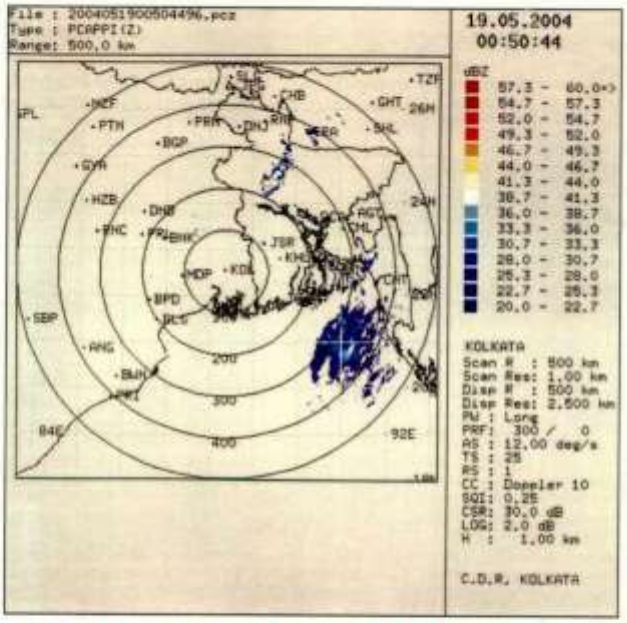
भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

REPORT ON CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN DURING 2004

INSAT 3A - MAY 18, 2004 (0600UTC)



Doppler Radar picture of Kolkata of VSCS on May 19, 2004

RSMC-TROPICAL CYCLONES, NEW DELHI

JANUARY 2005

INDIA METEOROLOGICAL DEPARTMENT

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INTRODUCTION

Regional Meteorological Centre (RMC) New Delhi was re-designated as Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones New Delhi with effect from July 1988 with the responsibility of issuing Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the countries in the WMO/ESCAP Panel region bordering the Bay of Bengal and the Arabian Sea, namely, Bangladesh, Maldives, Myanmar, Sultanate of Oman, Pakistan, Sri Lanka and Thailand.

Cyclone Warning Division

As per the recommendations of the Cyclone Review Committee (CRC) set up by the Government of India a Cyclone Warning Directorate, co-located with RSMC Tropical Cyclones - New Delhi, was established in 1990 in the India Meteorological Department's (IMD) HQ, New Delhi to co-ordinate and supervise the cyclone warning in the country.

Functions

The broad functions of RSMC- Tropical Cyclones New Delhi are as follows:

- Round the clock watch over weather situations over the entire North Indian Ocean.
- Analysis and processing of global meteorological data for diagnostic and prediction purposes.
- Detection, tracking and prediction of cyclonic storms in the Bay of Bengal and the Arabian Sea.
- Running of numerical models for tropical cyclone track prediction.
- Interaction with Disaster Management Agencies to provide timely information and warnings for emergency support services.
- Implementation of the Regional Cyclone Operational Plan of WMO/ESCAP Panel.
- Issue of Tropical Weather Outlook and Tropical Cyclone Advisories to the Panel countries.
- Issue of Tropical Cyclone Advisories for International Aviation at 6 - hourly intervals.
- Collection, processing and archival of all data pertaining to cyclonic storms viz. wind, storm surge, pressure, rainfall, satellite information etc. and their exchange with Panel countries.
- Preparation of comprehensive annual reports on cyclonic storms and tropical depressions over North Indian Ocean every year.
- Research on storm surge, track and intensity prediction techniques.

CHAPTER 1

Activities of Regional Specialized Meteorological Centre – Tropical Cyclones New Delhi

Area of responsibility

The area of responsibility of RSMC Tropical Cyclones New Delhi (hereafter referred to as RSMC- New Delhi) covers sea areas of North Indian Ocean north of equator 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 as shown in fig. 1.1. The Centre issues Tropical Weather Outlook daily at 0600 UTC and Cyclone Advisories on tropical cyclones (at three hourly interval) when they develop over the north Indian Ocean. Recently RSMC New Delhi has commenced the practice of issuing Tropical Cyclone Advisories for Aviation as per ICAO requirements.

As per recommendation of WMO/ESCAP Panel, RSMC- New Delhi started naming of Tropical Cyclones formed over north Indian ocean with effect from post monsoon season of 2004.

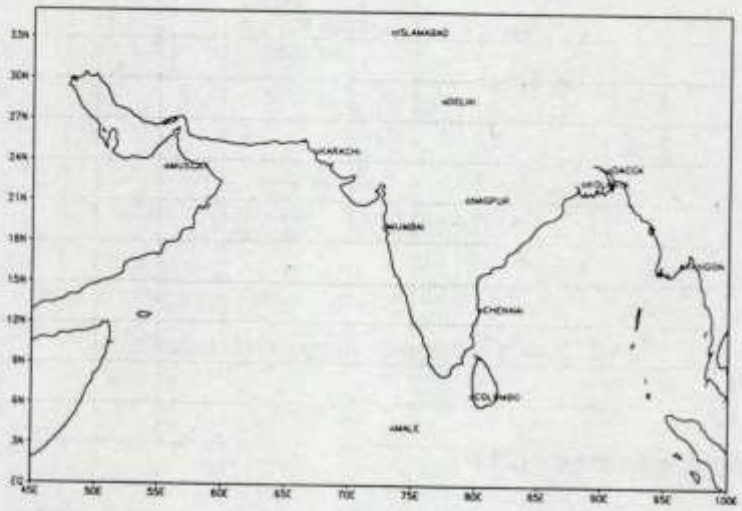


Figure 1.1 Area of responsibility of RSMC New Delhi

Analysis

Surface analysis of tropical disturbances is performed five times daily at 00, 03, 06, 12, and 18 UTC. During cyclone period synoptic charts are being prepared and analysed every three hour to monitor the tropical cyclonic storms that form over the North Indian Ocean.

Cloud images from Geostationary Meteorological Satellites INSAT – 3A and METSAT (Kalpana-1) are the main source of information for the analysis of tropical cyclones over the data-sparse region of North Indian Ocean in addition to a number of moored ocean buoys (shallow water and deep sea) deployed over the Indian sea , under the National Data Buoy programme of the Department of Ocean Development, Government of India. The existing Buoy network is given in fig 1.2. The direction and speed of the movement of a tropical cyclone are determined primarily from the three hourly displacement vectors of the centre position and inputs from various numerical models. When the system comes closer to the coastline, the system location and intensity are determined based on hourly observations from Radar stations as well as coastal observatories.

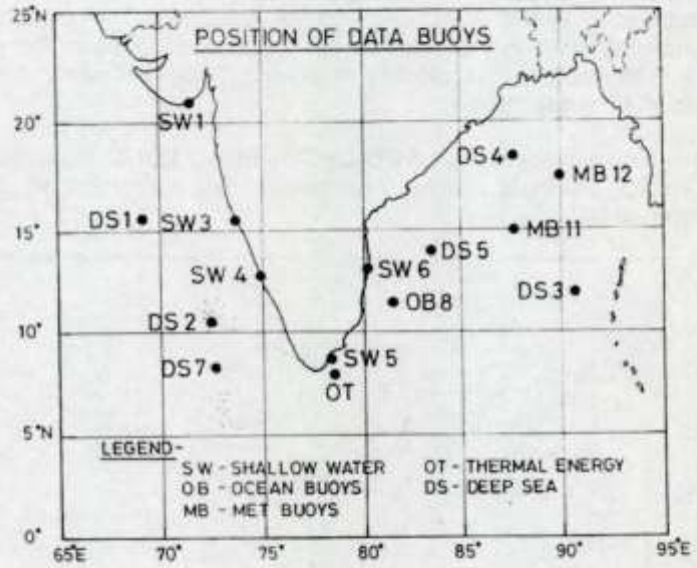


Fig 1.2 Existing buoys network over north Indian ocean

Forecast

(a) Quasi-Lagrangian Model (QLM)

The QLM, a multilevel fine-mesh primitive equation model with a horizontal resolution of 40 km and 16 sigma levels in the vertical, has been used for tropical cyclone track prediction. The integration domain consists of 111x111 grid points in a 4440x4440 km^2 domain that is centred on the initial position of the cyclone. The model includes parameterization of basic physical and dynamical processes associated with the development and movement of a tropical cyclone.

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. The initial fields and lateral boundary conditions are derived based on global model (T-80) forecasts obtained online from the National Centre for Medium Range Weather Forecasting (NCMRWF). The model is run up to 36 hrs. Very recently, model is updated to get six hourly track forecasts valid upto 72 hours. The track forecast products are disseminated as a World Weather Watch activity of RSMC, New Delhi.

(b) Limited Area Model (LAM)

The operational forecasting system known as Limited Area Forecast System (LAFS), is a complete system consisting of data decoding and quality control procedures, 3-D multivariate optimum interpolation scheme for objective analysis and a semi-implicit semi-Lagrangian multi-layer primitive equation model which is run twice a day based on 00 UTC and 12 UTC observations. The horizontal resolution of the model is 0.75 °x0.75 °lat. /long. with 16 sigma levels in the vertical. First guess and boundary conditions for running the LAFS are obtained online from global forecast model being operated by the National Center for Medium Range Weather Forecasting (NCMRWF), New Delhi. The model incorporates a synthetic vortex scheme for initialization of cyclone vortex. The forecast products are disseminated as a World Weather Watch activity of RSMC, New Delhi.

(c) Storm Surge Modelling

For the operational storm surge prediction India Meteorological Department (IMD) uses both Nomograms developed by IMD and Dynamical Storm Surge Model developed by IIT Delhi. The nomograms are based on the numerical solution to the hydrodynamical equations governing motion of the Sea. The nomograms are prepared relating peak surge with various parameters such as pressure drop, radius of maximum winds, vector motion of the cyclone and offshore bathymetry. The dynamical model of IIT Delhi 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 conventional quadratic equation. The bathymetry of the model is derived from Naval Hydrographic charts applying cubic spline technique.

Very recently IMD also has implemented Dynamical storm surge model of NIOT, Chennai for the east coast of India on experimental mode. The model is based on the finite elements algorithm.

Products generated by RSMC New Delhi

RSMC New Delhi prepares and disseminates the following RSMC bulletins via GTS and AFTN.

Tropical Weather Outlook

Tropical Weather Outlook is issued daily at 0600 UTC for use by the member Countries of WMO/ESCAP Panel.This contains description of synoptic systems over North Indian Ocean along with information on major cloud systems as seen in satellite imageries. In addition, a special weather outlook is also issued at 1700 UTC during situations when a tropical depression is formed expected to intensify and attain cyclone intensity. These bulletins are transmitted through the Global Telecommunication System (GTS).

Global Maritime Distress Safety System

Under Global Maritime Distress Safety System (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 MET AREA VIII (N), which covers a large portion of North Indian Ocean. As a routine two GMDSS bulletins are issued at 0900 and 1800 UTC. During cyclone situation additional bulletins (up to 4) are being issued for GMDSS broadcast. In addition, coastal weather and warning bulletins are also issued for broadcast through NAVTEX transmitting stations 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, expected direction and speed of movement, estimated central pressure and forecast of winds, squally weather and state of the sea in and around the system. Tropical cyclone advisories are also made available on real time basis through internet at IMD's website: http://www.imd.emet.in

Tropical Cyclone Advisories for Aviation

The practice of issuing Tropical Cyclone Advisories for Aviation was introduced in 2003. These bulletins are issued for Aviation as soon as any disturbance over the north Indian Ocean attains or likely to attain the intensity of Cyclonic Storm within next six hours (sustained wind speed ≥ 34 knots). These bulletins are issued at six hourly intervals based on 00, 06, 12, 18 UTC synoptic charts and the time of issue will be H+03 hrs.

Satellite Activities

India has launched an exclusive Meteorological Geo-stationary Satellite METSAT, now named KALPANA-I, in September 2002 over the Indian Ocean purely for meteorological purposes. It provides satellite imageries in VIS, IR, and WV channels. In addition another Geo-stationary satellite under INSAT series (INSAT-3A) was launched in April, 2003 with the meteorological payloads identical to those of INSAT-2E. The INSAT-3A was made operational in May, 2003.

CHAPTER 2

1. Cyclonic Activities over North Indian Ocean during 2004

The North Indian Ocean witnessed development of ten disturbances (Table 1.1) out of which four systems attained the intensity of Cyclonic Storms viz., one Very Severe Cyclonic Storm and three Severe Cyclonic Storms. Four systems were depressions out of which two became deep depressions. Remaining two are land depressions. Tracks of the systems are given in fig. 1.1

During this year, out of the four cyclones, three developed over the Arabian sea and only one formed over the Bay of Bengal. Two depressions formed over the Bay of Bengal and two in the Arabian sea. In addition there was two depression that formed over land.

First cyclone formed over Bay of Bengal as a low pressure area over southwest Bay of Bengal on 1st May. Moving across south peninsula, it emerged into southeast Arabian sea and concentrated into a depression in the morning of 5th May and further into a cyclonic storm by the same evening. Initially the system moved in a northwesterly direction and attained the intensity of severe cyclonic storm in the morning of 7th May. It then moved in a north-northwesterly direction, weakened over the northeast Arabian sea off Gujarat coast in the evening of 10th May.

The second cyclone formed as a depression over eastcentral Bay of Bengal on 16th May and moved in a northwesterly direction. It intensified into a cyclonic storm in the morning of 17th and further into a severe cyclonic storm in the noon of 18th over northwest Bay of Bengal. The system then re-curved and moved in a easterly direction and intensified into a very severe cyclonic storm on 18th night itself. Moving northeastwards it crossed Myanmar coast north of Akyab in the forenoon of 19th May and weakened gradually over Myanmar.

The third cyclone formed as a low pressure area over eastcentral Arabian sea in the morning of 29th september,2004. It intensified into a depression and subsequently into a deep depression in the evening of 30th September. Moving in a northwesterly direction the system intensified into a cyclonic storm in the evening of 1st October, 2004. The system moved in a northerly direction for some time, then re-curved northeastwards and further intensified into a severe cyclonic storm in the afternoon of 2nd October. Moving in the same direction the system weakened into a depression over Gujarat-Kutch coast in the evening of 3rd October without crossing the coast.

The fourth cyclone formed as a depression over southeast Arabian sea close to equator in the morning of 29th November, it intensified rapidly into a deep depression and then cyclonic storm in the evening of same day. Moving slowly in a west-northwesterly direction it intensified into a severe cyclonic storm in the morning of 30th November. The system moved in a northwesterly direction and gradually weakened into cyclonic storm and then deep depression in the afternoon of 1st December and subsequently into a depression in the morning of 2nd December, 2004.

Salient features :

The notable feature is that the Arabian sea was more active than the Bay of Bengal during 2004. Out of the total eight cyclonic disturbances that formed over North Indian Ocean, three cyclones and two depressions formed over the Arabian sea. Only one cyclonic storm and two depressions formed over the Bay of Bengal.

The Arabian sea severe cyclone "Agni" in November formed very close to the equator near latitude 1.5^0 N. Cyclogenesis over the North Indian Ocean at such low latitudes has not occurred in the past. The coexistence of cyclonic disturbances over the Arabian sea and the Bay of Bengal as occurred in June , 2004 is also not so common. This had however helped the progress of the southwest monsoon across the country during the onset phase.

Comprehensive information on Tropical Cyclone activity over the North Indian Ocean for last four years is given in table 1.2.

Table-1.1
List of cyclonic disturbances during 2004

1.	Severe Cyclonic Storm over Arabian Sea, May 05-10
2.	Very Severe Cyclonic Storm over the Bay of Bengal, May 16-19
3.	Deep Depression over the Arabian Sea, June 10-13
4.	Deep Depression over the Bay of Bengal, June 11-14
5.	Land Depression over Gangetic West Bengal, September 12-15
6.	Severe Cyclonic Storm "ONIL" over Arabian sea, September 30- October 03
7.	Depression over the Bay of Bengal, October, 02-04
8.	Land Depression over Gangetic west Bengal, October 07-08
9.	Deep Depression over Arabian Sea, November 02-07
10.	Severe Cyclonic Storm " AGNI" over Arabian sea, November 29- December 2

Table 1.2

Year		D	DD	CS	SCS	VSCS	Total
2000	BOB	1		3		2	6
	ARB	--	--	--	--	--	-
2001	BOB	2	--	1	--	--	3
	ARB	--	--	2	--	1	3
2002	BOB	1	1	2	1	--	5
	ARB	--	--	1	--	--	1
2003	BOB	2	2	--	1	1	6
	ARB	--	--	--	1	--	1
2004*	BOB	2				1	3
	ARB	1	1		3		5

Note: *2 Land Depressions.

Some of the characteristic features of these ten cyclonic disturbances are given in Table 1.3. The statistical data pertaining to the monthly frequencies, total life time (days), frequency distribution (intensity-wise and basin-wise) are given in Table 1.4.

RSMC New Delhi mobilized all its resources, both technical and human, to track the tropical disturbances that formed over the North Indian Ocean and issued advisories to WMO / ESCAP Panel countries.

Table 1.3

Some Characteristic features of cyclonic disturbance during 2004

Cyclonic Storm / Depression	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	Maximum T. No. attained
Severe Cyclonic Storm over Arabian sea, May 05-10	May 05 at 0300 UTC near lat. 11.5° N/long.73.5° E	Weakened over northeast Arabian sea	984 hPa at 1200 UTC on May 07 near lat. 13.0° N/long. 71.5° E	55kt on May 07 at 0300UTC	3.5
Very Severe Cyclonic Storm over Bay of Bengal, May 16-19	May 16 at 0900 UTC near lat. 17.0° N/long. 91.5° E	Crossed Myanmar coast north of Akyab between 0400 UTC to 0500 UTC on May 19	952 hPa at 0300 UTC on May 19 near lat. 20.5° N/long. 92.0° E	90kt on May 19 at 0300UTC	5.0
Deep Depression over Arabian sea, June 10-13	June 10 at 0300 UTC near lat. 17.5° N/long. 67.5° E	Weakened over eastcentral Arabian sea in the forenoon of June 13	992 hPa at 1200 UTC on June11 near lat. 18.0° N/long. 66.0° E	30kt on June 11 at 0900 UTC	2.0
Deep Depression over Bay of Bengal June 11-14	June 11 at 0300 UTC near lat. 15.5° N/long. 90.0° E	Crossed Orissa coast near Puri between 0400 UTC to 0500 UTC June 13	992 hPa at 0000 UTC on June13 near lat. 19.5° N/long. 85.5° E	30kt on June 12 at 0300 UTC	2.0
Land depression, September 12-15	September 12 at 0300 UTC near lat. 22.5° N/long. 88.5° E	------	996 hPa at 0300 UTC on September 12 near lat. 22.5° N/long. 88.5° E	25kt on September 12 at 0300UTC	-
Severe Cyclonic Storm over Arabian sea, September 30 October 03	September 30 at 0900 UTC near lat. 16.0° N/long. 69.0° E	Weakened over northeast Arabian sea on October 3	990 hPa at 0900 UTC on October 2 near lat. 21.5° N/long. 67.0° E	55kt on October 02 at 0900 UTC	3.5
Depression over Bay of Bengal, October 02-04	October 2 at 0300 UTC near lat. 11.5° N/long. 87.0° E	Weakened over coastal Andhra Pradesh-south Orissa coast on October 4	1002 hPa at 1200 UTC on October 2 near lat. 12.5° N/long. 86.0° E	25kt on October 03 at 0300 UTC	1.5
Land Depression, October 07-08	October 7 at 0300 UTC near lat. 22.5° N/long. 87.0° E	------	1004 hPa at 1200 UTC on October 7 near lat. 23.5° N/long. 88.0° E	25kt on October 07 at 0300 UTC	-
Deep Depression over Arabian sea, November 02-07	November 2 at 1200 UTC near lat. 12.0° N/long. 67.0° E	Weakened over westcentral Arabian sea on November 07	1004 hPa at 0300 UTC on 5 November 14.0° N/long. 67.0° E	30kt on November 05 at 0300 UTC	2.0
Severe Cyclonic Storm over Arabian sea, November 29 December 2	November 29 at 0300 UTC near lat. 1.5° N/long. 66.0° E	Weakened over southwest Arabian sea on December 2	994 hPa at 0600 UTC on November 30 near lat. 5.5° N/long. 61.5° E	55kt on November 30 at 0600 UTC	3.5

Table -1.4

Statistical data relating to cyclonic disturbances in the North Indian Ocean during 2004

a) **Monthly frequencies and total lifetime of cyclonic disturbances (CI ≥ 1.5)**

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

b) **Frequency distribution of Cyclonic disturbances of different intensities based on satellite assessment.**

CI No.	≥2.0	≥2.5	≥3.0	≥4.0	≥5.0	≥6.0	≥7.0
No. of Disturbances	7	4	4	1	1	-	-
No. of days with Cyclone Intensity	6.88	7.13	2.88	0.63	0.13	-	-

c) **Basin-wise distribution of cyclonic disturbances**

Bay of Bengal	3
Arabian sea	5
Land depression	2

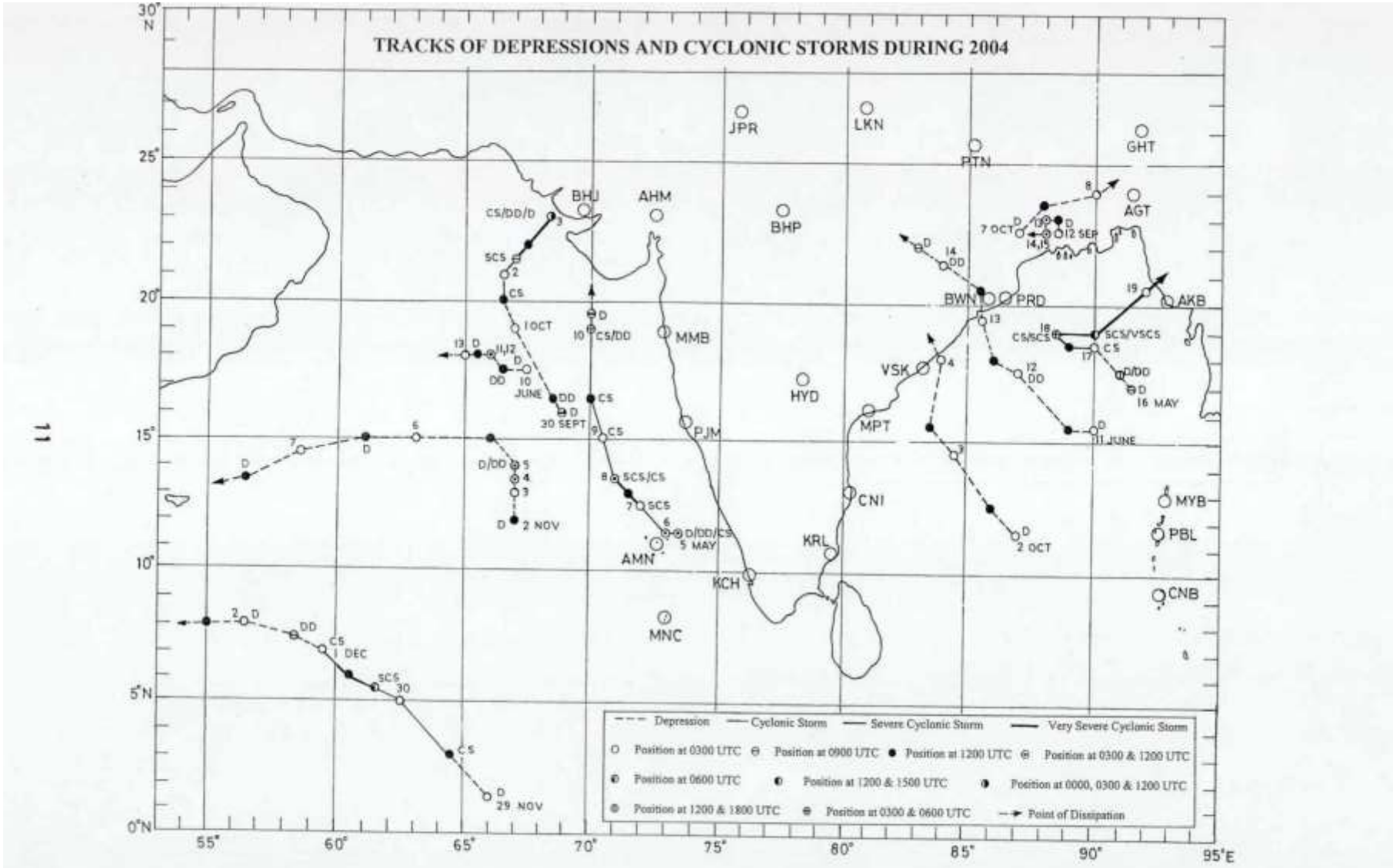

TRACKS OF DEPRESSIONS AND CYCLONIC STORMS DURING 2004
30° N
25°
20°
15°
10°
5°N
0°N
55°
60°
65°
70°
75°
80°
85°
90°
95°E
JPR
LKN
PTN
GHT
BHJ
AHM
BHP
AGT
MMB
BWN
PRD
AKB
HYD
VSK
MPT
PJM
CNI
MYB
PBL
CNB
KRL
KCH
AMN
MNC
CS/DD/D
SCS
CS
1 OCT
10 CS/DD
10 JUNE
30 SEPT
2 NOV
1 DEC
29 NOV
5 MAY
7 OCT
12 SEP
16 MAY
11 JUNE
2 OCT
SCS/CS
D/DD/CS
CS/SCS
SCS/VSCS
D/DD
Depression
Cyclonic Storm
Severe Cyclonic Storm
Very Severe Cyclonic Storm
Position at 0300 UTC
Position at 0900 UTC
Position at 1200 UTC
Position at 0300 & 1200 UTC
Position at 0600 UTC
Position at 1200 & 1500 UTC
Position at 0000, 0300 & 1200 UTC
Position at 1200 & 1800 UTC
Position at 0300 & 0600 UTC
Point of Dissipation

Fig. 1.1

2. Brief Description of the Systems

2.1 Severe Cyclonic Storm over Arabian Sea- May 05-10, 2004

A low pressure area formed over south west Bay of Bengal on 1st May, moved across south peninsula and emerged into southeast Arabian sea off north Kerala and south Karnataka coasts by 4th May. The system concentrated into a **depression** over southeast Arabian sea and lay centred at 050300 UTC near lat. 11.5° N/ long. 73.5° E (observation from Buoy DS2 about 135 kms southeast of the system centre reporting northwesterly 30kt and Amini Divi reporting northwesterly, 35kt and pressure 1000.4 hPa supported this) and was showing signs of ongoing intensification. Remaining practically stationary it rapidly intensified into a **deep depression** at 050600 UTC and subsequently into a **cyclonic storm** at 1200 UTC. Moving in a northwesterly direction, it further intensified into a **severe cyclonic storm** and lay centred at 070300 UTC near lat. 12.5° N/ long. 72.0° E, and remained stationary over the same area till 072100 UTC. The system thereafter moved slowly northwest wards and was located at 080300 UTC near lat. 13.5° N/ long. 71.0° E. The system weakened into a **cyclonic storm** by the evening of 8th over the same place. Subsequently it moved in a north northwesterly direction and was centred near lat. 15.0° N/ long. 70.5° E at 090300 UTC, and near lat. 15.5° N/ long. 70.0° E at 090600 UTC. Thereafter the system had a steady northerly movement with its positions near lat. 16.5 N/ long 70.0 E at 1200 UTC, and near lat 19.0° N / long. 70.0° E at 100300 UTC. The cloud mass associated with the system got sheared off and the low level circulation was seen northeast of the system. Under the influence of the cold waters of northeast Arabian sea and possible dry air incursion from northwest the system rapidly weakened into a **deep depression** at 100600 UTC near lat. 19.0° N/ long. 70.0° E and subsequently into a **depression** near lat. 19.5° N/ long. 70.0° E at 100900 UTC and then into a low pressure area in the sea areas off Gujarat coast on the same evening.

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 A few INSAT cloud imageries of the system are given in Fig. 2.1(a-d) and damage photograph from Lakshadweep in fig 2.2 (a-b).

Realised Weather:

Under the influence of this system Amini Divi recorded an exceptionally heavy rainfall of 117 cm for the 24 hours period ending at 0300 UTC of May 6. Heavy to very heavy rainfall was also reported along the west coast on some days as the system moved northward. Some significant amounts of rainfall recorded (in cm) in Kerala are given below:

5-5-2004 Amini Divi 43, Agathi 10, Kodungallur 9.

6-5-2004 Amini Divi 117, Kodungallur 20, Kochi AP 19, Agathi 17, Piravom 15, Cherthala 14, Aluva 12.

7-5-2004 Amini Divi 24, Kozhikode AP 21, Thiruvalla, Kunnamkulam 15 each, Kollam 14, Vadakara 12.

8-5-2004 Kozhikode 10, Vadakancherry 6.

9-5-2004 Kannur 15, Panambur 13, Mangalore 11.

Damage:

The system did not cause any damage over the mainland, as it dissipated over the sea. But in its formative stage it caused widespread damage to Lakshadweep Island. Amini recorded an unprecedented rainfall of 117 cm on 6.

The system caused the following damage in Kerala and Lakshadweep

(a) Communication between mainland and island cut off.

(b) Several houses in Island damaged due to wind, falling of trees, sea waves and floods.

(c) 45 houses and 35 boats and small mechanized sailing cargo ships lost in the sea near land.

(d) 16 boats reported sunk and a cargo boat damaged

(e) Sea erosion reported over Kerala

(f) In Kerala 9 persons reported dead and 17 persons missing

(g) Total loss worth Rs. 30 crores

Table 2.1

Best track positions and other parameters for Arabian Sea Severe Cyclonic Storm, May 05-10, 2004

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
05-05-2004	0300	11.5/73.5	1.5	1002	25	--	D
	0600	11.5/73.5	2.0	1000	30	4	**DD**
	0900	11.5/73.5	2.0	1000	30	4	DD
	1200	11.5/73.5	2.5	994	35	6	**CS**
	1500	11.5/73.0	2.5	994	35	6	CS
	1800	11.5/73.0	2.5	994	35	6	CS
	2100	11.5/73.0	2.5	992	35	6	CS
06-05-2004	0000	11.5/73.0	2.5	992	35	6	CS
	0300	11.5/73.0	3.0	992	45	10	CS
	0600	11.5/73.0	3.0	992	45	10	CS
	0900	11.5/73.0	3.0	990	45	10	CS
	1200	11.5/73.0	3.0	988	45	10	CS
	1500	11.5/73.0	3.0	990	45	10	CS
	1800	11.5/73.0	3.0	990	45	10	CS
	2100	11.5/73.0	3.0	990	45	10	CS
07-05-2004	0000	11.5/73.0	3.0	990	45	10	CS
	0300	12.5/72.0	3.5	988	55	14	**SCS**
	0600	13.0/71.5	3.5	986	55	14	SCS
	0900	13.0/71.5	3.5	986	55	14	SCS
	1200	13.0/71.5	3.5	984	55	14	SCS
	1500	13.0/71.5	3.5	986	55	14	SCS
	1800	13.0/71.5	3.5	986	55	14	SCS
	2100	13.0/71.5	3.5	986	55	14	SCS
08-05-2004	0000	13.5/71.0	3.5	986	55	14	SCS
	0300	13.5/71.0	3.5	986	55	14	SCS
	0600	13.5/71.0	3.5	986	55	14	SCS
	0900	13.5/71.0	3.5	986	55	14	SCS
	1200	13.5/71.0	3.0	988	45	10	**CS**
	1500	13.5/71.0	3.0	990	45	10	CS
	1800	14.0/71.0	3.0	990	45	10	CS
	2100	14.5/70.5	3.0	992	45	10	CS
09-05-2004	0000	14.5/70.5	3.0	992	45	10	CS
	0300	15.0/70.5	3.0	992	45	10	CS
	0600	15.5/70.0	3.0	992	45	10	CS

Continued

Table 2.1

Best track positions and other parameters for Arabian Sea Severe Cyclonic Storm, May 05-10, 2004

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
	0900	16.0/70.0	3.0	990	45	10	CS
	1200	16.5/70.0	3.0	990	45	10	CS
	1500	17.0/70.0	3.0	990	45	10	CS
	1800	17.5/70.0	3.0	990	45	10	CS
	2100	18.0/70.0	3.0	992	45	10	CS
10-05-2004	0000	18.5/70.0	2.5	996	35	6	CS
	0300	19.0/70.0	2.5	998	35	6	CS
	0600	19.0/70.0	2.0	1000	30	4	DD
	0900	19.5/70.0	1.5	1002	25	–	'D'

The system weakened into a low pressure area over the sea areas of Gujarat coasts in the evening of May 10, 2004.

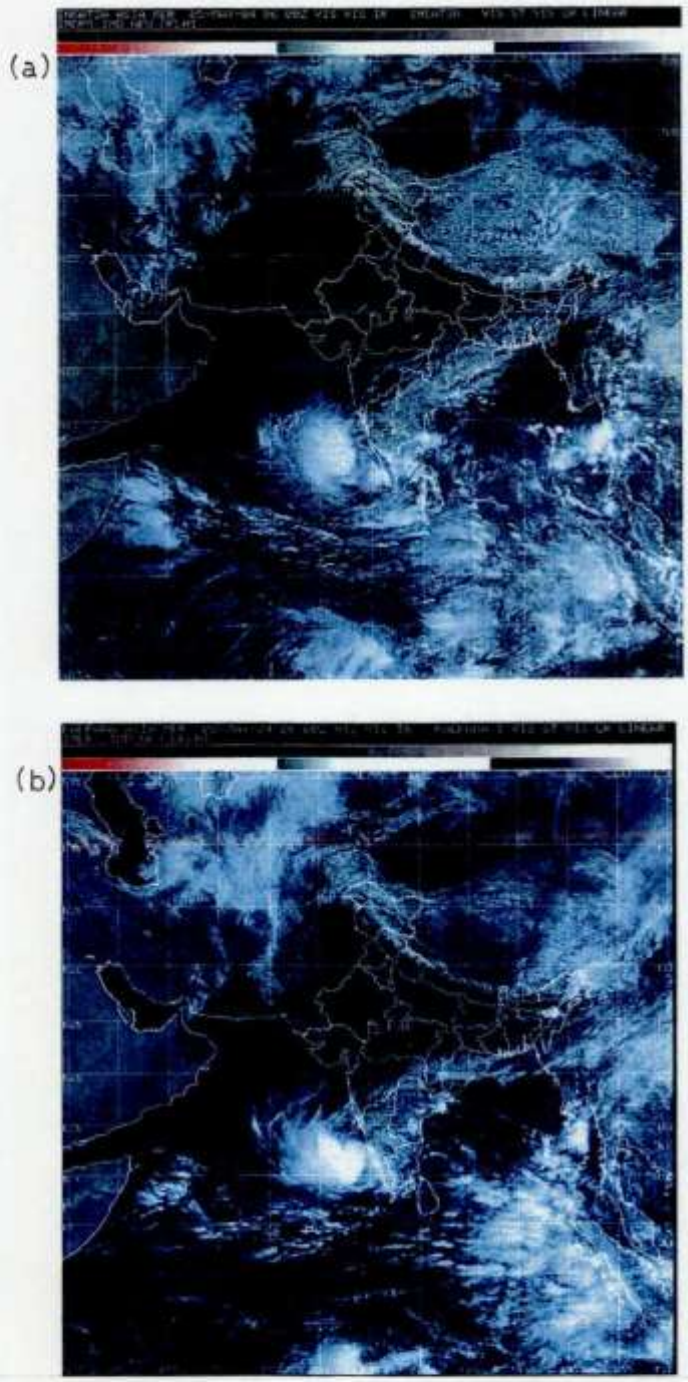


Fig. 2.1 Satellite picture shows (a) intensification of the system at 0600 UTC on May 5, 2004 (b) Dense cloud mass north west sector of the system at0600 UTC on May 06,2004.

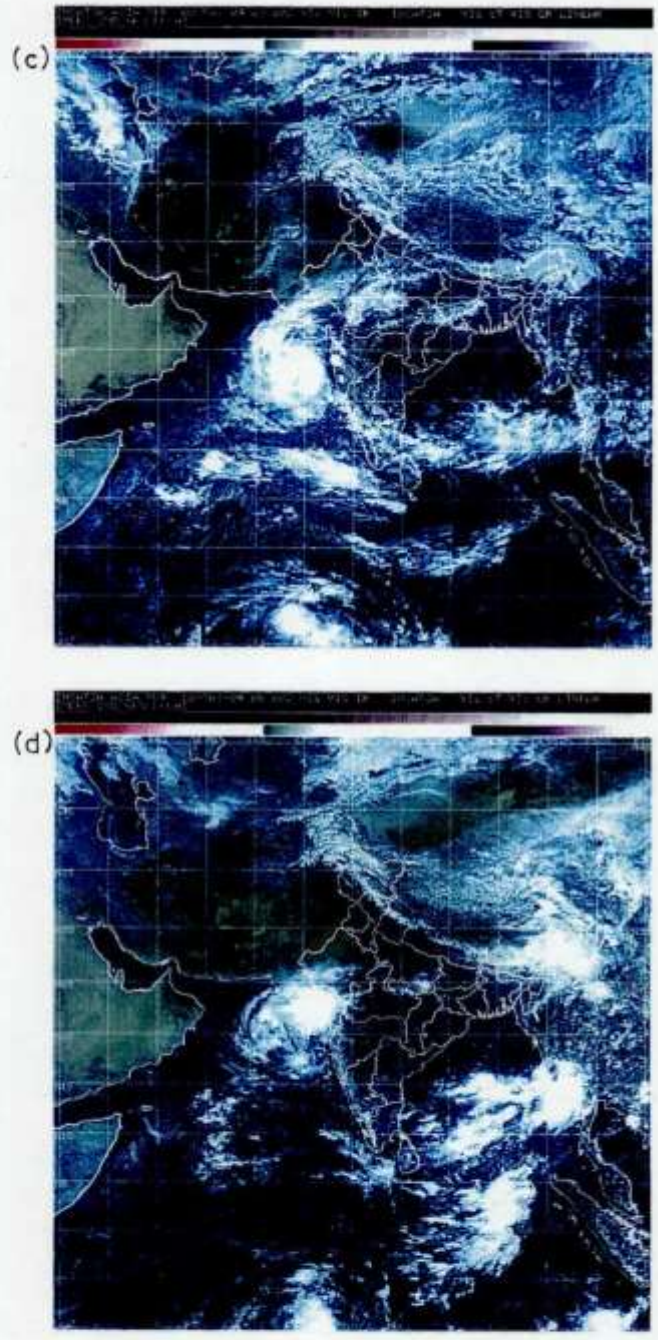


Fig. 2.1 Satellite picture shows (c) spiral bands at 0900 UTC on May 09,2004 (d) System sheared off, as cloud mass ahead of the system over Gujarat and adjoining sea areas while the low level circulation centre still in the sea at 0600 UTC on May 10,2004.

(a)

(b)

Fig. 2.2 (a) A vessel broken into pieces at Amini Divi port on 6th May 2004. and
(b) Coconut trees uprooted in Amini Divi on 5th and 6th May 2004.

2.2 Very Severe Cyclonic Storm over Bay of Bengal- May 16-19, 2004

A low pressure area formed over eastcentral Bay of Bengal in the evening of 15th May. It moved slightly northwestwards and intensified into a **depression** in the afternoon of 16th and lay centred at 160900 UTC near lat. 17.0° N / long. 91.5° E and further intensified rapidly into a **deep depression** at 161800 UTC when it was centred near lat. 17.5° N/ long. 91.0° E. Subsequently the system moved in a northwesterly direction and intensified further into a **cyclonic storm** in the morning of 17th and lay centred at 170300 UTC near lat. 18.5° N/ long. 90.0° E. The wind and pressure observations of nearby buoy MB12 located at Lat. 17.4° N / Long. 89.9° E at 170300 UTC, 0900 UTC and 1200 UTC reported 40kt/235; pressure 994.3 hPa, 30kt/235; pressure 994.9 hPa and 30kt/235;pressure 995.5 hPa respectively. Infrared Satellite picture of 210900 UTC of May 17 showed irregular pattern of cloud dense overcast (CDO). The system remained stationary till 171800 UTC and than started moving north-westward and lay centred at 180300 UTC near lat. 19.0° N/ long. 88.5° E. Remaining stationary it further intensified into a **severe cyclonic storm** at 180600 UTC. The system came close to the ridge position (along 22.0°N) at 200 hPa over Indian region during this period and started moving eastward.

The system attained its peak intensity of **very severe cyclonic storm**, at 181500 UTC when it lay centred near lat. 19.0° N/ long. 90.0° E, and it further moved northeastwards. The same buoy (MB12) reported wind and pressure at 180300 UTC as 30kt/250; 995.5 hPa and at 181200 UTC as 33kt/250; 993.7 hPa. The system was all along out of the range of Doppler Radar of Kolkata as only some dense convection was seen at 0000UTC on 19th. In the morning of 19 May, 'eye' was clearly visible, which supported that the system was with the intensity more than T4.0. The system attained its peak intensity T5.0 at 190300 UTC prior to crossing the coast. The estimated lowest pressure 952 hPa was reported at 190300 UTC. Moving in the same direction it crossed Myanmar coast north of Aakyab (Lat.20.5° N/ Long. 92.8° E) between 0400 and 0500 UTC on 19th May, as **very severe 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 2.2. A few INSAT cloud imageries of the system are given in fig. 2.2 (a-d). Cloud pictures of the cyclone, taken by Doppler weather Radar, Kolkata is given in fig. 2.2.1(a-b).

Weather Realised :

There were no reports of significant rainfall along the east coast as system was away and moved northeast wards and crossed. However, light to moderate rainfall occurred at many places over north Orissa and at isolated places over south Orissa . Chief amount of rainfall (cms) recorded in Orissa are:

16-05-2004 Mahendargarh, Nimpada 4 each and
17-05-2004 Angul 3.

Damage: No damage were reported, as system re-curved towards northeastwards. (Damage report from Myanmar has not been received)

Table 2.2

Severe Cyclonic Storm over Bay of Bengal May 16-19, 2004

Date	Time (UTC)	Centre lat.° N/ long.° E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
16-05-2004	0900	17.0/91.5	1.5	1000	25	---	D
	1200	17.5/91.0	1.5	1000	25	---	D
	1800	17.5/91.0	2.0	998	30	4	**DD**
	2100	18.0/90.5	2.0	998	30	4	DD
17-05-2004	0000	18.5/90.5	2.0	998	30	4	DD
	0300	18.5/90.0	2.5	998	35	6	**CS**
	0600	18.5/90.0	2.5	998	35	6	CS
	0900	18.5/89.5	3.0	988	45	10	CS
	1200	18.5/89.0	3.0	988	45	10	CS
	1500	18.5/89.0	3.0	988	45	10	CS
	1800	18.5/89.0	3.0	986	45	10	CS
	2100	19.0/88.5	3.0	986	45	10	CS
18-05-2004	0000	19.0/88.5	3.0	986	45	10	CS
	0300	19.0/88.5	3.0	986	45	10	CS
	0600	19.0/88.5	3.5	982	55	14	**SCS**
	0900	19.0/89.5	3.5	980	55	14	SCS
	1200	19.0/90.0	3.5	980	55	14	SCS
	1500	19.0/90.0	4.0	974	65	20	**VSCS**
	1800	19.5/90.5	4.0	974	65	20	VSCS
	2100	19.0/91.0	4.0	972	65	20	VSCS
19-05-2004	0000	20.0/91.5	4.5	962	77	28	VSCS
	0300	20.5/92.0	5.0	952	90	40	VSCS

The Very Severe Cyclonic Storm crossed Myanmar coast north of Akyab between 0400 to 0500 UTC on May 19, 2004.

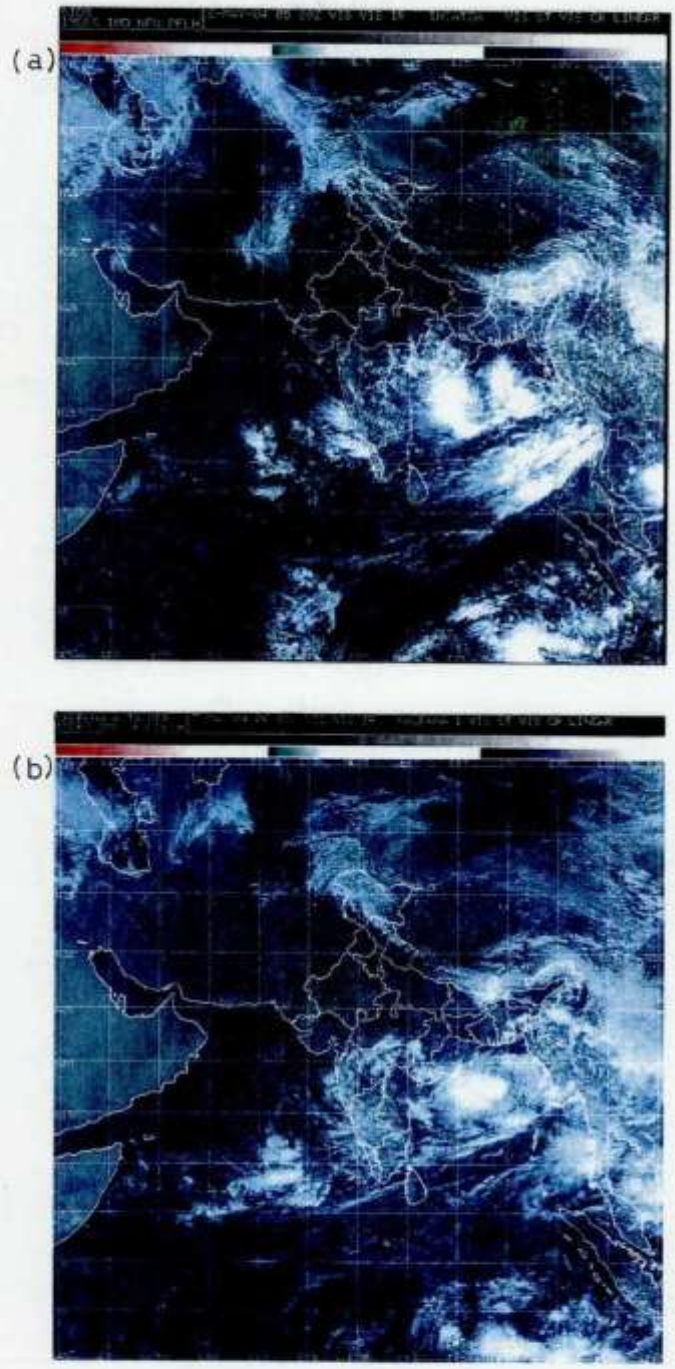
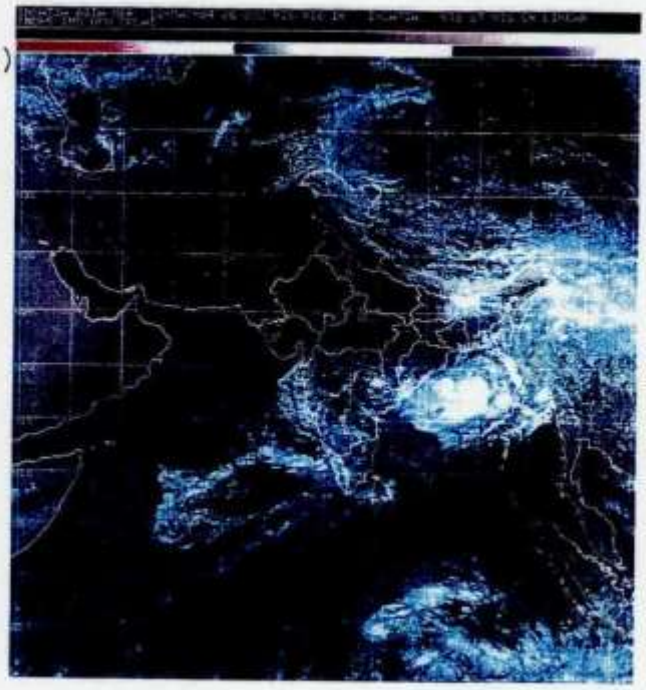


Fig. 2.2 Satellite picture shows (a) convective cloud over eastcentral Bay of Bengal in association with the Depression at 0500 UTC on May 16,2004 (b) Dense cloud mass seen over western sector of the system at 0600 UTC on May 17,2004.

(c)



(d)

Fig. 2.2 Satellite picture shows (C) re-curving of the system in a north eastwards direction at 0600 UTC on May 18, 2004 (d) Very Severe Cyclonic Storm crossing the Myanmar coast at 0500 UTC on May 19,2004.

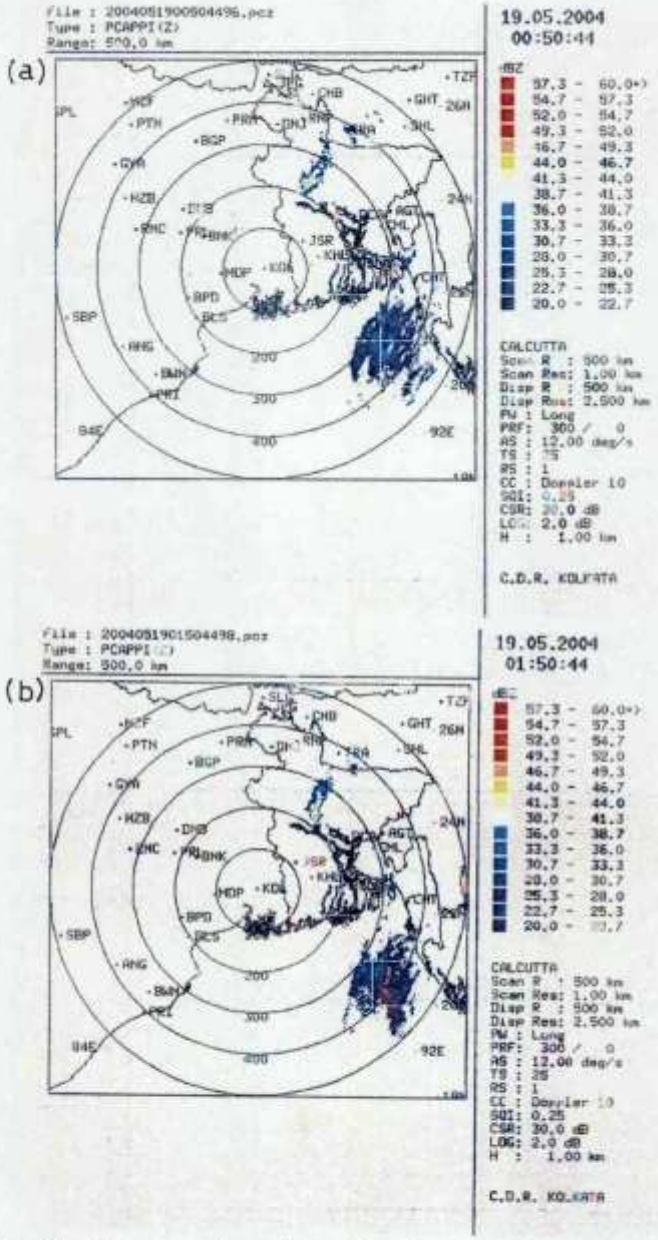


Fig. 2.2.1 (a) Doppler radar picture showing dense convective cloud with centre Of the system about 330 km south east of Kolkata (b) Doppler radar picture showing expansion of convective cloud around the system centre.

2.3 Deep Depression over Arabian sea - June 10-13, 2004

A low pressure area formed over eastcentral Arabian sea in the morning of 8th June. This low pressure area persisted till the evening of June 9. The buoy DS1 (15.5° N / 69.2° E) reported wind 195 /10kt and pressure 1003.6 hPa at 0300 UTC on June 8. wind 225°/25kt, pressure 1003.5 03 UTC on June 9 and MB1 (Lat.20.0° N/67.5° E) reported 045°/10kt, pressure 1003.2 at 0300UTC on June 9. The same buoys DS1, MB1 reported 230°/ 25kt pressure 1002.1 and 045°/15kt, pressure 999.7 hPa respectively at 0300 UTC on June 10. These observations from buoys supported the intensity and location of the deep depression. The system was declared as **depression** in the morning of 10th June when it lay centred at 100300 UTC near lat 17.5° N/ long. 67.5° E. It remained practically stationary and intensified into a **deep depression** at 100900 UTC near lat 17.5° N/ long. 66.5° E. The ridge line at 200 hPa level was seen along 20.0° N during this period, and the system was under the influence of upper level easterlies suggesting a west-northwesterly movement. The system however moved slowly in a westerly direction and was centred at 110300 UTC near lat 18.0° N/ long. 66.0° E.

Without moving further the system started weakening in the afternoon of June 12 probably due to strong vertical wind shear and lay centred at 121200 UTC near lat 18.0° N/long. 65.5° E and at 130300 UTC near lat 18.0° N/ long. 65.0° E as a **depression**. The system moved in a westerly direction and weakened gradually into a low pressure area over eastcentral Arabian sea in the forenoon of 13th June.

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. A few INSAT cloud imageries of the system are given in Fig. 2.3 (a-b).

Weather Realised :

No weather was reported as the system was far away from the coast line.

Damage: Nil

Table 2.3

Deep Depression over Arabian Sea June 10-13, 2004

Date	Time (UTC)	Centre lat.° N/ long.° E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
10-06-2004	0300	17.5/67.5	1.5	996	25	-	**D**
	0600	17.5/67.5	1.5	996	25	-	**D**
	0900	17.5/66.5	2.0	996	30	4	DD
	1200	17.5/66.5	2.0	996	30	4	DD
	1500	17.5/66.5	2.0	996	30	4	DD
	1800	17.5/66.5	2.0	996	30	4	DD
	2100	17.5/66.0	2.0	996	30	4	DD
11-06-2004	0000	18.0/66.0	2.0	996	30	4	DD
	0300	18.0/66.0	2.0	996	30	4	DD
	0600	18.0/66.0	2.0	994	30	4	DD
	0900	18.0/66.0	2.0	994	30	4	DD
	1200	18.0/66.0	2.0	992	30	4	DD
	1500	18.0/66.0	2.0	992	30	4	DD
	1800	18.0/66.0	2.0	994	30	4	DD
	2100	18.0/66.0	2.0	994	30	4	DD
12-06-2004	0000	18.0/66.0	2.0	994	30	4	DD
	0300	18.0/66.0	2.0	996	30	4	DD
	0600	18.0/66.0	2.0	996	30	4	DD
	0900	18.0/66.0	2.0	996	30	4	DD
	1200	18.0/65.5	1.5	996	25	-	**D**
13-06-2004	0300	18.0/65.0	1.5	996	25	-	D

The system moved westwards and weakened gradually into a low pressure area over east central Arabian sea in the forenoon of June 13, 2004

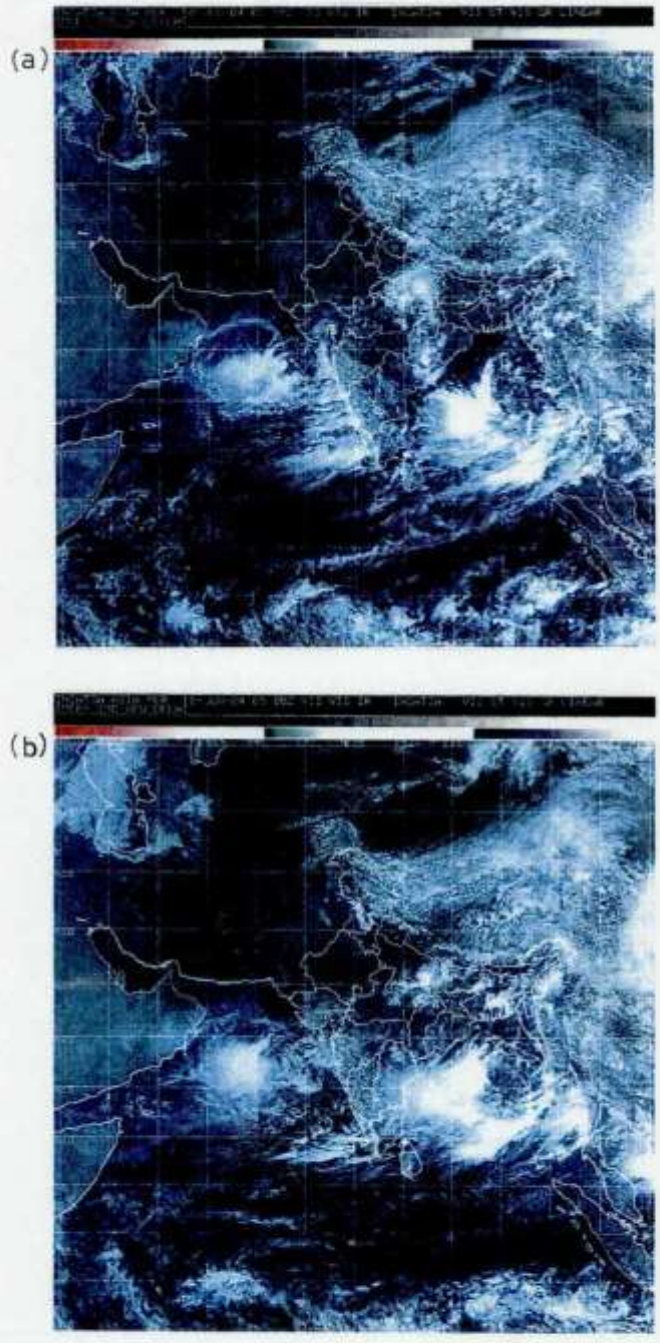


Fig. 2.3 Satellite picture shows (a) dense cloud mass over north Arabian sea in association with the Depression at 0500 UTC on June 10,2004 (b) The cloud mass drifted westward, from the system centre at 0500 UTC on June 11,2004.

2.4 Deep Depression over Bay of Bengal - June 11-14, 2004

The convective activity developed over Andaman sea ahead of the monsoon current during the first week of June. Under its influence a low pressure area formed over central Bay and adjoining North Andaman Sea. It concentrated into a **depression** over east central Bay and lay centred at 110300 UTC near lat.15.5° N and long. 90.0°E, about 700 km. southeast of Bhubaneshwar. The system initially moved in a westerly direction and was near lat. 15.5° N and long. 89.0° E. the same evening. Thereafter the system moved northwestwards and intensified further into a **deep depression** at 120300 UTC near lat.17.5° N and long.87.0°E and near lat. 18.0°N and long. 86.0° E at 121200 UTC. As the system moved northwestwards the ridge line at 200 hPa also shifted gradually north wards over the Indian region. The system continued to move in a north-northwesterly direction and lay centred very close to Orissa coast, just south of Puri (19.5°N and 85.5° E) at 130300 UTC. (The system has maximum pressure gradient before crossing the coast, with the estimated central pressure was 990 hPa at 140900 UTC.

The 200 hPa wind field also depicted good difflunce aloft with moderate to high vertical wind shear). The Buoy MB12 (17.5° N/ 89.9° E) reported southeasterly / 25kt, pressure 994.8 hPa at 111200 UTC when the system was nearby. The same buoy reported wind southwesterly / 15 kt, pressure 998.7 hPa and on 130300 UTC west-southwesterly / 25kt, pressure 1001.0 hPa. The system crossed Orissa coast close to Puri between 0400 to 0500 UTC and lay centred near lat.20.5° N and long. 85.5° E at 131200 UTC. It was overland, northwest of Puri on same day evening. The surface observations at 0300 UTC of 14th suggested, that the system maintained its intensity as deep depression and lay centred near Sambalpur (42883). It subsequently weakened into a **depression** at 140900 UTC and lay close to Rajgarh (42557). Moving in a northwesterly direction, it further weakened into a well marked low pressure area over Chattishgarh and neighbourhood in the evening of June 14, 2004.

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 A few INSAT cloud imageries of the system are given in Fig. 2.4(a-d).

Weather Realised:

Since the system formed on the leading-edge of the monsoon current and its subsequent track overland favored the advancement of South-West monsoon and enhancement of rainfall activities. The significant rainfall (3.0 cm and above) are given below:

ORISSA

12-6-2004 Painaghar 13, Pottangi 10, ,Junagarh 9, Paralakhemundi 8.

13-6-2004 Madanpur Rampur -32, Kharalar 31, Junagarh 28, Lanjigarh 20, Bhogiri, Jeypore 15, Jaleswar, Malkangiri, Umarkot, 12, Rajghat, Rajkanika, Pottangi 10, Balasore, Akhuapada, Soro, Jenapur 9, Swampatna, Kotraguda 8,

14-6-2004 Titlagarh 31, Komna, Kantamal, Balimundali 18, Dashpalla, Turoikola 16, Bhavanipatna, Kolagarh 15, Panagarh 14, Kharlar, Nawarangpur 13, Umerkote, Navapura, Malkaguri 12, Jaleswar 11, Pottangi, Jeypore, Swampatna, Narsingpur, Baliguda10, Rajghat, Bangurposhi, Baripada, Binka, Sonepur 9 each, , Keonjhargarh, Tikarpada, Guddar, Raigada 8

ANDHRA PRADESH

12-6-2004 Dowleswaram 8.

13-6-2004 Paderu 16, Tekkali 13, Kalingapatnam 11, Narsipatnam 10, Tuni, Yelamanchili 8.

14-6-2004 Parvathipuram 7, Salur 6.

WEST BENGAL

12-6-2004 Digha 15, Contai 11, Durgachak 7.

13-6-2004 Midnapore 8.

Damage : No damage was reported from the coastal districts of Andhra Pradesh, Orissa and West Bengal.

Table 2.4

Deep Depression over Bay of Bengal June 11-14, 2004

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
11-06-2004	0300	15.5/90.0	1.5	998	25	-	D
	0600	15.5/90.0	1.5	998	25	-	D
	0900	15.5/89.5	1.5	998	25	-	D
	1200	15.5/89.0	1.5	998	25	-	D
	1500	15.5/89.0	1.5	998	25	-	D
	1800	15.5/89.0	1.5	998	25	-	D
	2100	15.5/89.0	1.5	998	25	-	D
12-06-2004	0000	16.0/88.0	1.5	998	25	-	D
	0300	17.5/87.0	2.0	996	30	4	DD
	0600	17.5/87.0	2.0	996	30	4	DD
	0900	17.5/86.5	2.0	996	30	4	DD
	1200	18.0/86.0	2.0	994	30	4	DD
	1500	18.0/86.0	2.0	994	30	4	DD
	1800	18.5/85.5	2.0	994	30	4	DD
	2100	19.0/85.5	2.0	994	30	4	DD
13-06-2004	0000	19.5/85.5	2.0	992	30	6	DD
	0300	19.5/85.5	2.0	992	30	6	DD
	0600	19.5/85.5	-	992	30	4	DD
	0900	20.0/85.5	-	992	30	4	DD
	1200	20.5/85.5	-	992	30	4	DD
14-06-2004	0300	21.5/84.0	-	992	30	4	DD
	0900	22.0/83.0	-	990	25	-	D

The Deep Depression crossed near Puri in Orissa between 0400 and 0500 UTC on June 13 and weakened into a well marked low pressure area over Chattishgarh and neighbourhood in the evening of June 14, 2004.

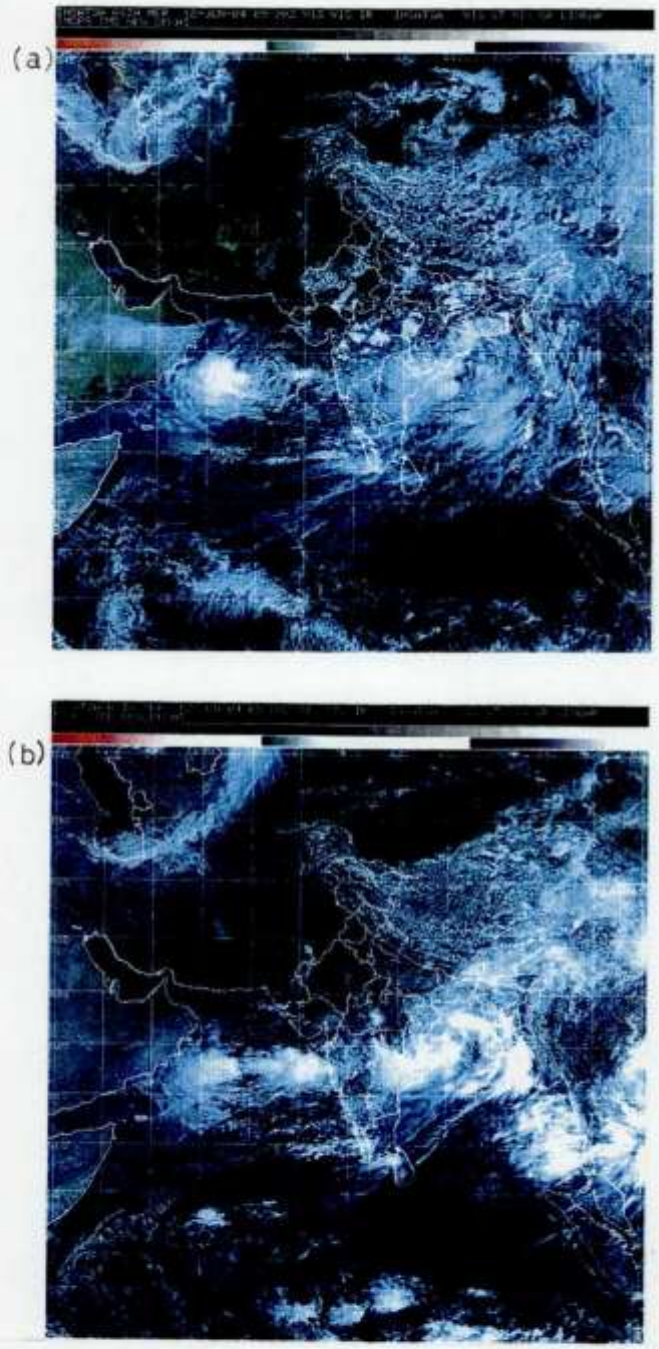


Fig. 2.4 Satellite picture shows (a) when the system had become a deep depression near lat. 17.5^0 N/long. 86.5^0 E at 0900 UTC on June 12, 2004 (b) Dense cloud mass over Orissa, north Andhra Pradesh and adjoining sea areas in association with deep depression at 0500 UTC on June 13, 2004.

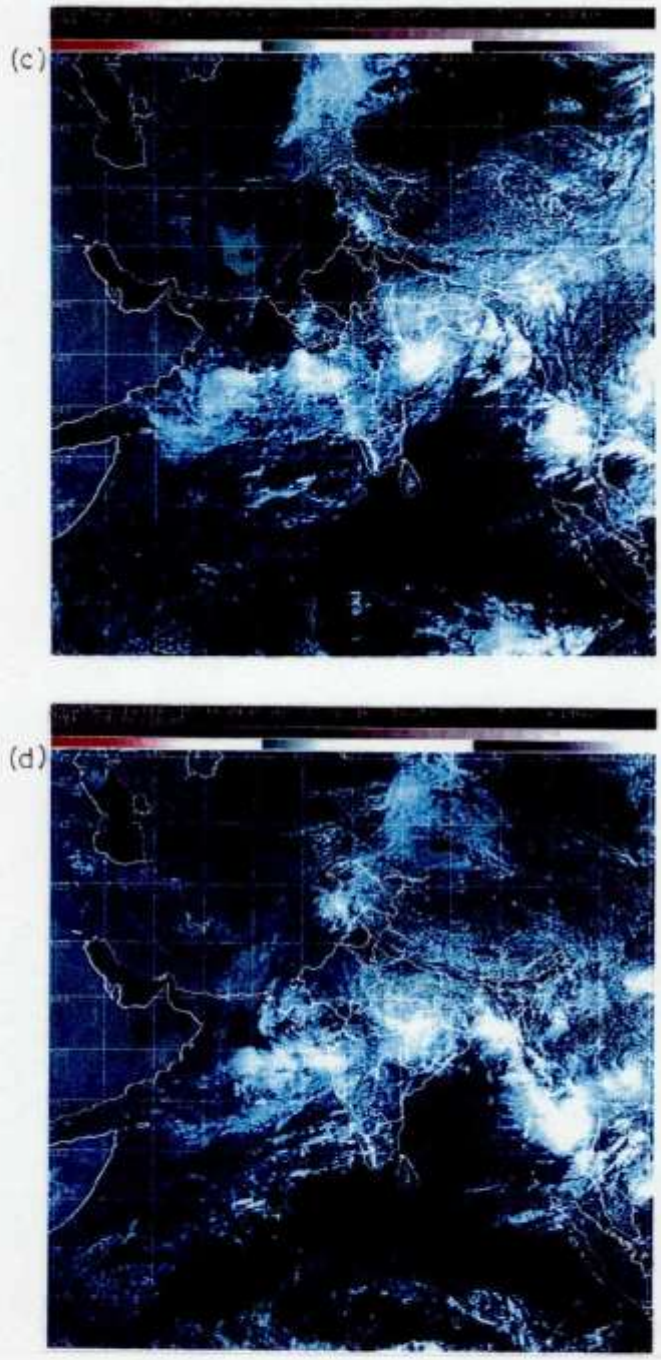


Fig. 2.4 (cont.) Satellite picture shows (c) Dense cloud mass over eastern India in association with the deep depression at 0500 UTC on June 14, 2004 and (d) Cloud mass also enhancing over west coast of India after weakening the depression over Chattishgarh at 0500 UTC on June 15, 2004.

2.5 Land depression over Gangetic West Bengal - September 12-15, 2004

A low pressure area formed over north west Bay of Bengal in the eastern end of the monsoon trough on 10th September. It moved in a north-northwesterly direction and concentrated into a **depression** over Gangetic West Bengal on 12th morning and lay centred near Kolkata (42807). The system meandered around Kolkata till 15th evening as it was located under the upper level col region. The system moved slowly northwestwards and subsequently weakened into a low pressure area over Gangetic West Bengal and neighbourhood in the night of September 15, 2004..

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. A few INSAT cloud imageries of the system are given in Fig. 2.5(a-d).

Weather realized:

Under the influence of the depression widespread rainfall with isolated heavy falls occurred over Gangetic West Bengal, Orissa and Jharkhand during the depression period. The significant rainfall is given below:

Sub-Himalayan West Bengal & Sikkim

9-9-2004 Chepan 34, Mathabhanga 28, Damohani 21, Alipurduar 20, Gajoldoba, Jalpaiguri 19, Barobisa 18, Champasarai, Hasimara, Murti 13

Gangetic West Bengal

12-9-2004 Jhalda 9.

13-9-2004 Canning Town 9.

14-9-2004 Krishnanagar 9

15-9-2004 Krishnanagar 10

Damage: According to press reports, 4 people lost their lives due to heavy rains.

Table 2.5

Land depression over Gangetic West Bengal September 12-15, 2004

Date	Time (UTC)	Centre lat.° N/ long.° E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
12-09-2004	0300	22.5/88.5	-	996	25	4	D
	1200	23.0/88.5	-	998	25	4	D
13-09-2004	0300	23.0/88.0	-	1000	25	4	D
	1200	23.0/88.0	-	998	25	6	D
14-09-2004	0300	22.5/88.0	-	998	25	4	D
	1200	22.5/88.0	-	1000	25	4	D
15-09-2004	0300	22.5/88.0	-	1002	25	4	D
	1200	22.5/88.0	-	998	25	4	D

The depression weakened into a low pressure area over Gangetic West Bengal and adjoining Jharkhand, in the night of September 15, 2004.

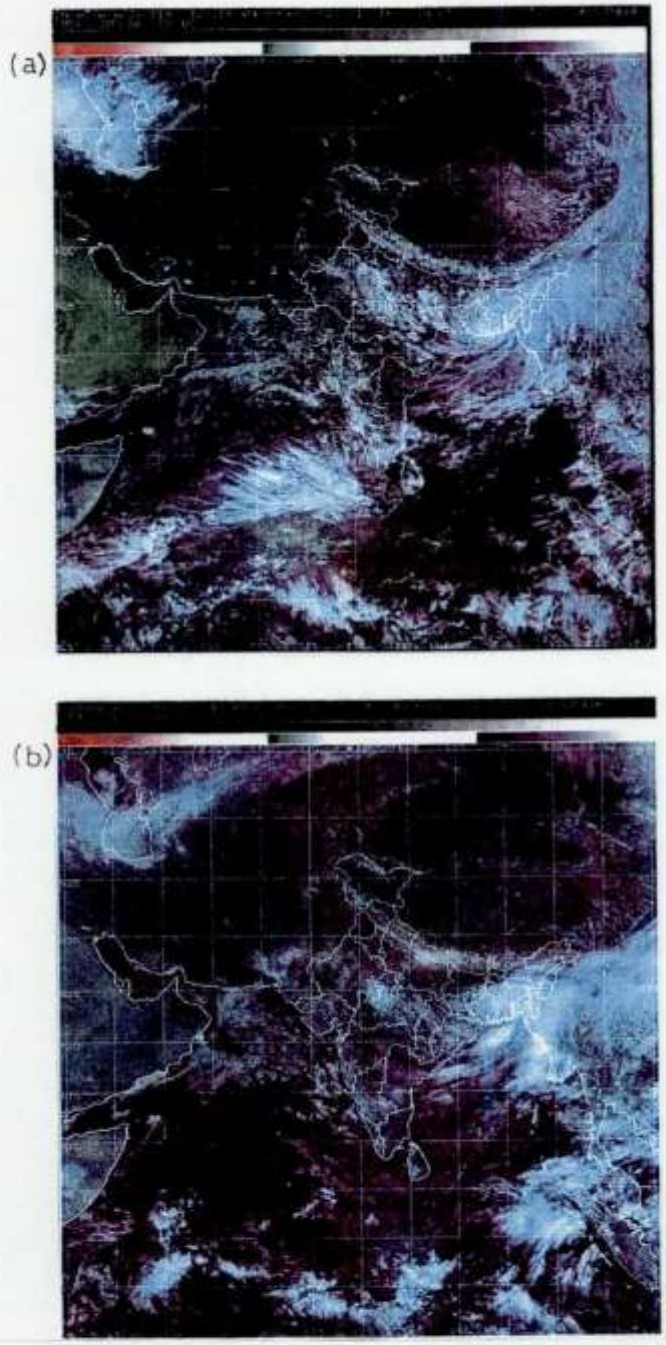
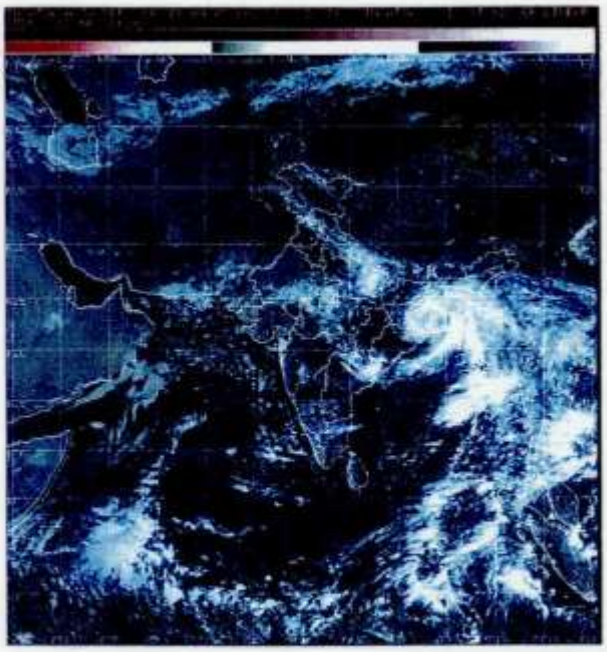


Fig. 2.5 Satellite picture shows (a) Dense cloud mass over Gangetic West Bengal, Bangladesh and adjoining sea areas when the depression lies centred near lat.2.5^0 N / long. 88.0^0 E at 0900 UTC on September 12, 2004 (b) Cloud shifted north-westwards along with the system at 0600 UTC on September 13, 2004.

(c)



(d)

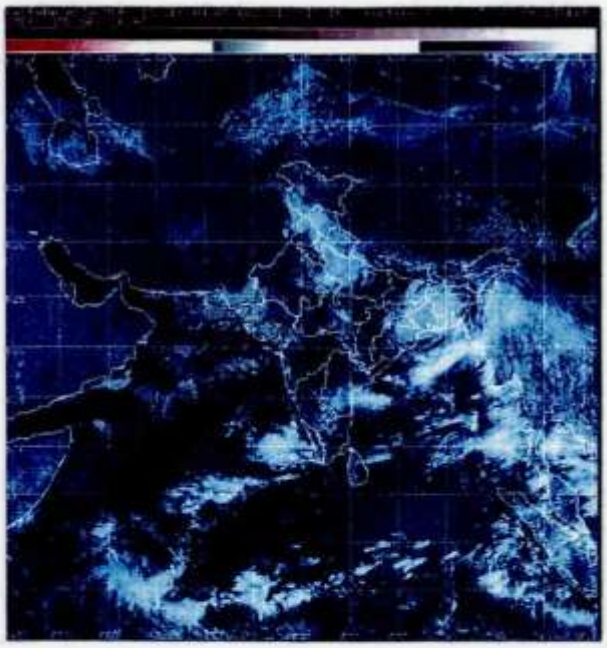


Fig. 2.5 (cont.) Satellite picture shows (c) organised cloud mass over Bangladesh and adjoining areas of northeastern states of India in association with the depression at 0500 UTC on September 14, 2004 and (d) system moved away from northeastern parts of India.

2.6 Severe Cyclonic Storm 'ONIL' over Arabian sea - 30 September - 3 October, 2004

A low pressure area formed over east central Arabian sea in the morning of 29th September. It concentrated into a **depression** on 30th afternoon when it lay centred at 300900 UTC near Lat.16.0° N and Long.69.0° E. The system moved in a north-northwesterly direction and further intensified into a **deep depression** and was centred at 301200 UTC near Lat.16.5° N /Long.68.5° E. Satellite picture of 1200 UTC showed well organised cloud mass with banding features, suggesting the intensification of the system. Continuing to move in the same direction it further intensified into a **cyclonic storm** on 1st October and lay centred at 010900 UTC near Lat.19.5° N / Long 66.5° E. Buoy MB1 near lat 20.0° N long.67.5° E reported at 0300 UTC winds of east-northeasterly /20kt. The system subsequently moved in a northerly direction and lay centred at 020300 UTC near lat 21.0° N / long 66.5° E, subsequently it re-curved north-eastwards and further intensified into a **severe cyclonic storm** at 020900 UTC near lat 21.5° N and long 67.0° E. Satellite picture showed maximum convection in the northern sector of the system.

The system weakened rapidly into a **cyclonic storm** and lay centred at 030000 UTC near Lat 23.0^0 N / Long 68.5^0 E close to Naliya (42631). The system remained practically stationary and gradually weakened into a **deep depression** on 3rd morning, as **depression** the same day evening and into a low pressure area in the morning of 4th May.

The hourly coastal observations of Saurashtra & Kutch indicated that the system remained almost stationary and weakened in situ without crossing the coast under the influence a weak steering environment between the two ridges. Low Level Circulation (LLC) associated with the system meandered over Northeast Arabian sea for a few more days.

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. A few INSAT cloud imageries of the system are given in Fig. 2.6(a-d).

Weather Realised:

The system has not produced any significant rainfall over Gujarat coast.

Damage: No damage caused due to this system.

Table 2.6

Best track positions and other parameters for Arabian Sea Severe Cyclonic Storm, 30 September- 3 October, 2004

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
30-09-2004	0900	16.0/69.0	1.5	1006	25	-	**D**
	1200	16.5/68.5	2.0	1004	30	4	**DD**
	1500	17.0/68.0	2.0	1004	30	4	DD
	1800	17.5/68.0	2.0	1006	30	4	DD
	2100	18.0/67.5	2.0	1006	30	4	DD
01-10-2004	0000	18.5/67.0	2.0	1006	30	4	DD
	0300	19.0/67.0	2.0	1006	30	4	DD
	0600	19.0/67.0	2.0	1006	30	4	DD
	0900	19.5/66.5	2.5	1002	35	6	**CS**
	1200	20.0/66.5	2.5	1000	35	6	CS
	1500	20.0/66.5	2.5	1000	35	6	CS
	1800	20.0/66.5	2.5	1002	35	6	CS
	2100	20.0/66.5	2.5	1002	35	6	CS
02.10.2004	0000	21.0/66.5	2.5	1002	35	6	CS
	0300	21.0/66.5	2.5	1000	35	8	CS
	0600	21.5/67.0	3.0	996	45	12	CS
	0900	21.5/67.0	3.5	990	55	16	**SCS**
	1200	22.0/67.5	3.5	990	55	16	SCS
	1500	22.0/67.5	3.5	990	55	16	SCS
	1800	22.5/68.0	3.5	992	55	16	SCS
	2100	22.5/68.5	3.5	992	55	16	SCS
03.10.2004	0000	23.0/68.5	2.5	998	35	10	**CS**
	0300	23.0/68.5	2.0	1002	30	6	**DD**
	0600	23.0/68.5	2.0	1004	30	4	DD
	0900	23.0/68.5	2.0	1002	30	4	**DD**
	1200	23.0/68.5	1.5	1000	25	-	**D**
	1500	23.0/68.5	1.5	1002	25	-	D
	1800	23.0/68.5	1.5	1002	25	-	D

The system weakened into a well marked low pressure area over northeast Arabian sea off kutch coast on 4th morning.

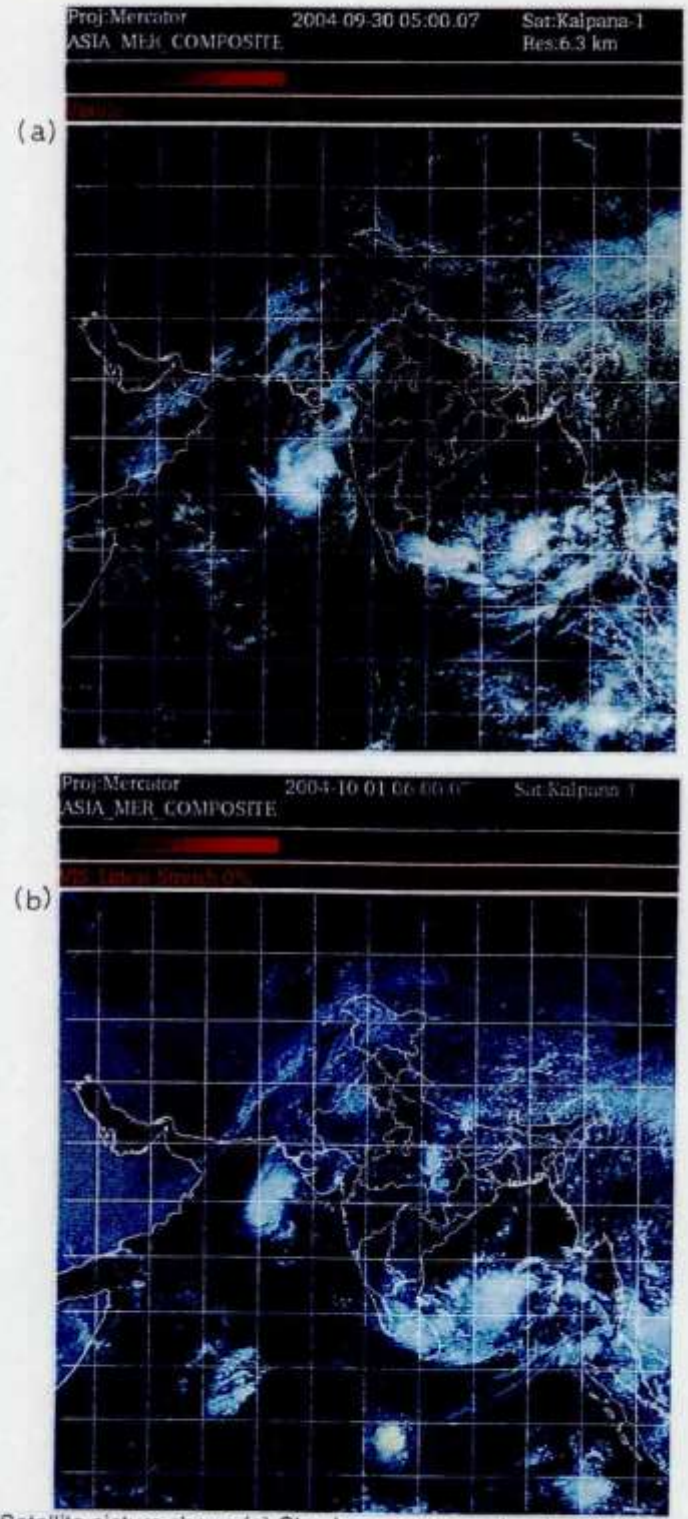


Fig. 2.6 Satellite picture shows (a) Cloud mass over eastcentral Arabian sea when the System become depression at 0500 UTC on September 30, 2004 (b) spiral bands cloud elongated north-southwards at 0600 UTC on October 1, 2004.

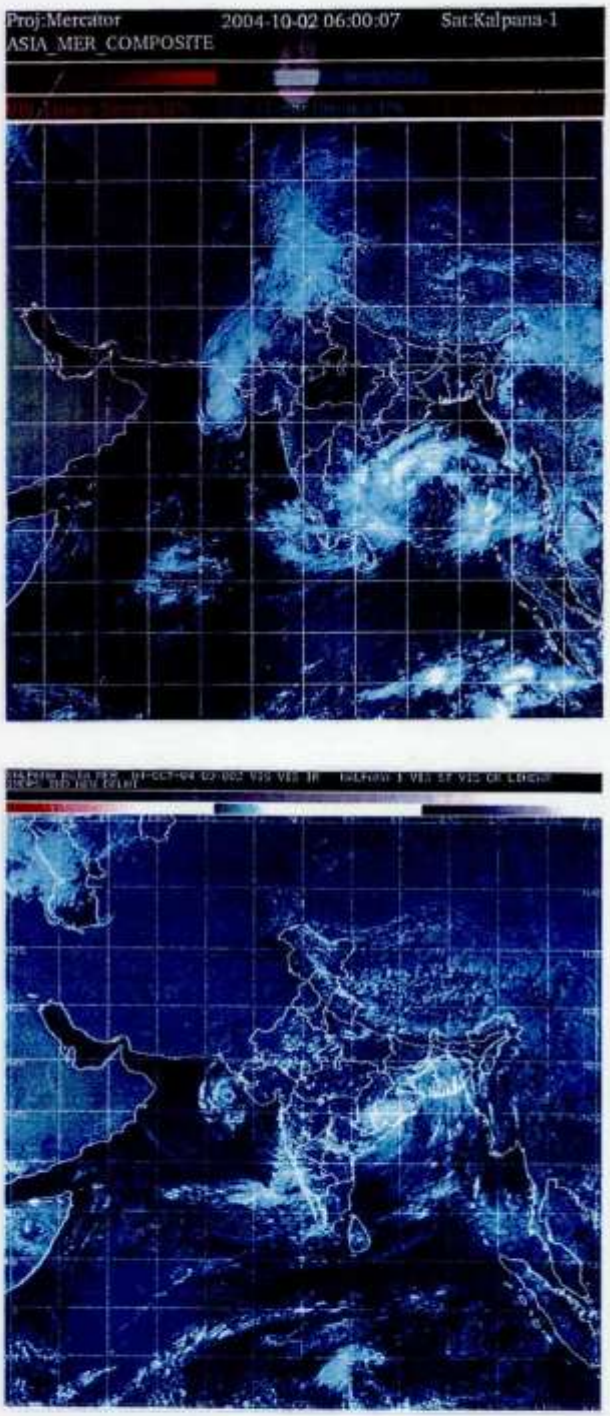


Fig. 2.6 (cont.) Satellite picture shows (c) system close to Gujarat coast with elongated cloud northwards and merge with western disturbance at 0600 UTC on October 2, 2004 and (d) system weakened over sea itself in the Gujarat coast at 0900 UTC on October 4, 2004.

2.7 Depression over Bay of Bengal - October 02-04, 2004

A low pressure area formed over south east Bay of Bengal in the morning of 30th September and became well marked in the evening of same day. Moving in north-westerly direction, it concentrated into **depression** in the morning of 2nd October and lay centred near Lat. 11.5° N and Long. 87.0° E at 020300 UTC. Subsequently moving in a northwesterly direction it lay centred near Lat. 14.5° N and Long. 84.5° E & Lat. 15.5° N and Long. 83.5° E at 030300 UTC and 031200 UTC respectively. Buoys DS3 (Lat. 12.5° N /Long. 72.0° E) & MB11 (Lat.15.1° N/ Long. 87.6° E) reported wind south-southwesterly/15kt pressure 1009.6 hPa and easterly/15kt. These Buoys were located at east and north of the Depression during that period. The 24 hour pressure fall was of the order of 2-3 hPa over south coastal Andhra Pradesh, and of the order of 4 hPa over the same area on 3rd October. The depression started giving weather in the form of rain and wind prior to reaching the coast. The depression crossed north Andhra Pradesh coast close to Kalingapatnam (43105) in the forenoon of 4th October and weakened into a Well Marked Low pressure area over north central Andhra Pradesh and adjoining Orissa and sea areas in the evening.

The track of the system is given in Fig.1.1. The best track and other parameters have been included in the table 2.7 A few INSAT cloud imageries of the system are given in Fig. 2.7(a-b).

Weather Realised :

Under the influence of the system heavy to very heavy rainfall occurred over coastal Andhra Pradesh and widespread rainfall occurred over south coastal Orissa and rest Andhra Pradesh. The significant amount of rainfall (in cm) are given as under.

1-10-2004 Venkatagiri 4

2-10-2004 Chittoor 3

3-10-2004 Yelamanchili 2

4-10-2004 Kalingapatnam 27, Santhabommali 25, Tekkali 23, Vajrapur, Kothur & Nandigama 21 each, Pallana 20, Kotabommali 17, Kanchili, Ranasthalam 16, Sompeta, Narsannapeta & Laveru 15, Srikakulam 14, Jalmuru, Polaki & lohapuram 13, Kaviti 12, Kakinada, Nagarjunsagar Dam 11, Waltair 9, Koderu 7.

Rainfall also occurred at most places with isolated heavy falls over Orissa. Some of the rainfall amounts are given below:

4-10-2004 Jeypore, Soro, Balasore 8, Nilgiri 7.

5-10-2004 Athagarh 18, Balasore 14, Chandbali 12, Rajkanika 11, Jeypore, Rajghat, Akhuapada 10, Jaleswar, Soro, Alipingal 9, Pollangi, Raigarh 16, Khandapada 14, Banpur 13, Dhenkanal, Koraput 12, Chandanpur, Nayagarh, Ranpur 10.

6-10-2004 Jaipatna 13, Balimundali, Madanpur Rampur 10, Baripada, Titlagarh, Bolgaon, 9, Panagarh 8.

Damge report:

As per the report from CWC Visakhapatnam, most of the damage occurred in north coastal Andhra Pradesh, particularly in Srikakulam district.

(a) Villages marooned in Srikakulam – 25

(b) Villages partially marooned – 15.

© Number of acres of paddy submerged - 50,000

(d) Number of tanks breached – 200

(e) Number of houses collapsed – 50

Table 2.7

Best track positions and other parameters for depression of Bay of Bengal during October 02-04, 2004

Date	Time (UTC)	Centre lat.° N/ long.° E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
02-10-2004	0300	11.5/87.0	1.5	1006	25	-	D
	0600	12.0/86.5	1.5	1006	25	-	D
	0900	12.5/86.0	1.5	1004	25	-	D
	1200	12.5/86.0	1.5	1002	25	-	D
	1500	13.0/85.5	1.5	1004	25	-	D
	1800	13.0/85.5	1.5	1006	25	-	D
	2100	13.0/85.5	1.5	1006	25	-	D
03-10-2004	0000	13.5/85.0	1.5	1006	25	-	D
	0300	14.5/84.5	1.5	1006	25	-	D
	0600	14.5/84.5	1.5	1006	25	-	D
	0900	15.0/84.0	1.5	1006	25	-	D
	1200	15.5/83.5	1.5	1006	25	-	D
	1500	15.5/83.5	1.5	1006	25	-	D
	1800	16.5/83.0	1.5	1006	25	-	D
	2100	17.0/83.0	1.5	1006	25	-	D
04-10-2004	0000	17.5/82.5	1.5	1006	25	-	D
	0300	18.0/84.0	1.5	1006	25	-	D

The depression crossed north Andhra Pradesh coast close to Kalingapatnam in the forenoon of 4th October, 2004.

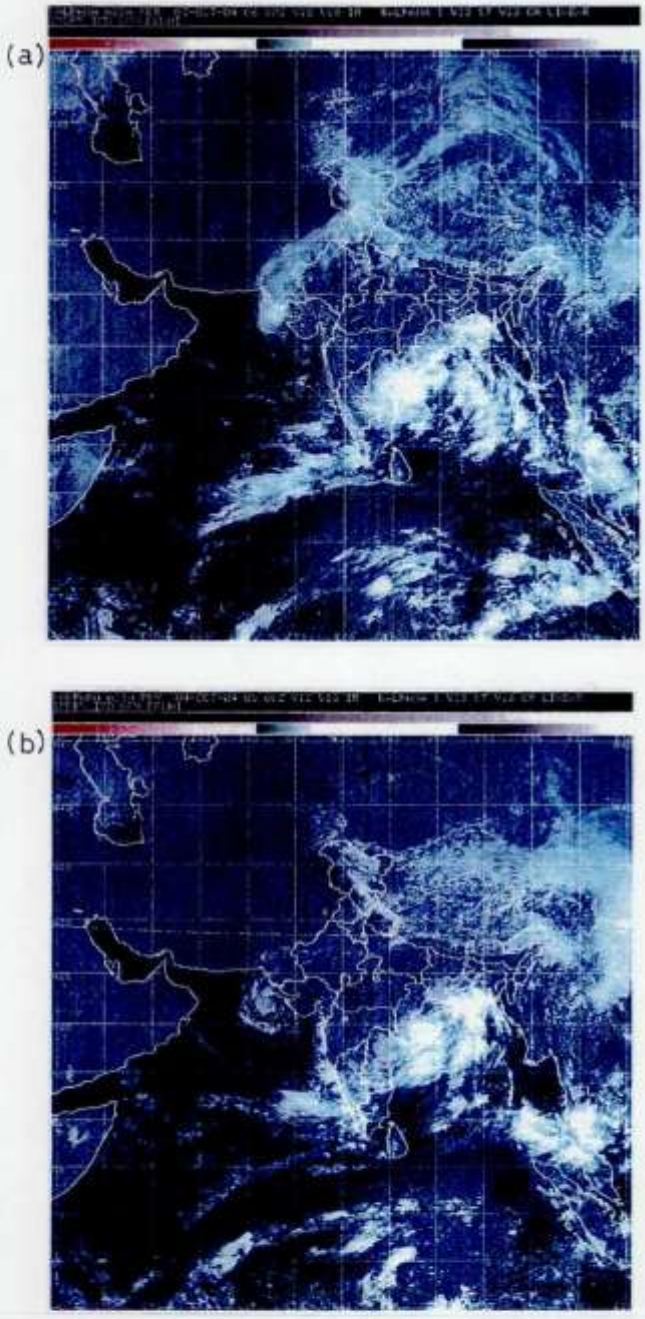


Fig. 2.7 Satellite picture shows (a) Dense cloud mass over west central Bay of Bengal in association with the depression at 0600 UTC on October 3, 2004 and (b) dense cloud mass over Gangetic West Bengal , Orissa and adjoining sea areas in association with depression at 0500 UTC on October 4, 2004, the remnant of Arabian sea cyclonic storm also seen over Gujarat coast.

2.8 Land Depression - October 07- 08, 2004

The depression which crossed north Andhra coast close to Kalingapatnam in the forenoon of October 04, 2004 weakened rapidly into a Well Marked Low pressure area in the evening. It moved northeastwards and re-intensified into a **depression** overland and lay centred at 070300 UTC, close to Bankura (42706) in Gangetic West Bengal. It further moved in an east-northeasterly direction and lay centred in the afternoon of the same day close to Shantiniketan (42708) and at 080300 UTC over Bangladesh (near lat. 24.0^{0}N/ long. 90^{0}E). Due to incursion of moisture from the Bay of Bengal, the system caused exceptionally heavy rainfall over Gangetic West Bengal and northeastern states during its life span. The system weakened gradually into a **Low Pressure Area** over northern parts of Bangaladesh and neighbourhood in the evening of October 8, 2004.

The track of the system is given in Fig.1.1. The best track and other parameters have been included in the table 2.8 A few INSAT cloud imageries of the system are given in Fig. 2.8(a-b).

Weather Realised:

The system resulted in exceptional heavy to very heavy rainfall that occurred along its movement during the period October 7-9, 2004. The significant amount of rainfall (in cm) is given below:

07.10.2004
Malda-28, Tantloi -27, Tilpara-26, Mahro-23, Suri-20, Massanjore-18, Khesiary-16, Durgapur-15. Shillong Guwahati and Diamond Harbour-14 each, Kolkata-13,Haldia-12, Honawar-10, Canning-8, Shantiniketan, Talchar and Telkoi-7 each and Mundali-6.

08.10.2004
Alipurduar (NH)-31, Shillong-26, Malda-15, Guwahati-15, Tejpur-11, Kolkata, Berhampur, Hindol, Udala and Lanjigarh-6 each Jalpaiguri, Canning town, Agartala, Sevoke, Gajoldoba and Mathabhanga-5, each.

09.10.2004
Tejpur, Passighat and Dibrugarh-4 each and Imphal-2.

Damage:

Gangetic West Bengal
People died =51, Birds died = 3000 Migratory Birds , House damage = 1 0
Agricultural crop damage = Rs. 110 Crores, People affected = 10 Lakh

Orissa
People died = 4, One bridge washed away and Several Villages affected due to flood.

Northeastern States
People died = 218
People affected = 783622
Agricultural crop damage = 98721 Hectares.

Table 2.8

Best track positions and other parameters for land depression during October 07-08, 2004, 2004

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
07-10-2004	0300	22.5/87.0	-	1006	25	-	D
	1200	23.5/88.0	-	1004	25	-	D
08-10-2004	0300	24.0/90.0	-	1004	25	-	D

The depression weakened into a low pressure area over northern parts of Bangladesh and neighbourhood in the evening of October 8, 2004

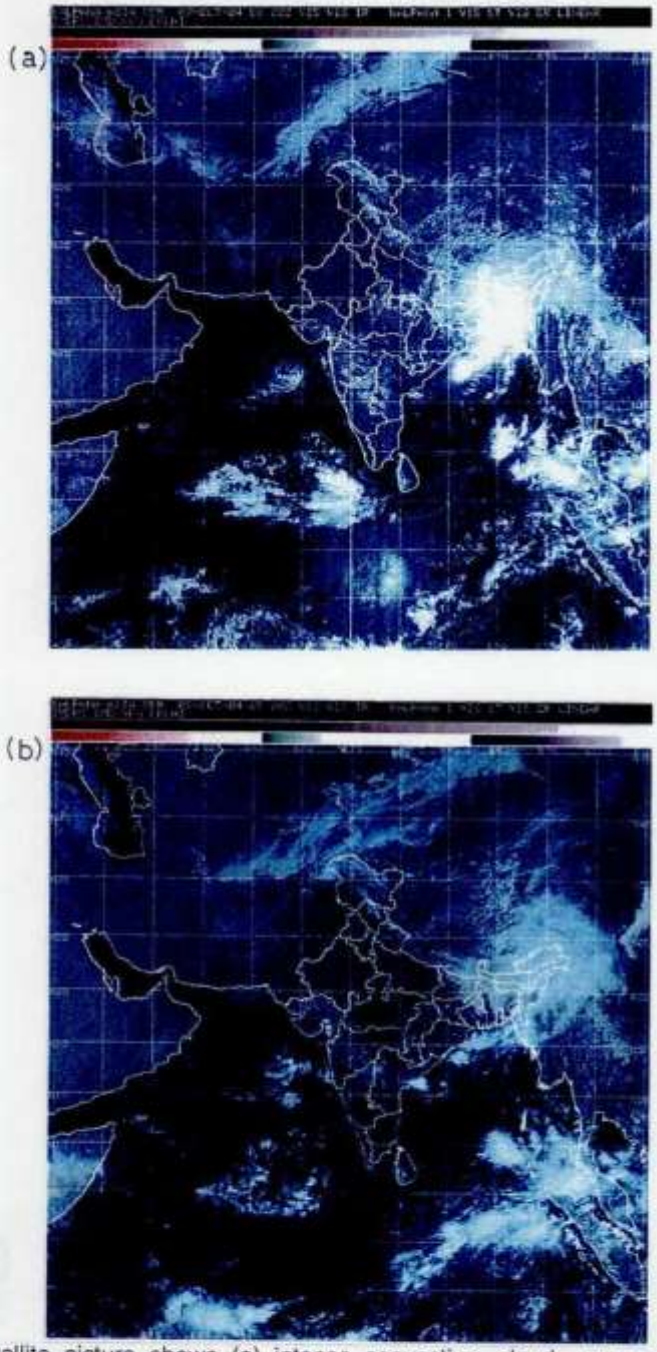


Fig. 2.8 Satellite picture shows (a) intense convective cloud over eastern India in Association with Land Depression at 0600 UTC on October 7, 2004 and (b) system weakened into a low pressure area and moved away from northeast India at 0500 UTC on October 8, 2004.

2.9 Deep Depression over Southeast Arabian sea - November 02-07, 2004

A low pressure area formed over southeast Arabian sea on 1st November, It concentrated into a **depression** at 021200 UTC and lay centred near Lat. 12.0° N / Long 67.0° E. The depression moved in a west-northwesterly direction and lay centred at 030300 UTC and 031200 UTC near lat. 13.0° N/lat. 67.0° E and lat. 13.5° N/lat. 67.0° E respectively. The depression moved in a northerly direction and lay centred at 041200 UTC near lat. 14.0° N / lat. 67.0° E. Remaining practically stationary it intensified into a **deep depression** at 050300 UTC. Moving in a west-northwesterly direction it lay centred at 051200 UTC near lat. 15.0° N / long. 66.0° E. Thereafter it moved in a westerly direction and was centred at 060300 UTC near lat. 15.0° / long. 63.0° E. It weakened into a **depression** at 060900 UTC and was located at 061200 UTC near lat. 15.0° N/ long. 61.0° E. Subsequently it moved west-southwestwards and weakened into a low pressure area in the morning of November 8, 2004.

The track of the system is given in Fig.1.1. The best track and other parameters have been included in the table 2.9. A few INSAT cloud imageries of the system are given in Fig. 2.9 (a-b)

Weather realised : No adverse weather occurred over the Indian sub-continent as the system was far away.

Damage: Nil

Table 2.9

Best track positions and other parameters for deep depression of Arabian sea during November 2-7, 2004

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
02-11-2004	1200	12.0/67.0	1.5	1006	25	--	D
03-11-2004	0300	13.0/67.0	1.5	1006	25	--	D
	1200	13.5/67.0	1.5	1006	25	--	D
04-11-2004	0300	13.5/67.0	1.5	1006	25	--	D
	1200	14.0/67.0	1.5	1006	25	--	D
05-11-2004	0300	14.0/67.0	2.0	1004	30	4	DD
	1200	15.0/66.0	2.0	1004	30	4	DD
06-11-2004	0300	15.0/63.0	2.0	1006	30	4	DD
	0900	15.0/61.5	1.5	1006	25	-	D
	1200	15.0/61.0	1.5	1006	25	-	D
07-11-2004	0300	14.5/58.5	1.5	1006	25	-	D
	0900	14.0/57.0	1.5	1008	25	-	D
	1200	13.5/56.5	1.5	1010	25	-	D

The depression weakened into a low pressure area in the morning of November 8, 2004 over westcentral Arabian sea.

(a)

(b)

Fig. 2.9 Satellite picture shows (a) intense convective cloud over central Arabian sea in association with depression at 0600 UTC on November 5, 2004 and (b) cloud picture when the system close to Somalia coast as deep depression, the dense cloud mass was in the northeastern sector of the system at 0900 UTC on November 7, 2004.

2.10 Severe cyclonic storm ' AGNI' over Arabian sea – Nov 29 to Dec 02, 2004

A low pressure area formed over southeast Arabian sea on 28th November, 2004 closed to the equator. The system concentrated into a **depression** at 290300 UTC and lay centred near lat 1.5° N long 66.0° E. Subsequently it moved in a northwesterly direction and intensified rapidly into a **cyclonic storm** and lay centred at 291200 UTC near lat 3.0° N long 64.5° E and at 300300 UTC near lat 5.0° N/long 62.5° E. The system intensified further into a **severe cyclonic storm** and lay centred at 300600 UTC near lat 5.5° N/long 61.5° E and started to move in a west-northwesterly direction due to upper air ridge which lay along 10.0° N over north Indian ocean. It maintained its intensity as a severe cyclonic storm till mid night of 30th November. Thereafter under the influence of cold water and strong vertical wind shear the system weakened into a cyclonic storm at 301800 UTC centred near Lat 6.0° N/Long. 60.0° E. The system continued to weaken while moving in the same direction and lay centred near Lat 7.5° N/ Long 58.5° E as **deep depression** on 010900 UTC, and into a **depression** at 020300 UTC near lat 8.0° N / Long 56.5° E and at 021200 UTC near lat 8.0° N/Long 55.0° E. Moving in a westerly direction the depression further weakened into a low pressure area in the morning of 3rd December.

The track of the system is given in Fig.1.1. The best track and other parameters have been included in the table 2.10 A few INSAT cloud imageries of the system are given in Fig. 2.10 (a-d)

Weather realised : No weather realised as system is far away from the Indian sub-continent.

Damage: Nil

Table 2.10

Best track positions and other parameters for deep depression of Arabian sea - Nov. 29-Dec. 2, 2004

Date	Time (UTC)	Centre lat.° N/ long.° E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimate Pressure drop at the Centre (hPa)	Grade
29-11-2004	0300	1.5/66.0	1.5	1006	25	-	D
	0600	2.0/65.5	1.5	1006	25	-	D
	0900	2.5/65.0	1.5	1006	25	4	D
	1200	3.0/64.5	2.5	1004	35	6	CS
	1500	3.5/64.0	2.5	1004	35	6	CS
	1800	3.5/64.0	2.5	1004	35	6	CS
	2100	3.5/63.5	2.5	1004	35	6	CS
30-11-2004	0000	4.5/63.0	2.5	1004	35	6	CS
	0300	5.0/62.5	3.0	998	45	10	CS
	0600	5.5/61.5	3.5	994	55	14	SCS
	0900	6.0/61.0	3.5	994	55	14	SCS
	1200	6.0/60.5	3.5	994	55	14	SCS
	1500	6.0/60.5	3.5	994	55	14	SCS
	1800	6.0/60.0	3.0	998	45	10	CS
	2100	6.5/60.0	3.0	1000	45	10	CS
01-12-2004	0000	7.0/59.5	2.5	1002	35	8	CS
	0300	7.0/59.5	2.5	1002	35	8	CS
	0600	7.0/59.5	2.5	1002	35	8	CS
	0900	7.5/58.5	2.0	1004	30	4	DD
	1200	7.5/58.5	1.5	1006	25	4	DD
02-12-2004	0300	8.0/56.5	1.5	1006	25	-	D
	1200	8.0/55.0	1.5	1006	25	-	D

The depression moved west-northwestward and weakened into a low pressure area over southwest Arabian sea in the in the morning of December 3,2004

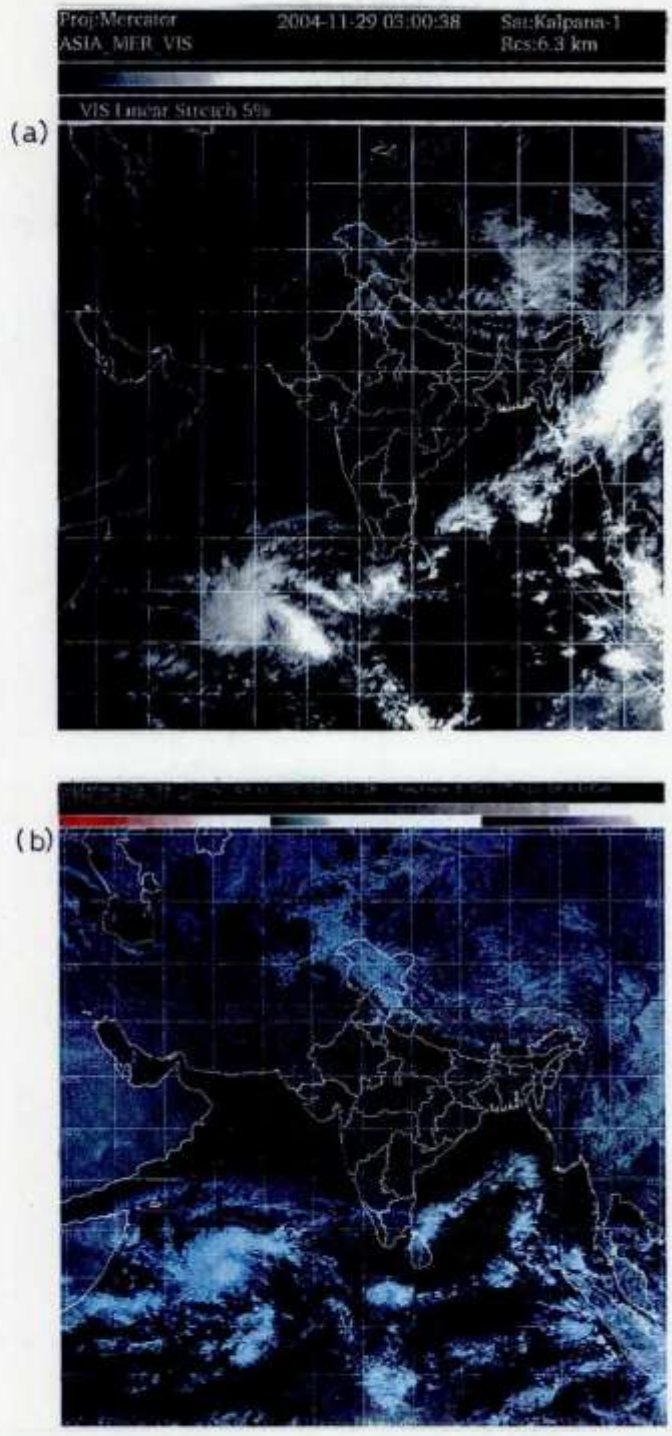
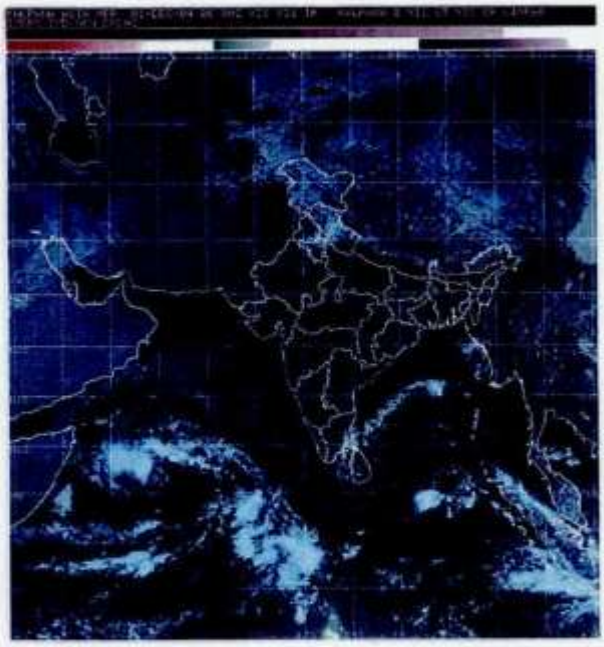


Fig. 2.10 Satellite picture shows (a) intense convective cloud over southeast Arabian sea in association with depression at 0300 UTC on November 29, 2004 and (b) cloud dense overcast (CDO) seen over the system centre in association with cyclonic storm at 0600 UTC on November 30, 2004.

(c)



(d)

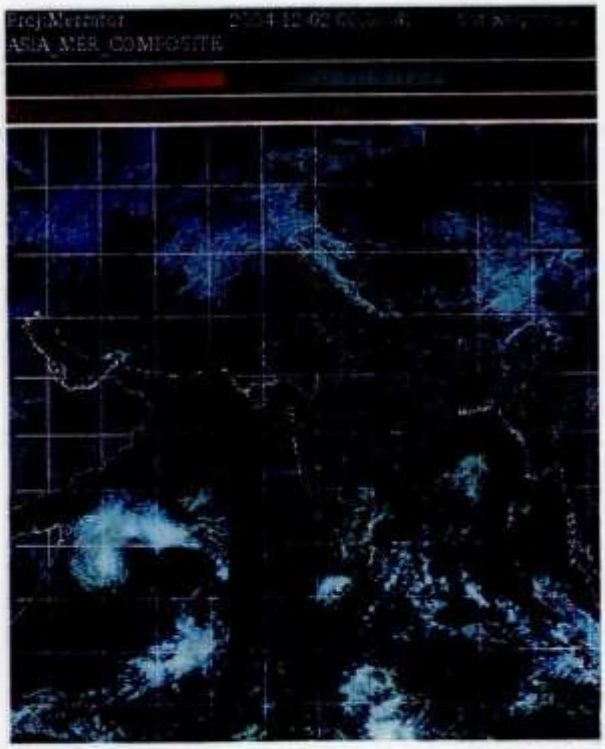


Fig. 2.10 (contd) Satellite picture shows (c) intense convective cloud with weakening sign over northeast sector of the cyclonic storm at 0600 UTC on December 1, 2004 and (d) cloud picture, when the system weakened into a depression and convection over western sector of the depression at 0600 UTC on December 2, 2004.

Chapter III

Track prediction by Numerical Models

During the year 2004 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 over the Bay of Bengal and Arabian Sea. The QLM model was run to produce track forecasts based on the initial conditions of each day based on 00 UTC and 12 UTC observations when the disturbance was in cyclonic storm stage, where as the LAM forecasts were produced regularly in respect of 00 UTC and 12 UTC observations for day-to-day operational use.

A quantitative assessment of the performance of forecast model (QLM) was made by computation of track prediction errors. Two types of prediction errors have been computed. Direct position errors were 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.

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). The mean position errors for 24H forecast by QLM ranges between 144 to 200 km with an average of 176 km for all the four cases and for the 36 hours forecast mean position error ranges from 200 km to 244 km with an average of 223 km.. The angular deviation for 24 hours forecast ranges from 18 ° to 25 ° with an average of 21 ° and for 36 hours forecast it ranges from 11° to 30 ° with an average of 22 °.

TABLE 3.1: TRACK PREDICTION ERRORS (QLM)

Period	24 H		36 H	
	Position Error (km)	Angular Deviation (Deg)	Position Error (km)	Angular Deviation (Deg)
SCS of 06-10 May (Arabian Sea)	171	18	244	11
VSCS of 16-19 May (Bay of Bengal)	200	20	220	20
SCS 30 Sept to 04 October (Arabian Sea)	190	22	200	25
SCS of 29 Nov to 02 Dec (Arabian Sea)	144	25	230	30
Mean of above four cases	176	21	223	22

Results of 72 hours experimental run for the case of Severe Cyclonic Storm of May 2004 over the Arabian Sea

Very recently the QLM is upgraded and the upgraded version is run in experimental mode for the 72 hours forecast for the case of severe cyclonic storm of May 2004 over the Arabian Sea. The results of six hourly forecast valid upto 72 hours are described below:

Fig. 1 shows the map of mean sea level pressure analysis on the QLM grid at 00 UTC of 06 May 2004, as obtained from the operational global output fields of NCMRWF, following the procedure describer earlier. Observed Track of the cyclonic storm along with the predicted track are also shown in the Fig. 1. Five closed isobars are very clearly seen in the analysis with lowest isobar is of the value 994 hPa, located over southeast Arabian Sea north off Lakshdweep. Similarly Fig. 2 shows the map of mean sea level pressure analysis at 00 UTC of 07 May 2004, which indicates six closed isobars with lowest value of 992 hPa and is centered at slightly north-northwesterly position compared to that of previous day as shown in Fig. 1.

The corresponding 72h forecast of streamline flow at 850 hPa valid on 00 UTC of 09 May and 00 UTC of 10 May are shown in Fig. 3 and Fig. 4 respectively. The forecast tracks show the north-northwesterly movement of the system like that of observed tracks in Fig.3 and Fig. 4. However, with respect to the speed of the system, it is more or less matching well with the observed speed in case of forecast based on 00 UTC of 06 May, when the system was relatively weak (Fig. 3). But the predicted tracks show very rapid movement in case of the forecast based on 00 UTC of 07 May, when the system was relatively stronger than previous day (Fig. 4). The maximum forecast error in the position of the system is about 1^0 to 1.5^0 (Fig. 3) in case of analysis of 00 UTC of 06 May, and is slightly higher (about 2^0) in case forecast based on the analysis of 00 UTC of 07 May (Fig.4).

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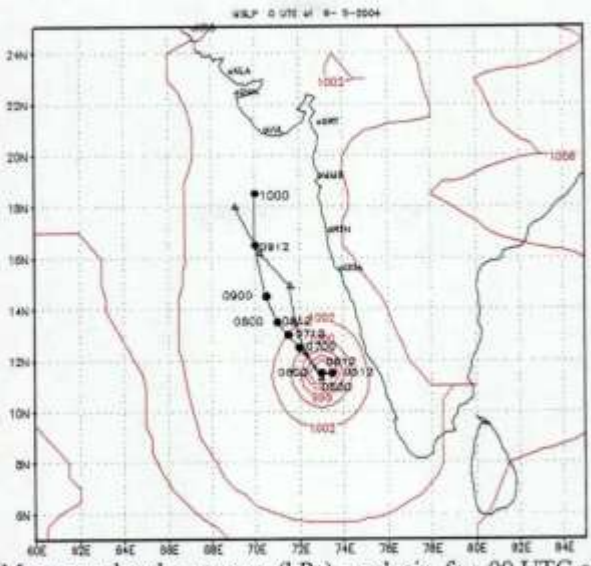

Fig. 1 : Mean sea level pressure (hPa) analysis for 00 UTC of 06 May 2004 and track forecast based on 06 May/00 UTC initial conditions with idealized vortex (• : observed; Δ : predicted).

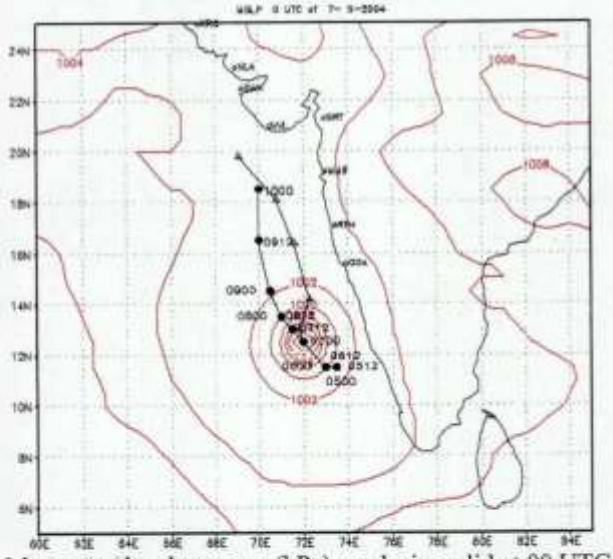

Fig. 2 : Mean sea level pressure (hPa) analysis valid at 00 UTC of 07 May 2004 and track forecast based on 07 May/00 UTC initial conditions with idealized vortex (• : observed; Δ : predicted).

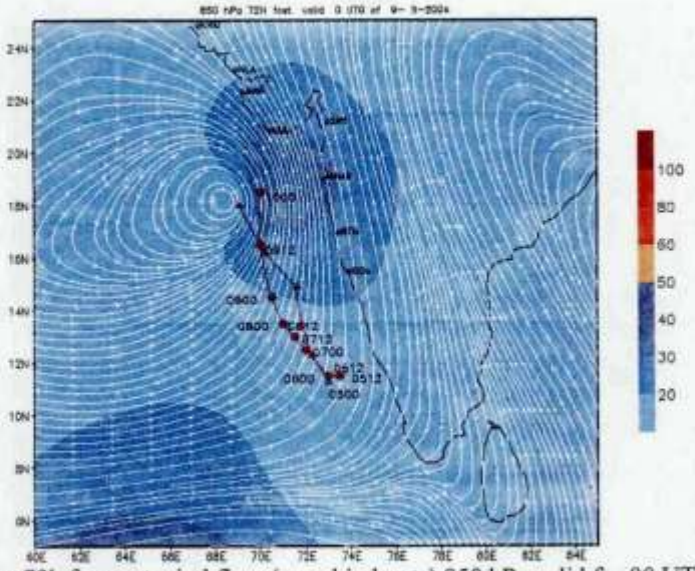

Fig. 3: 72h forecast wind flow (speed in knots) 850 hPa valid for 00 UTC of 09 May 2004 with idealized vortex (• : observed; Δ : predicted).

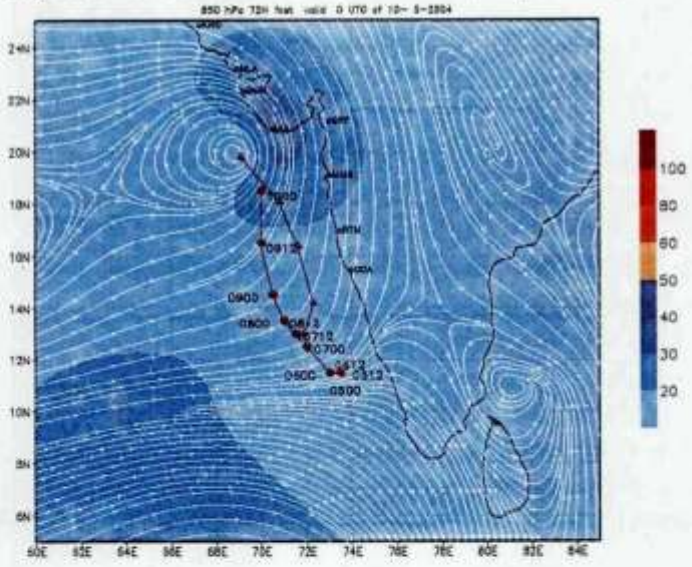

Fig. 4: 72h forecast wind flow (speed in knots) 850 hPa valid for 00 UTC of 10 May 2004 with idealized vortex (• : observe d; Δ : predicted).

THE MODEL FORECAST BY PERSISTENCE (P),CLIMATOLOGY (C) AND CLIPER (CLIP)

The errors in the predicted positions by PERSISTENCE (P),CLIMATOLOGY (C) , AND CLIPER (CLIP) models from the actual track positions for the tropical cyclones in north Indian Ocean during 2004 are given below in table 3.2. Persistence forecast for severe cyclonic storm May 5-10, was very close to actual position such that the error was 78 km for 12 hrs. and 55 km for 24 hrs .For the severe cyclonic storm September 30 – October 03 Climatology forecast for 12 hrs. was close to actual position i.e. 71 km. for 24 hours. Persistence forecast was also close to the actual position i.e. 78 km for 24 hrs for the severe cyclonic storm Nov. 29-Dec 02, 2004.

Table 3.2

Forecast position errors for tropical cyclones in the Bay of Bengal and the Arabian sea during 2004 based on PERSISTENCE (P),CLIMATOLOGY (C) , AND CLIPER (CLIP) Models.

Date	PERSISTANCE (Km)			CLIMATOLOGY (Km)			CLIPER (Km)		
	12 hrs	24 hrs	36 hrs	12 hrs	24 hrs	36 hrs	12 hrs	24 hrs	36 hrs
May 5-10, 2004,SCS, ARB	78	55	174	132	145	139	105	95	141
May 16-19, 2004, VSCS, BOB	156	198	296	248	376	405	201	285	324
Sept. 30-Oct. 03, 2004, SCS, ARB	94	233	332	71	143	102	74	183	153
Nov. 29-Dec 02, 2004, SCS, ARB	110	78	165	--	--	--	----	--	--
Average	**110**	**141**	**242**	**150**	**221**	**215**	**127**	**188**	**206**

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Uprooted coconut trees in Lakshadweep area on 6th May 2004
due to Arabian Sea Severe Cyclonic Storm