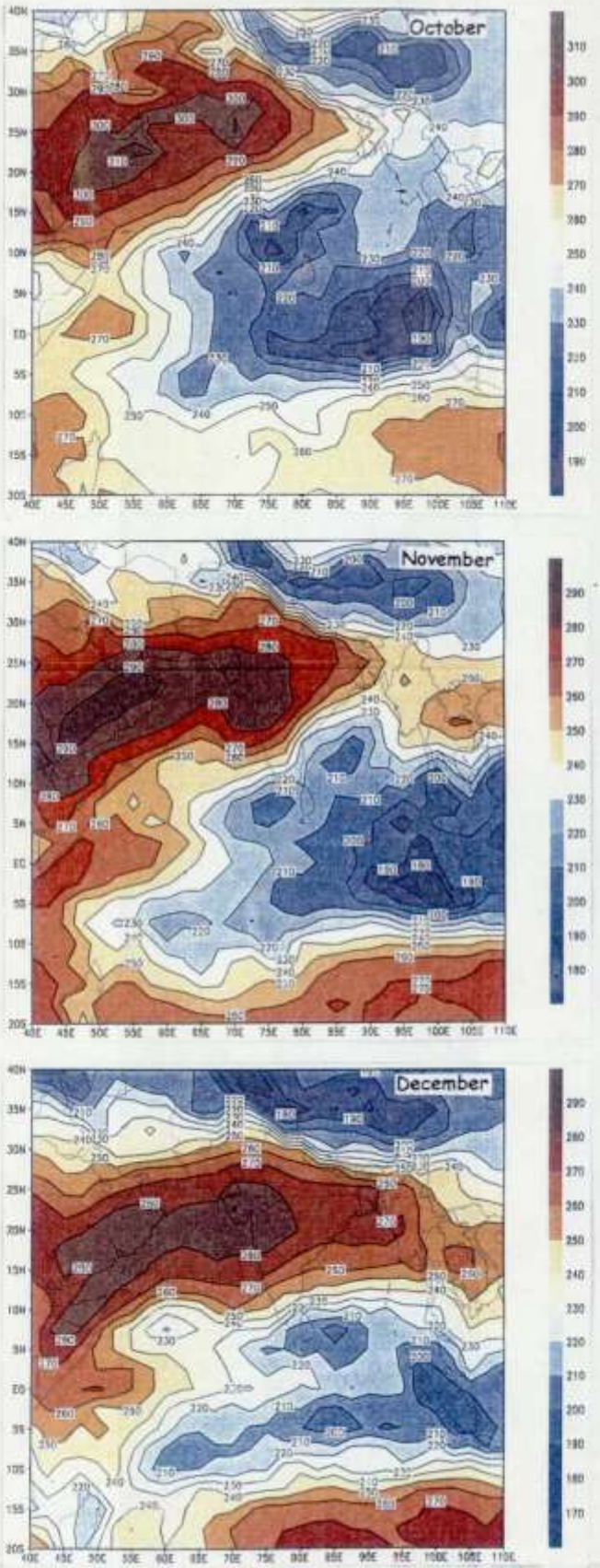


Fig. 1.2 Mean Outgoing Long Wave Radiation (OLR) in Watts/m^2 during post Monsoon Season of 2002.

CHAPTER 2

Brief Description of the Systems

2.1 Cyclonic Storm over the Arabian Sea (06-10 May 2002)

A depression developed over southeast Arabian Sea in the morning of 6 May. Moving northnorthwest it intensified into a deep depression in the morning of 7 May. Thereafter it moved in a westerly direction till the morning of 9 May. Moving in a north-westerly direction it intensified into a cyclonic storm by the noon of 9 May. Continuing to move in a west-northwesterly direction it crossed Arabian coast close to and south of Salalah Port (Sultanate of Oman) around noon of 10 May.

A low pressure area formed over southeast Arabian Sea in the vicinity of Lakshadweep islands in the evening of 4 May. Signature of vortex development was also seen in the INSAT infra-red cloud imagery of 041200 UTC in the area bounded by longitudes 65° E and 70° E and latitude 10° N in the form of the development of two small curved cloud bands hooking into each other at the leading edge of the deep layer convection spreading from Arabian Sea to the south-west Bay of Bengal. In the subsequent 3-hourly cloud pictures the convection increased around the center and decreased to its east and south indicating ongoing development of a system. At 051200 UTC ship near 10.0° N / 67.7° E reported wind ENE/25 Kt. At 060000 UTC a ship near 13.0° N / long. 68.5° E reported wind SE/25 Kt. indicating the gradual concentration of the low pressure area in to a depression which formed in the morning of 6 May and was centred at 060300 UTC near lat. 11.0° N / long. 67.0° E. In the morning of 6 May the sub-tropical ridge line at 200 hPa level was running across the Arabian Sea around 13° N latitude.

The system moved initially in a north-westerly direction and became deep depression at 070300 UTC near lat.13.5° N / long.64.5° E. Thereafter it moved in a westerly direction till the morning of 8 May. At 080300 UTC the system center was located 1.5° away from the main convective cloud mass. The system was downgraded to a depression at 080300 UTC near lat.13.5° N / long.62.0° E. The depression continued to move in a westerly direction and showed west-north-westerly movement after 081200 UTC . In the morning of 9 May the curvature of the cloud band around the system center increased showing strengthening of the system. Continuing to move in a west-north-westerly direction the system intensified into a cyclonic storm at 090600 UTC near lat. 14.5° N / Long 58.5° E. It continued its west-north-westerly movement till 100300 UTC. Coming close to the Arabian coast the system moved in a northerly direction and crossed Arabian coast close to and south of Salalah Port (Sultanate of Oman) by the noon of 10 May as a cyclonic storm.

The track of the system is given in Fig. 1.1. The best track and other parameters have been included in the Table 2.1.1. A few INSAT cloud imageries of the system are given in Fig. 2.1.2.

Historical data shows that only a few cyclones that develop in the Arabian Sea in the month of May could track westwards up to the Arabian Coast. This had happened in the years 1896, 1898,1911, 1916, 1919, 1927, 1959,1960, and 1963. The cyclonic storm of May 1959 had also crossed Arabian coast close to and south of Salalah Port.

Weather realized:

(Source: Sultanate of Oman, Ministry of Transport and Communication)

The storm was associated with severe thunderstorms rain and strong winds. Salalah was flooded by rain waters. Significant amount of rainfall (in cm) are given below:

Salalah (41316)	5 .9	Thamrait (41314)	2.4
Mina Salalah (41312)	6.7	Qairoon Hairiti (41315)	25.1

Storm Surge

The Storm surge caused rough sea conditions raising wave height up to 4 meters.

Damage

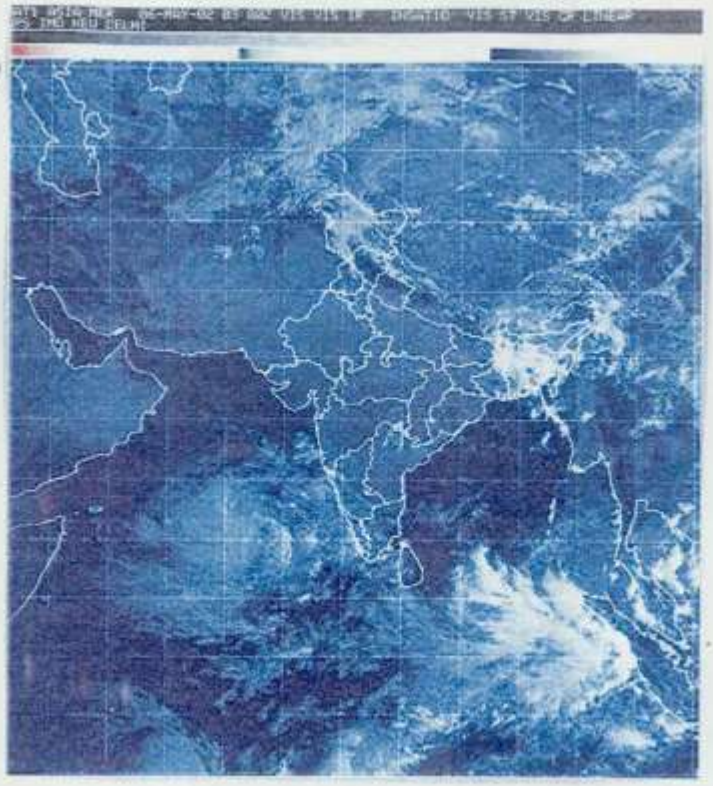
The system caused a great deal of social, economic, infrastructure and environmental damage. Nine people died and several others injured.

Table 2.1.1

Best track positions and other parameters for the Arabian Sea cyclonic Storm (06-10 May 2002)

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
6.5.2002	03	11.0 /67.0	1.5	1002	25	4	D
	06	11.5/66.5	1.5	1002	25	4	D
	12	12.0 /66.0	1.5	1000	25	4	D
	18	12.0 /65.5	1.5	1000	25	4	D
7.5.2002	00	13.0/65.0	1.5	1000	25	4	D
	03	13.5 /64.5	2.0	998	30	6	DD
	06	13.5 /64.0	2.0	998	30	6	DD
	12	13.5 /63.0	2.0	996	30	6	DD
	18	13.5 /62.5	2.0	998	30	6	DD
8.5.2002	00	13.5 /62.5	2.0	996	30	6	DD
	03	13.5 /62.0	1.5	1002	25	4	D
	06	13.5 /61.5	1.5	1002	25	4	D
	12	13.5/61.0	1.5	1000	25	4	D
	18	14.0/60.5	1.5	998	25	4	D
	21	14.0/60.0	1.5	998	25	4	D
9.5.2002	00	14.0/60.0	1.5	998	25	4	D
	03	14.0/59.5.	2.0	998	30	6	DD
	06	14.5/58.5	2.5	998	35	8	CS
	09	14.5/58.0	2.5	996	35	8	CS
	12	15.0/57.0	2.5	994	35	8	CS
	15	15.0/56.5	2.5	994	35	8	CS
	18	15.5 /56.0	2.5	996	35	8	CS
	21	15.5/55.0	2.5	998	35	8	CS
10.5/.2002	00	16.0 /54.5	2.5	998	35	8	CS
	03	16.0 /54.0	2.5	998	35	8	CS
	06	16.5 /54.0	2.5	998	35	8	CS
	09	The system crossed Arabian coast south of Salalah Port (41 316) Sultnate of Oman around 0900 UTC.					

(a)



(b)

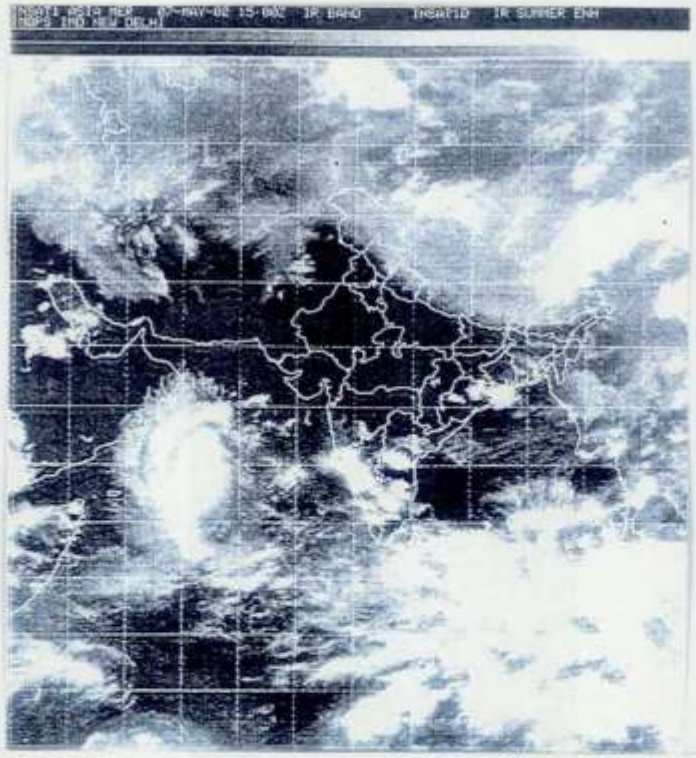
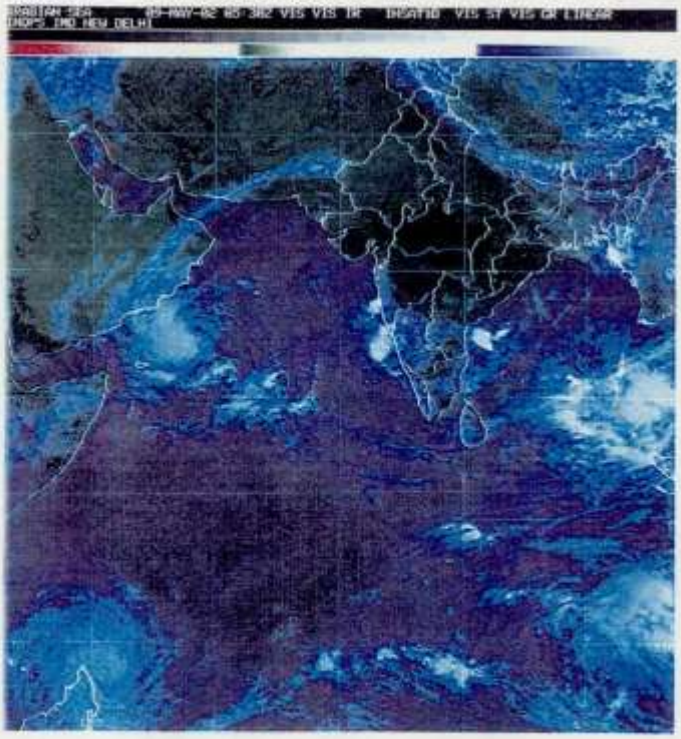


Fig. 2.1.2 Satellite pictures showing cloudiness associated with (a) a depression over Southeast Arabian Sea on 6 May and (b) a well developed comma shaped cloud when the system had deepened into a deep depression on 7 May.

(c)



(d)

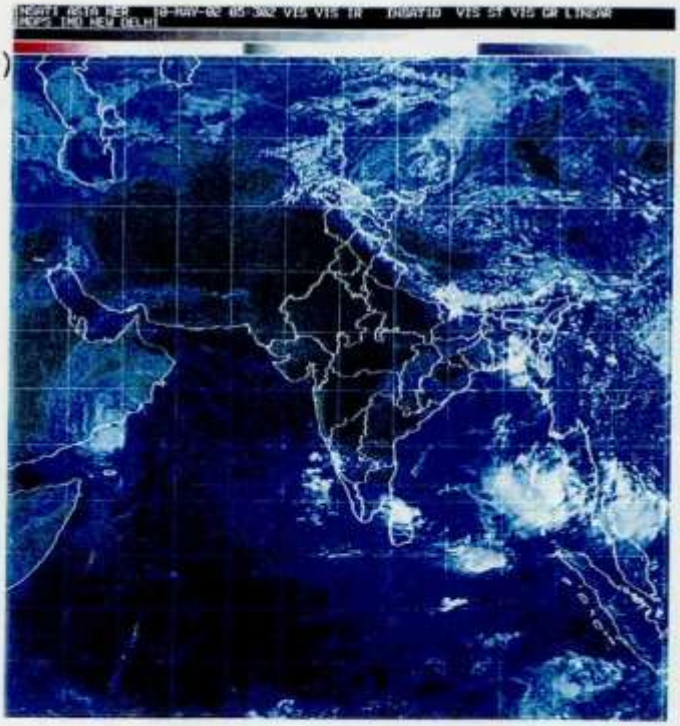


Fig. 2.1.2 (Contd) (c) Satellite picture showing the cyclonic storm over westcentral Arabian sea on 9 May and (d) when the cyclonic storm was close to Arabian coast on 10 May. Also seen in the picture is a developing system over north Andaman Sea.

2.2 Deep Depression over the Bay of Bengal (11-12 May 2002)

A depression developed over south Andaman Sea at 110300 UTC near lat. 12.0° N / long.96.0° E. It moved in a north-northeasterly direction and intensified into a deep depression by 111200 UTC and lay centred near lat. 14.5° N/long. 96.5° E. Continuing to move in a north-northeasterly direction the deep depression crossed Tenasserim coast of southern parts of Myanmar in the morning of 12 May and lay centred at 0300 UTC near lat. 17.5° N/ long.97.0° E.

The track of the system is given in Fig. 1.1. The best track and other parameters have been included in the table 2.2.1. A few INSAT cloud imageries of the system are given in Fig. 2.2.2.

Weather realised

Under the influence of this system Andaman & Nicobar Island received heavy rains. Nancowry reported 4 cm rainfall on 11 May. Mayabandar and Hut Bay reported 8 cm & 3 cm respectively on 12 May. Port Blair and Nancowry reported 3 cm each ON 13 May.

Damage

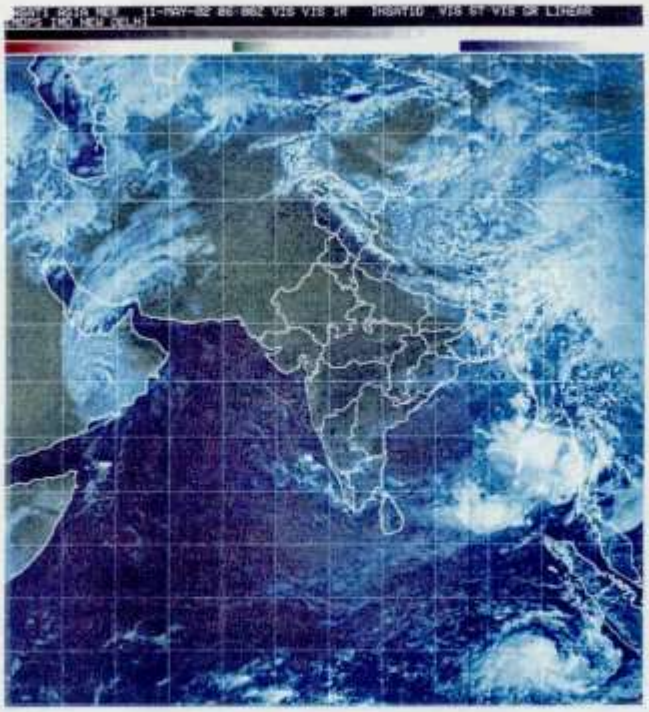
No damage to life and property was reported.

Table 2. 2. 1

Best track positions and other parameters for the Bay of Bengal Deep Depression (11-12 May 2002)

Date	Time (UTC)	Center 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
11.5.2002	03	12.0 /96.0	1.5	1006	25	4	D
	06	13.0 /96.5	1.5	1006	25	4	D
	12	14.5 / 96.5	2.0	1004	30	6	DD
	18	15.5 /96.5	2.0	1004	30	6	DD
12.05.2002	00	16.0 /96.5	2.0	1004	30	6	DD
	03	17.5 /97.0	2.0	1004	30	6	DD
		Crossed Mynamar coast as a deep depression around 0300 UTC on 12 May.					

(a)



(b)

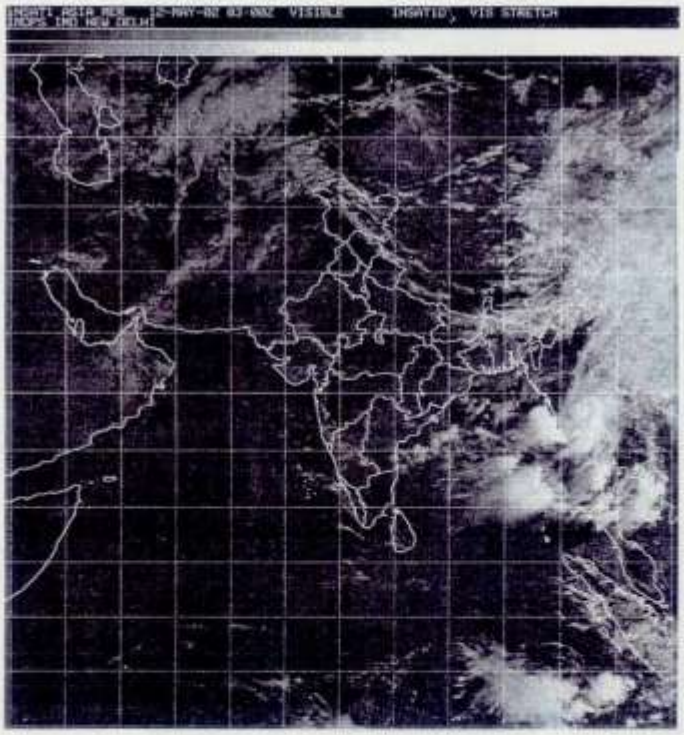


Fig. 2.2.2 Satellite pictures showing cloudiness associated with (a) a depression in north Andaman sea on 11 May. Also seen in the picture is the cloudiness associated with remnant of the cyclonic storm which crossed Arabian coast on 10 May and a developing system in southeast Indian Ocean, (b) cloudiness in association of the deep depression which crossed Mynamar coast in the morning of 12 May.

2.3 Depression over Bay of Bengal (22-23 October 2002)

A Well marked low pressure area formed over southwest & adjoining west-central Bay of Bengal concentrated into a depression at 220900 UTC near lat. 13.5° N/ Long. 81.5° E about 250 km south southeast of Ongole, Andhra Pradesh. The system moved in a northerly direction and lay centred at 221800 UTC near lat. 14.0° N / long. 81.5° E. The system remained practically stationary upto 1800 UTC on 23 October. The system started weakening and became low pressure area in the morning of 24 October over west central Bay of Bengal off Andhra Pradesh coast.

The track of the system is given in Fig. 1.1. The best track and other parameters have been included in the table 2.3.1. A few INSAT cloud imageries of the system are given in Fig. 2.3.2.

Weather realised

Under the influence of the system widespread rainfall with isolated heavy falls occurred over Andhra Pradesh coast, when system crossed north Andhra Pradesh coast as low pressure area.

Damage

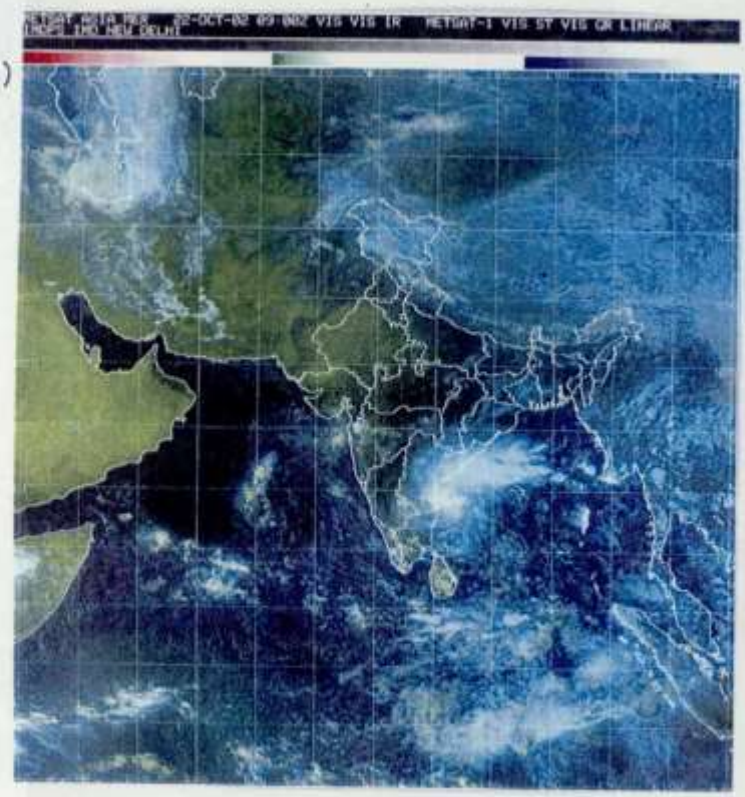
No damage to life and property were reported .

Table 2.3.1

Best track positions and other parameters for the Depression over the Bay of Bengal (22 -23 October 2002)

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
22.10.2002	0900	13.5 /81.5	1.5	1002	25	4	D
	1200	13.5 /81.5	1.5	1002	25	4	D
	1800	14.0 /81.5	1.5	1004	25	4	D
23.10.2002	0300	14.0 /81.5	1.5	1004	25	4	D
	0600	14.0 /81.5	1.5	1004	25	4	D
	1200	14.0 /81.5	1.5	1002	25	4	D
	1800	14.0 /81.5	1.5	1004	25	4	D
		Weakened into a low pressure area in the morning of 24 October over west central Bay of Bengal off Andhra Pradesh coast.					

(a)



(b)

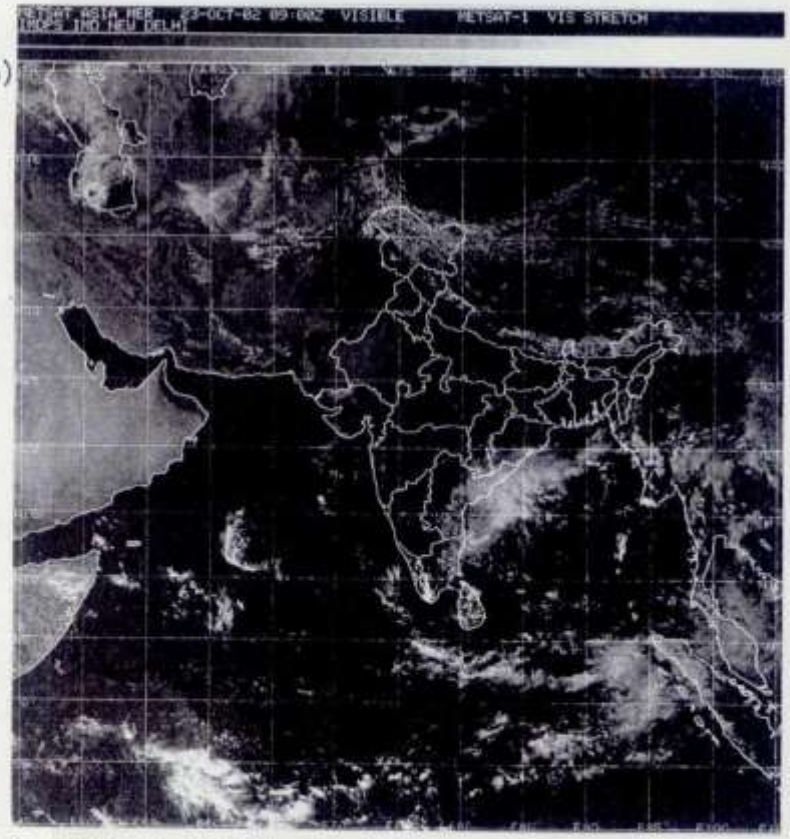


Fig. 2.3.2 (a) Satellite cloud imagery showing cloudiness in association of a depression in southwest Bay of Bengal on 22 October and (b) on 23 October when the cloud organization showed weakening of the system.

2.4 Severe Cyclonic Storm over the Bay of Bengal (10-12 November 2002)

A depression formed over southwest Bay of Bengal in the morning of 10 November and lay centred near lat. 12.0° N / long. 82.5° E at 0300 UTC. Remaining practically stationary, it intensified into a deep depression at 1200 UTC on the same day. Moving in a north-northeasterly direction it further intensified into a cyclonic storm at 1200 UTC near lat. 16.0° N / long. 84.5° E. At this time the system had come close to the 200 hPa ridge line. The system remained practically stationary during the night of 11 November. Thereafter it came under the influence of a mid-latitude westerly trough and moved rather fast and lay centred near lat. 20.0° N / long.87.0° E at 0300 UTC of 12 November. Continuing to move in a north-north-easterly direction the system further intensified into a severe cyclonic storm at 120600 UTC and lay centred near lat. 21.0° N /long. 87.5° E. At this stage a banding type eye was seen by the Doppler Weather Radar (DWR) at Kolkata . At the next synoptic hour i.e. at 0900 UTC it again weakened into a cyclonic storm and crossed West Bengal coast south of Kolkata around that time. Moving in a north-easterly direction the system further weakened into a depression over Bangladesh in late night of 12 November.

The track of the system is given in Fig.1.1. The best track and other parameters have been included in the table 2.4.1. A few INSAT cloud imageries of the system are given in Fig. 2.4.2. Cloud picture of the cyclone, taken by Doppler Weather Radar, Kolkata is given in Fig. 2.4.3

Weather realised

Under the influence of the system widespread rainfall with scattered heavy falls occurred over Orissa coast.

Damage caused

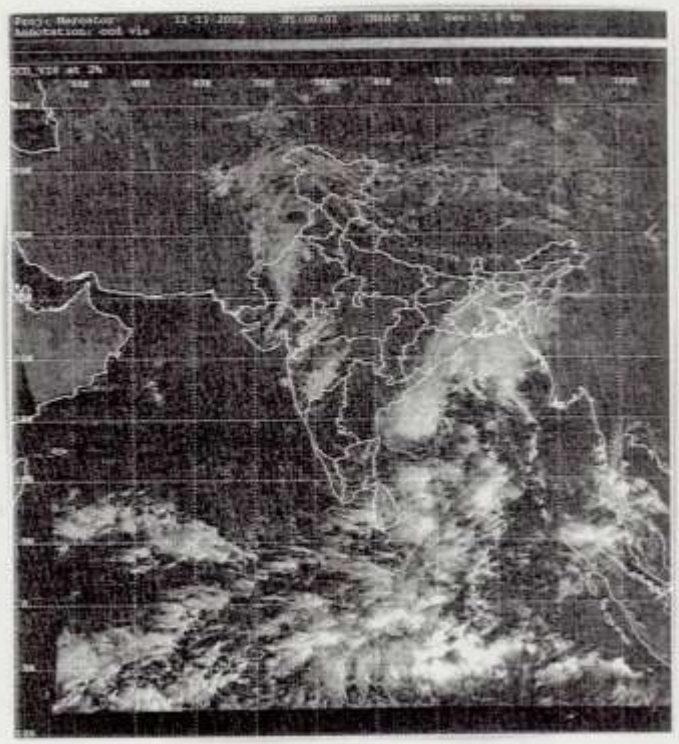
In Orissa, two trawlers collided head to head due to cyclonic storm and 18 inmates of the trawlers died and their dead bodies were seen floating near Dhamra port in Bhadrak district. Two trawlers were reported missing in Orissa . Two Persons died in West Bengal.

Table 2.4.1

Best track positions and other parameters for the Severe Cyclonic Storm over the Bay of Bengal (10-12 November 2002)

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
10.11.2002	03	12.0 / 82.5	1.5	1004	25	4	D
	06	12.0 / 82.5	1.5	1004	25	4	D
	12	12.0 / 82.5	2.0	1002	30	6	DD
	18	12.5 / 82.5	2.0	1004	30	6	DD
11.11.2002	00	13.5 / 82.5	2.0	1004	30	6	DD
	03	14.0 / 83.0	2.0	1004	30	6	DD
	06	14.5 / 83.5	2.0	1004	30	6	DD
	09	15.0 / 84.0	2.0	998	30	6	DD
	12	16.0 / 84.5	2.5	996	45	10	CS
	15	16.0 / 84.0	3.0	996	45	10	CS
	18	16.0 / 84.0	3.0	996	45	10	CS
	21	16.5 / 84.0	3.0	996	45	10	CS
12.11.2002	00	19.0/86.5	3.5	996	45	10	CS
	03	20.0 / 87.0	3.0	996	45	10	CS
	06	21.0 / 87.5	3.5	990	55	15	SCS
	Crossed West Bengal coast south of Kolkata near Sagar Island at 12090 0 UTC						
	09	22.5/88.5	---	---	---	8	CS
	12	24.0/90.0	---	---	---	6	DD
	15	25.0/91.5	---	---	---	6	D

(a)



(b)

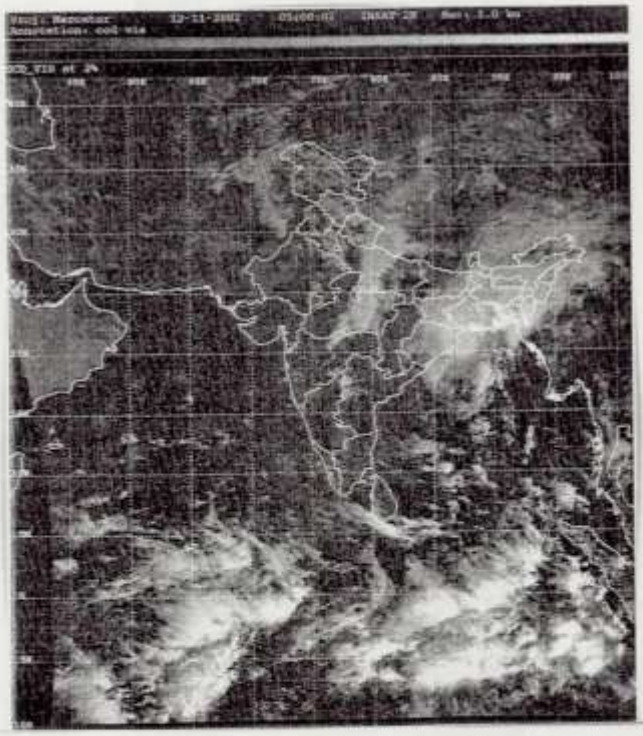


Fig. 2.4.2 Satellite cloud imagery showing cloudiness in association with (a) a deep depression over westcentral Bay of Bengal on 11 November (b) a cyclonic storm when it was close to West Bengal coast. Also seen in the picture is cloudiness over central and north India in association with a westerly trough.

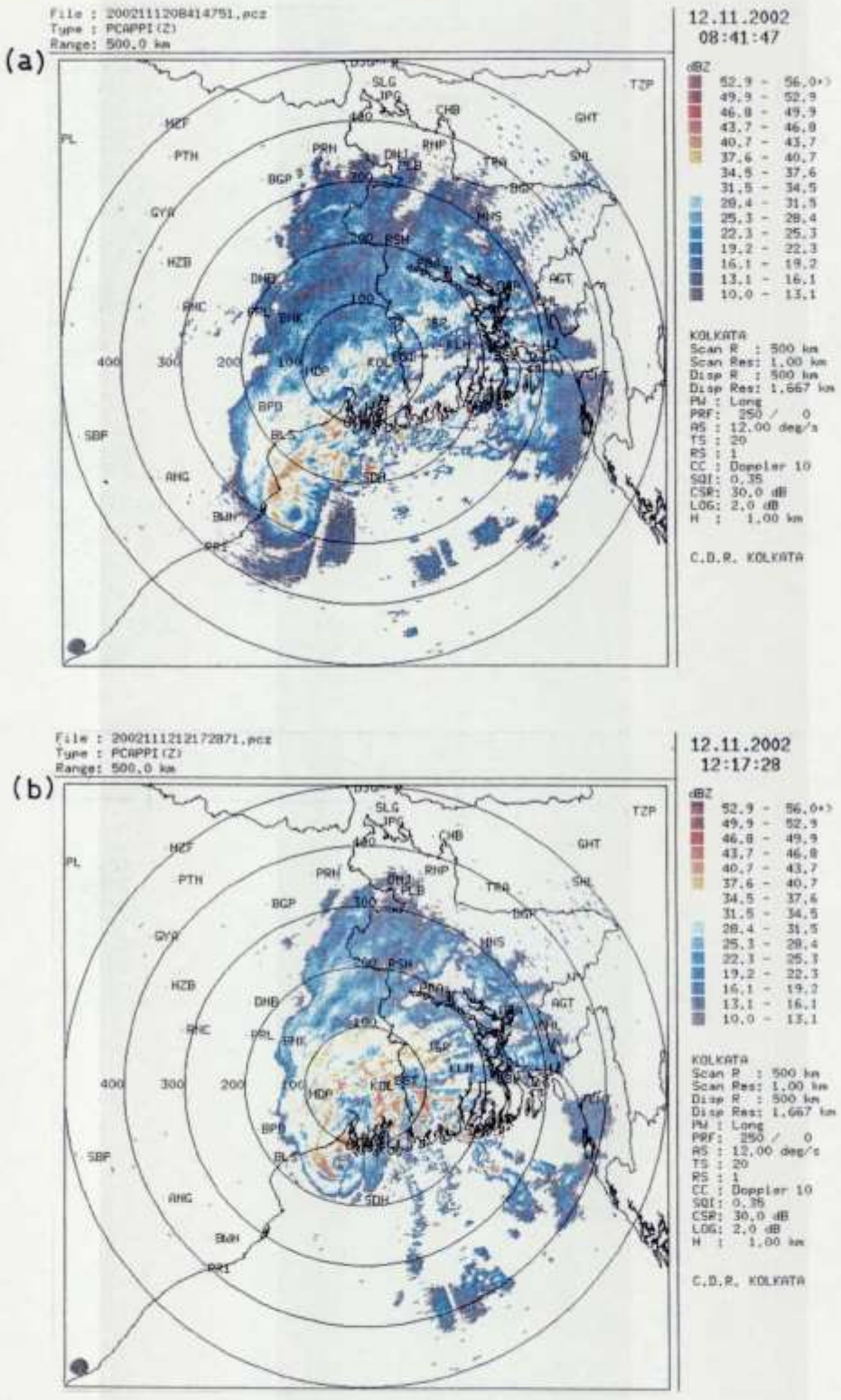


Fig. 2.4.3 Cloud Pictures of the cyclone taken by Doppler Weather Radar, Kolkata at (a) 08:41:47 and (b) 12:17:28 hours of 12 November 2002.

2.5 Cyclonic Storm over the Bay of Bengal (23 - 28 November 2002)

The equatorial trough was active in the Bay of Bengal in the week beginning from 21 November. In this active equatorial trough a low pressure area formed over south-east Bay of Bengal in the morning of 22 November at 0300 UTC. Moving in a north-westerly direction the low pressure area concentrated into a depression in the morning of 23 November and was located at 0300 UTC near lat. 10.0° N / long .87.0° E. Moving in a northerly direction it intensified into a deep depression at 1800 UTC near lat. 12.5° N / long. 87.0° E. It further intensified into a cyclonic storm on 24 November at 0300 UTC near lat.13.0° N / long. 87.5° E. The system moved slowly north-northeastwards for the next 24 hours. Once again it showed north-eastward movement between 0300 and 1200 UTC of 26 November and took east-northeasterly course thereafter. It weakened into a deep depression on 27 November at 1200 UTC near lat. 17.2° N / long. 91.0° E. Moving very slowly northeastwards it further weakened into a depression at 1800 UTC near lat. 17.5° N / long. 91.0° E. It moved in the same direction and maintained its intensity as a depression till 1200 UTC of 28 November. It further weakened into a low pressure area over sea itself.

The track of the system is given in Fig.1.1. The best track and other parameters have been included in the table 2.5.1. A few INSAT cloud imageries of the system are given in Fig. 2.5.2.

Weather realised

As the system remained far away from the coast, the east coast line of India was not affected.

Damage

No loss of life and damage to property was reported.

Table 2.5.1

Best track and other parameters for the Bay of Bengal Cyclonic Storm (23 -28 November 2002)

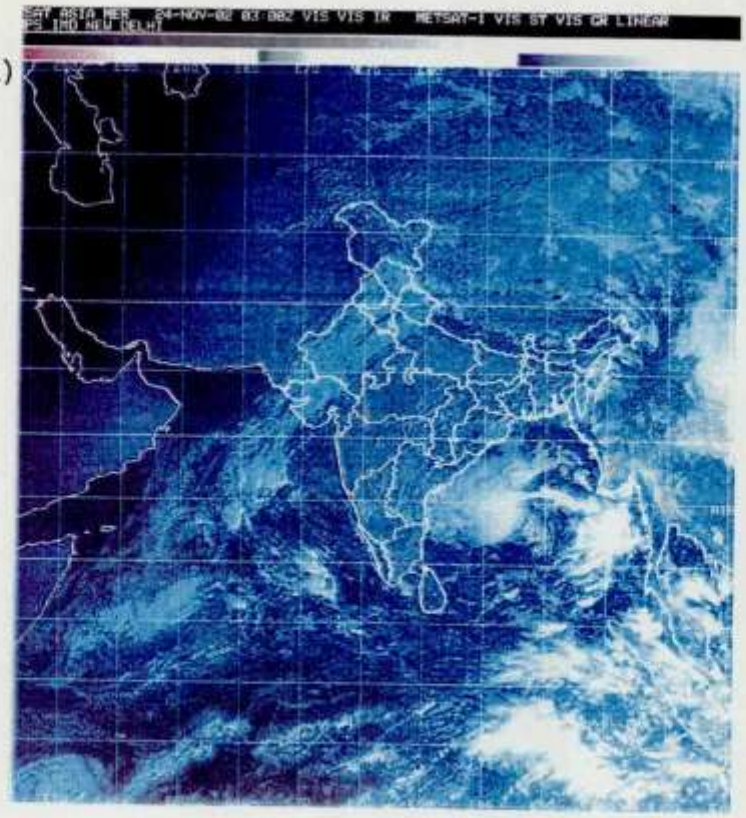
Date	Time (UTC)	Center Lat. ° N / Long. ° E	C. I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the centre (hPa)	Grade
23.11.2002	03	10.0/87.0	1.5	1004	25	4	D
	06	10.5 / 87.0	1.5	1004	25	4	D
	12	12.0 /87.0	1.5	1002	25	4	D
	18	12.5 /87.0	2.0	1002	30	6	DD
	21	12.5/87.5	2.0	1002	30	6	DD
24.11.2002	00	13.0 /87.5	2.0	1002	30	6	DD
	03	13.0 /87.5	2.5	1002	35	8	CS
	06	13.5 /87.5	2.5	1002	35	8	CS
	09	14.0 /87.5	2.5	1000	35	8	CS
	12	15.0 /88.0	2.5	1000	35	8	CS
	15	15.0 /88.0	2.5	1000	35	8	CS
	18	15.0/88.0	2.5	1000	35	8	CS
25.11.2002	00	15.5 /88.0	2.5	1002	35	8	CS
	03	15.5 /88.0	2.5	1002	35	8	CS
	06	15.5 /88.0	2.5	1002	35	8	CS
	09	15.5 /88.0	2.5	1002	35	8	CS
	12	15.5 /88.0	2.5	1000	35	8	CS
	15	15.5 /88.0	2.5	1002	35	8	CS
	18	15.5 /88.0	2.5	1002	35	6	CS
26.11.2002	00	16.0 /88.0	2.5	1002	35	8	CS
	03	16.0 /88.0	2.5	1002	35	8	CS
	06	16.0 /88.0	2.5	1002	35	8	CS
	09	16.0 /88.0	2.5	1000	35	8	CS
	12	16.5 /88.5	2.5	1000	35	8	CS
	15	16.5 /89.0	2.5	1002	35	8	CS
	18	16.5 /89.5	2.5	1002	35	8	CS
	21	16.5 /89.5	2.5	1002	35	8	CS

Table 2.5.1 (Continued)

Best track and other parameters for the Bay of Bengal
Cyclonic Storm 23-28 November 2002

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
27.11.2002	00	16.5 /90.0	2.5	1002	35	8	CS
	03	17.0 /90.0	2.5	1004	35	8	CS
	06	17.0 /90.5	2.5	1004	35	8	CS
	12	17.2 /91.0	2.0	1006	30	6	DD
	18	17.5 /91.0	1.5	1006	25	4	D
28.11.2002	00	17.5 /91.0	1.5	1008	25	4	D
	03	17.5 /91.5	1.5	1008	25	4	D
	06	17.5 /91.5	1.5	1008	25	4	D
	12	18.0 / 92.0	1.5	1008	25	4	D
	Weakened into a well marked low pressure over north-east and adjoining east-central Bay of Bengal in the night of 28 November.						

(a)



(b)

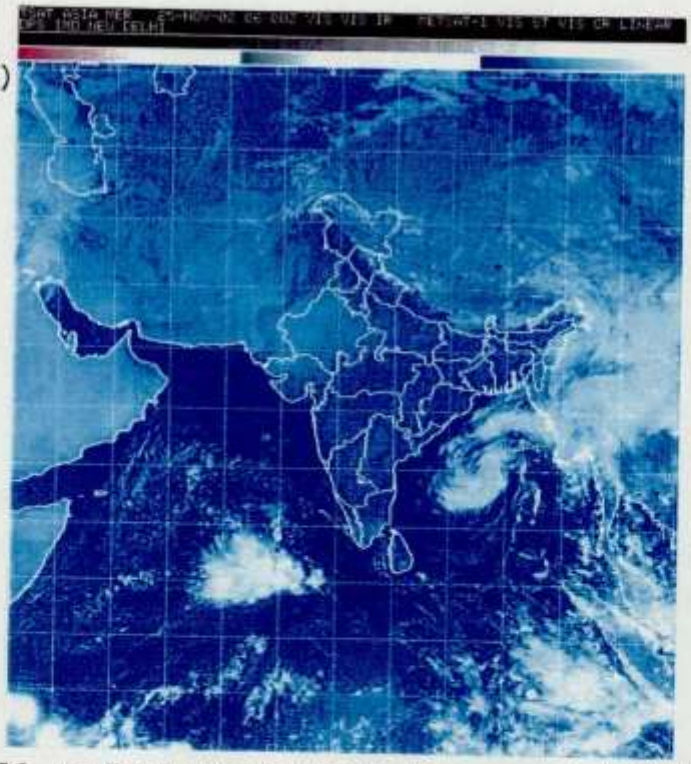


Fig. 2.5.2 Satellite pictures showing cloudiness associated with (a) Cyclonic storm on 24 November. Cumulus cloud lines clearly defining the center outside the convection over central parts of Bay of Bengal and (b) cyclonic storm on 25 November. Sharp boundary of the convection could be seen in eastern and southern sectors.

2.6 Cyclonic Storm over the Bay of Bengal (21-25 December 2002)

In an active equatorial trough a depression formed off southwest coast of Sri Lanka over extreme northern parts of equatorial Indian Ocean in the morning of 21 December and lay centred near lat. 4.0° N/ long. 77.0° E. The system almost tracked eastwards till 0300 UTC of 23 December when it was centred near lat. 4.5° N/ long. 80.5° E. under the influence of the steering flow of equatorial westerlies associated with a developing circulation close to the equator but south of it. The system continued to strengthen and intensified into a deep depression at 231800 UTC near at. 5.0° N / 81.0° E. Moving north-eastwards it further intensified into a cyclonic storm at 240300 UTC near lat. 5.5° N/ long. 81.5° E. Moving in a northeasterly direction the system maintained its intensity upto 250000 UTC and lay centred near lat.7.0° N/ long. 83.5° E. The system started weakening over southwest Bay of Bengal and moving in a northeasterly direction it weakened into a deep depression and was located at 250300 near lat. 7.0° N / long. 83.5° E. Moving east-northeastwards the system further weakened into a depression and was located at 251200 UTC near lat. 7.5° N / long. 86.0° E. It weakened into a low pressure area at 251800 UTC over the southwest and adjoining southeast Bay of Bengal .

The track of the system is given in Fig. 1.1. The best track and other parameters have been included in the table 2.6.1. A few INSAT cloud imageries of the system are given in Fig. 2.6.2.

Weather realised

As the system was away from the Indian coast line, no weather was experienced over the Tamil Nadu coast line of India .

Damage

No damage to life and property were reported.

Table 2.6.1

Best track and other parameters for the Bay of Bengal Cyclonic Storm (21-25 December 2002)

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
21.12.2002	03	4.0 / 77.0	1.5	1006	25	4	D
	06	4.5 / 77.5	1.5	1006	25	4	D
	12	4.5 / 78.0	1.5	1006	25	4	D
	18	4.5 / 78.0	1.5	1006	25	4	D
22.12.2002	00	4.5 / 78.3	1.5	1006	25	4	D
	03	4.5 / 78.5	1.5	1006	25	4	D
	06	4.5 / 79.0	1.5	1006	25	4	D
	12	4.5 / 79.5	1.5	1006	25	4	D
	18	4.5 / 80.0	1.5	1006	25	4	D
23.12.2002	00	4.5 / 80.5	1.5	1006	25	4	D
	03	4.5 / 80.5	1.5	1006	25	4	D
	06	4.5 / 80.5	1.5	1004	25	4	D
	12	5.0 / 81.0	1.5	1004	25	4	D
	18	5.0 / 81.0	2.0	1004	30	6	DD
24.12.2002	00	5.0 / 81.0	2.0	1004	30	6	DD
	03	5.5 / 81.5	2.5	1002	35	8	CS
	06	5.5 / 81.5	2.5	1002	35	8	CS
	09	6.0 / 82.0	2.5	1002	35	8	CS
	12	6.0 / 82.0	2.5	1000	35	8	CS
	15	6.5 / 82.5	2.5	1000	35	8	CS
	18	6.5 / 82.5	2.5	1002	35	8	CS
	21	6.5 / 82.5	2.5	1002	35	8	CS
25.12.2002	00	7.0 / 83.5	2.5	1002	35	8	CS
	03	7.0 / 83.5	2.0	1004	30	6	DD
	06	7.0 / 84.5	2.0	1004	30	6	DD
	12	7.5 / 86.0	1.5	1004	25	4	D
	15	7.5 / 86.0	1.5	1004	25	4	D
		The system weakened into a low pressure over the southwest and adjoining southeast Bay of Bengal after 1500 UTC					

(a)

(b)

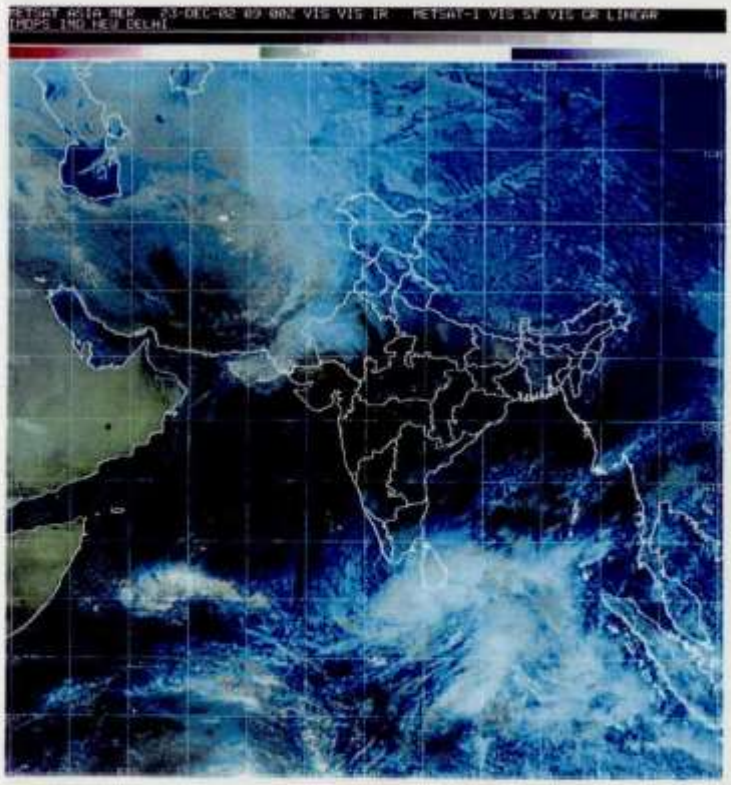
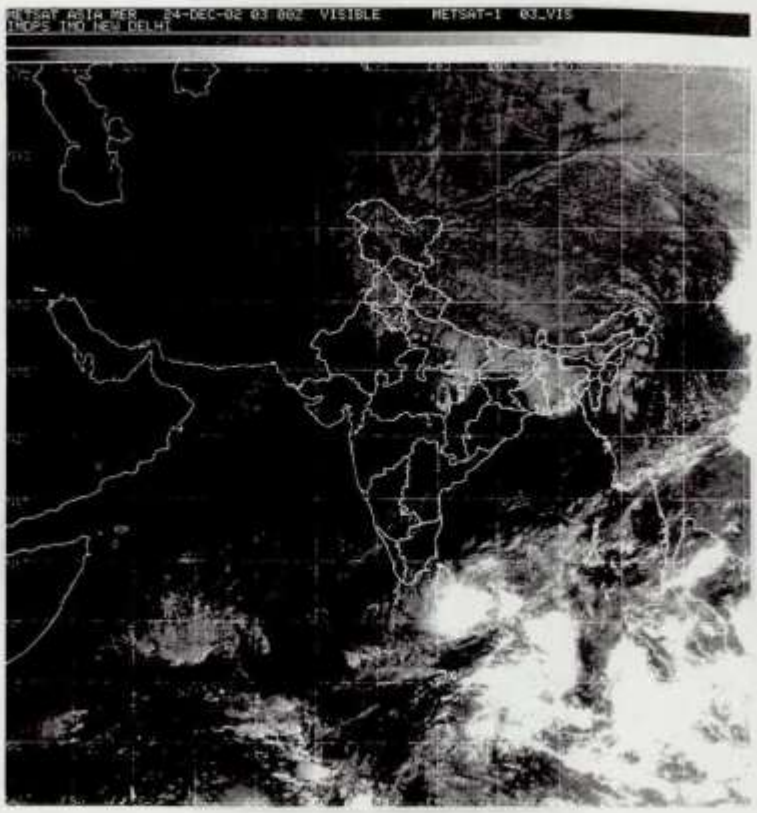


Fig. 2.6.2 Satellite cloud imagery showing cloudiness associated with a depression southwest of Sri Lanka and very close to equator (a) on 22 December and (b) on 23 December.

(c)



(d)

Fig. 2.6.2 (Contd) (c) Satellite cloud imagery showing the system as a cyclonic storm south of Sri Lanka on 24 December and (d) on 25 December when the system had weakened into a deep depression.

Chapter 3

Track Prediction

3.1 Track Prediction Models

Track prediction is made operationally at RSMC- Tropical cyclones New Delhi by utilising Limited Area Forecast Model (LAM) , quasi-Lagrangian model (QLM), Climatology, Persistence and combination of both (CLIPER) and Analogue.

3.1.1 Track prediction by Numerical Models

During the season LAM and QLM outputs such as initial development of the system and model predicted track forecasts were provided for the depression and cyclonic storms which formed during the year 2002. The QLM model was run to produce track forecasts based on the initial conditions of each day at 00 UTC and 12 UTC when the disturbance was in cyclonic storm stage, where as the LAM forecasts were produced regularly at 00 UTC and 12 UTC for day-to-day operational use.

A quantitative assessment of the performance of forecast model was made by computation of track prediction errors. Two types of prediction errors have been computed. Direct position errors 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, latter provides an indication of the closeness of the predicted direction of movement and the observed direction.

As the cyclones during November 2002 were either very fast moving or very slow moving, the model showed higher mean forecast track errors. Forecasts generated by other operational models also gave conflicting signals and no realistic and useful outputs could be achieved in respect of these cyclones.

Table 3.1 contains the verification statistics of the mean position errors (km) and the angular deviation of the predicted tracks from the observed track (degrees), in respect of the two remaining cases. The mean position errors for 24H forecast by QLM ranges between 100 to 200 km. The overall average position error for the two cases works out to 150 km for 24 H forecast and 115 km for 36 H forecast.

The angular deviations varied from 5° to 15° in respect of 24 H forecast with average angular deviation of 10° for 24 H forecast and 12° for 36 H forecast.

Table 3.1

TRACK PREDICTION ERRORS (QLM)

Period	24 H		36 H	
	Position Error (km)	Angular Deviation (Deg)	Position Error (km)	Angular Deviation (Deg)
06-10 May (Arabian Sea)	200	05	120	07
21-25 December (Bay of Bengal)	100	15	110	17
Mean of above two cases	150	10	115	12

3.1.2 Track Prediction by Other Models

The errors in the predicted positions from Persistence, Climatology, and Climatology & Persistence (Cliper) models for the tropical cyclones in North Indian Ocean during 2002 are given in table 3.2. As the cyclone of 10-12 November 2002 displayed very fast movement (from a moderate speed of 15 Kmph in its initial stages to more than 30 Kmph on 11th and 12th), the statistics of the same is not included in Table 3.2. On an average Persistence performed better for 12 Hrs forecast with a mean error of 109 Km, Climatology performed better in 24 Hrs and 48 Hrs forecasts with mean error of 130 Km and 293 Km respectively and Cliper performed better in 36 Hrs forecast with an average error of 236 Km.

Table 3.2

Forecast position errors (km) for Tropical Cyclones in the Bay of Bengal and the Arabian Sea in 2002 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
06-10 MAY,2002	142	155	109	313	63	251	451	--	329	790	--	533
23-28 NOV ,2002	88	121	127	122	198	115	158	278	143	146	293	155
21-25 DEC,2002	97	--	--	139	--	--	131	--	--	205	--	--
Mean for three cases	109	138	118	191	130	183	246	278	236	380	293	344

* * *