Activities of RSMC, New Delhi

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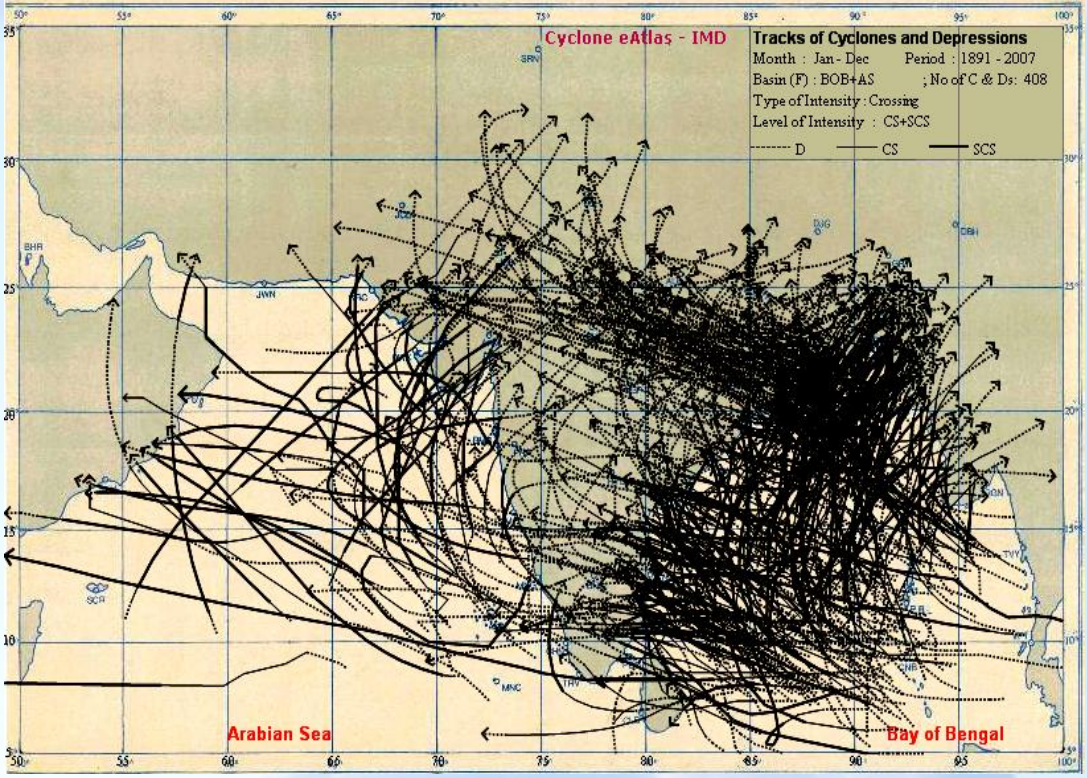
Presentation layout

- Introduction
- Role of Regional Cooperation
- Early Warning System for TC over north Indian Ocean
  - Observational network
  - Data availability
  - TC analysis and forecasting tools and techniques
  - Decision making Procedure
  - Bulletins and products
  - Gaps and Future Prospects

Impact of Cyclones

TYPES OF POTENTIAL DAMAGES ACCOMPANYING TROPICAL CYCLONES

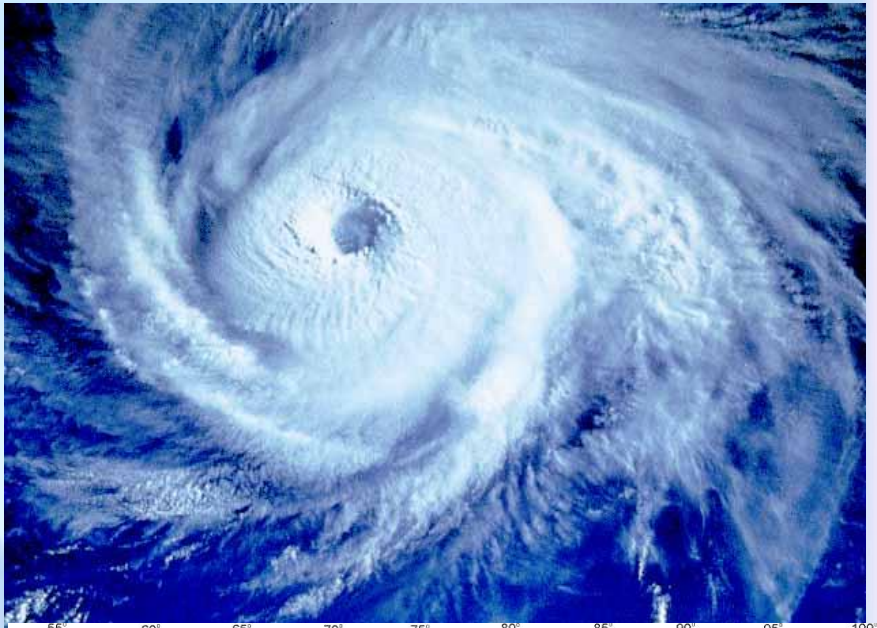
- CYCLONE → STORM SURGE
- LOCAL TIDES → STORM SURGE
- LOCAL COASTAL CONFIGURATION → STORM SURGE
  - FLOODING OF COASTAL AREAS
  - EROSION OF BEACHES
  - LOSS OF SOIL FERTILITY FROM SALINE INTRUSIONS
- WIND
  - DAMAGE TO STRUCTURES
  - LOSS OF POWER/COMMUNICATION
  - INJURIES & LOSS OF LIFE
  - DESTRUCTION OF CROPS, VEGETATION, LIVE-STOCK
- RAIN
  - CONTAMINATION OF WATER SUPPLY SYSTEM
  - LAND SUBSIDENCE
  - FLOODING OF INLAND AREA

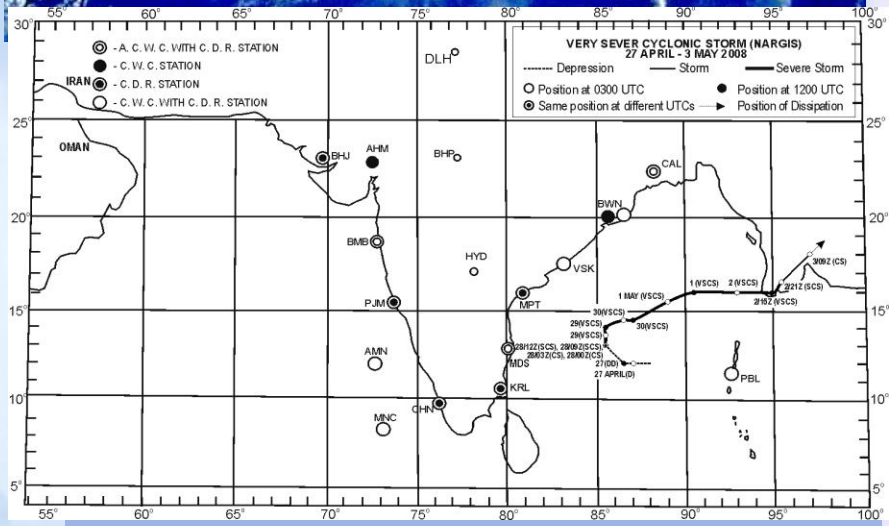


- Out of 80 forming over the globe, five form over north Indian Ocean
- Ratio of TCs between Bay of Bengal and Arabian Sea – 4:1
- Year to year variation - Quite large. Minimum No. of cyclones in a year - One (1949),Maximum No.of cyclones in a year –Ten (1893,1926,1930,1976)
- Bay of Bengal is a vast warm pool adjoining the warm pool of the western North Pacific.
- The ocean currents are quite complex.
- The bathymetry of the coast is also very complex due to a number of rivers, deltaic regions and orography

DEATHS IN TROPICAL CYCLONES

YEAR	COUNTRIES	DEATHS
1970	Bangladesh	500,000
1737	India	300,000
1886	China	300,000
1923	Japan	250,000
1876	Bangladesh	200,000
1897	Bangladesh	175,000
1991	Bangladesh	140,000
2008	Myanmar	138,000
1833	India	50,000
1864	India	50,000
1822	Bangladesh	40,000
1780	Antilles(West Indies)	22,000
1965	Bangladesh	19,279
1999	India	10,000
1963	Bangladesh	11,520
1961	Bangladesh	11,466
1985	Bangladesh	11,069
1971	India	10,000
1977	India	10,000
1966	Cuba	7,196
1900	USA	6,000
1960	Bangladesh	5,149
1960	Japan	5,000
1972	India	5,000





NARGIS :
An Example of recent devastating cyclone

WMO/ESCAP Panel on Tropical Cyclones

- Established in 1973
  - Members

Bangladesh

India

(RSMC, New-Delhi)

Maldives

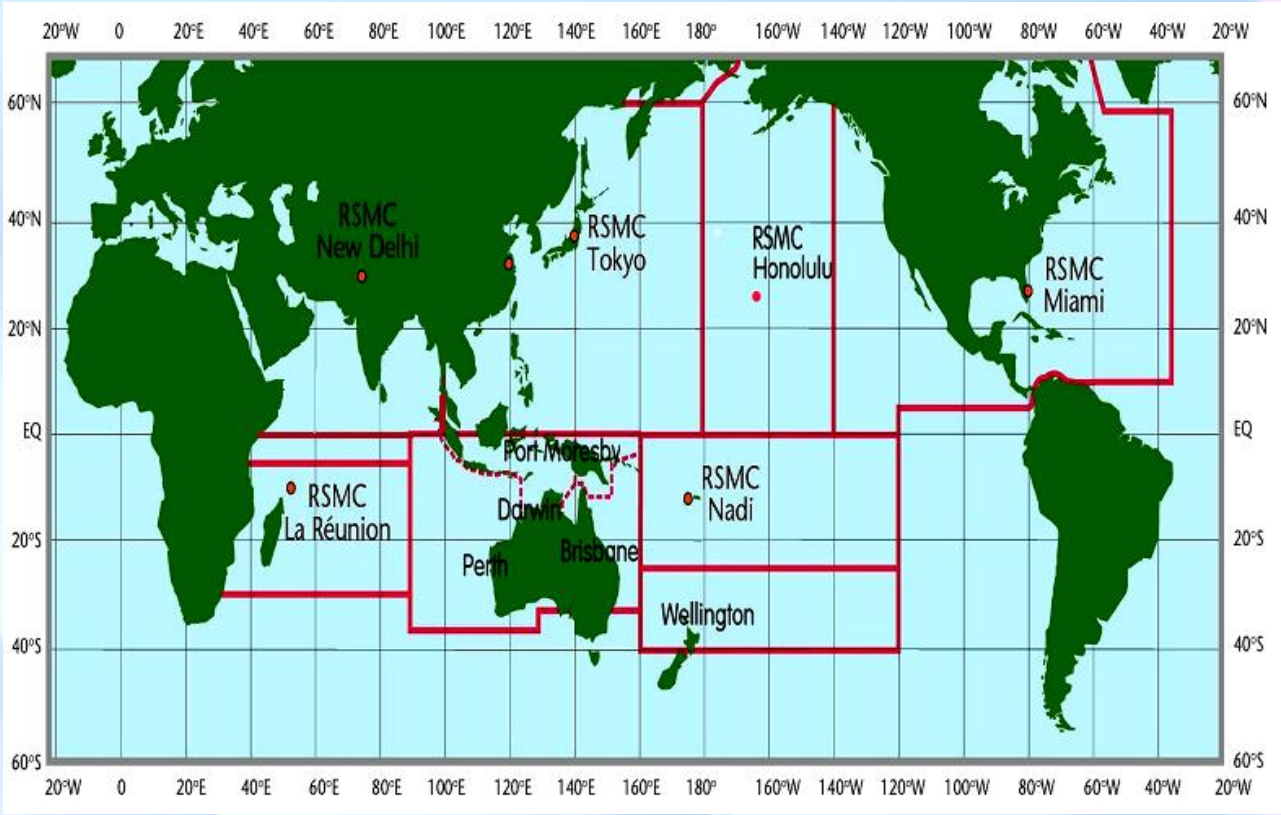
Myanmar

Oman

Pakistan

Sri Lanka

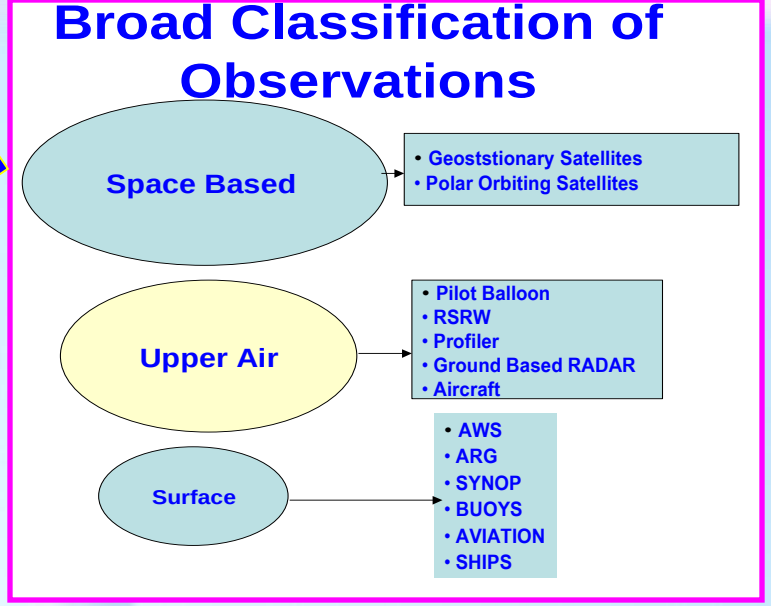
Thailand



Functions of RSMC - New Delhi

- Monitoring Cyclonic Disturbances over the North Indian Ocean (Bay of Bengal and Arabian Sea)
- Running Numerical Models for Cyclone Track prediction (QLM) and Storm Surge prediction models (IIT Delhi)
- Issue of Tropical weather outlook/ Cyclone Advisories to the Panel Countries
- Issue of Tropical Cyclone Advisories for Aviation as per the guidelines of ICAO
- Collection, Processing & archival of data pertaining to tropical cyclones over the NIO and their exchange with member countries of the Panel
- Implementation of Regional Cyclone Operation Plan of WMO/ESCAP Panel
- Preparation of Annual Review, RSMC reports and updating of Cyclone operational cyclone operational plan
- Research on Storm Surge, Track & Intensity Prediction Techniques

Monitoring and Forecast Process



Initial conditions (Observations)

Runs of different Models,

Consecutive runs from the same model,

Ensemble runs ("choosing the best member")

Model runs

Forecaster

Decision maker

Action

Numerical forecasts

End forecast

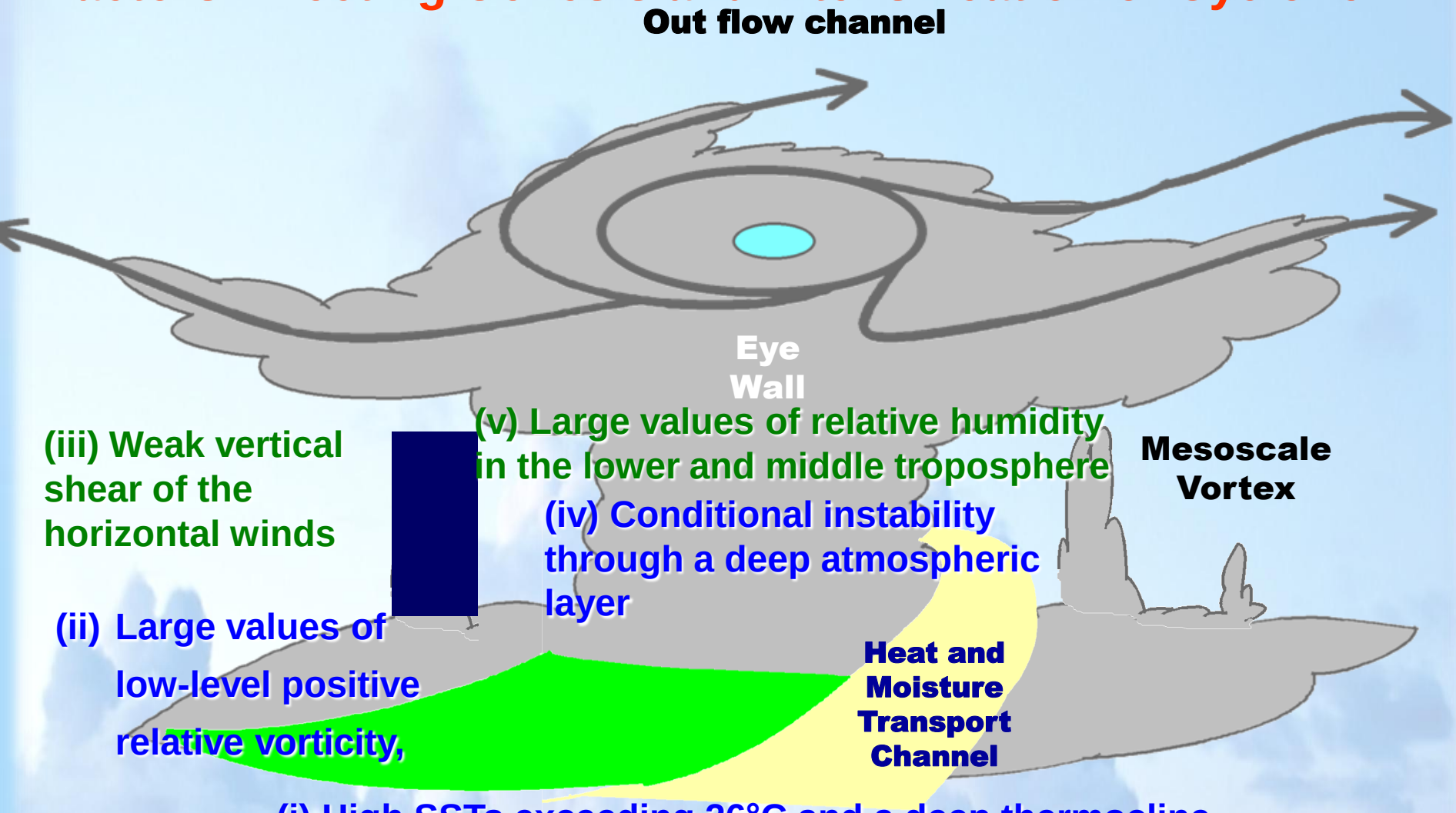
Monitoring and Forecast Process of Tropical Cyclone

Evolution of Cyclonic disturbances Over the Indian Seas

Low pressure system	Maximum sustained winds	
Low	< 17 knots	< 31 kmph
Depression	17 – 27 kts	31 – 51 kmph
Deep Depression	28 – 33 kts	52 – 62 kmph
Cyclone	34 – 47 kts	63 – 87 kmph
Severe Cyclone	48 – 63 kts	88 – 117 kmph
Very Severe Cyclone	64 – 119 kts	118 – 221 kmph
Super Cyclone	120 kts & above	222 kmph & above

System	No. of closed isobars at interval of 2 hPa
Low	1
Depression	2
Deep Depression	3
Cyclone	4 -7
Severe Cyclone	8-10
Very Severe Cyclone	11-39
Super Cyclone	40 or more

Factors Affecting Genesis and intensification of Cyclone



(Heavily dependent on Ocean observations)

Observational Organisation

Cyclone Track and Intensity Data Sources

For monitoring and prediction purpose, the following data sources are used in general

Global Data Networks

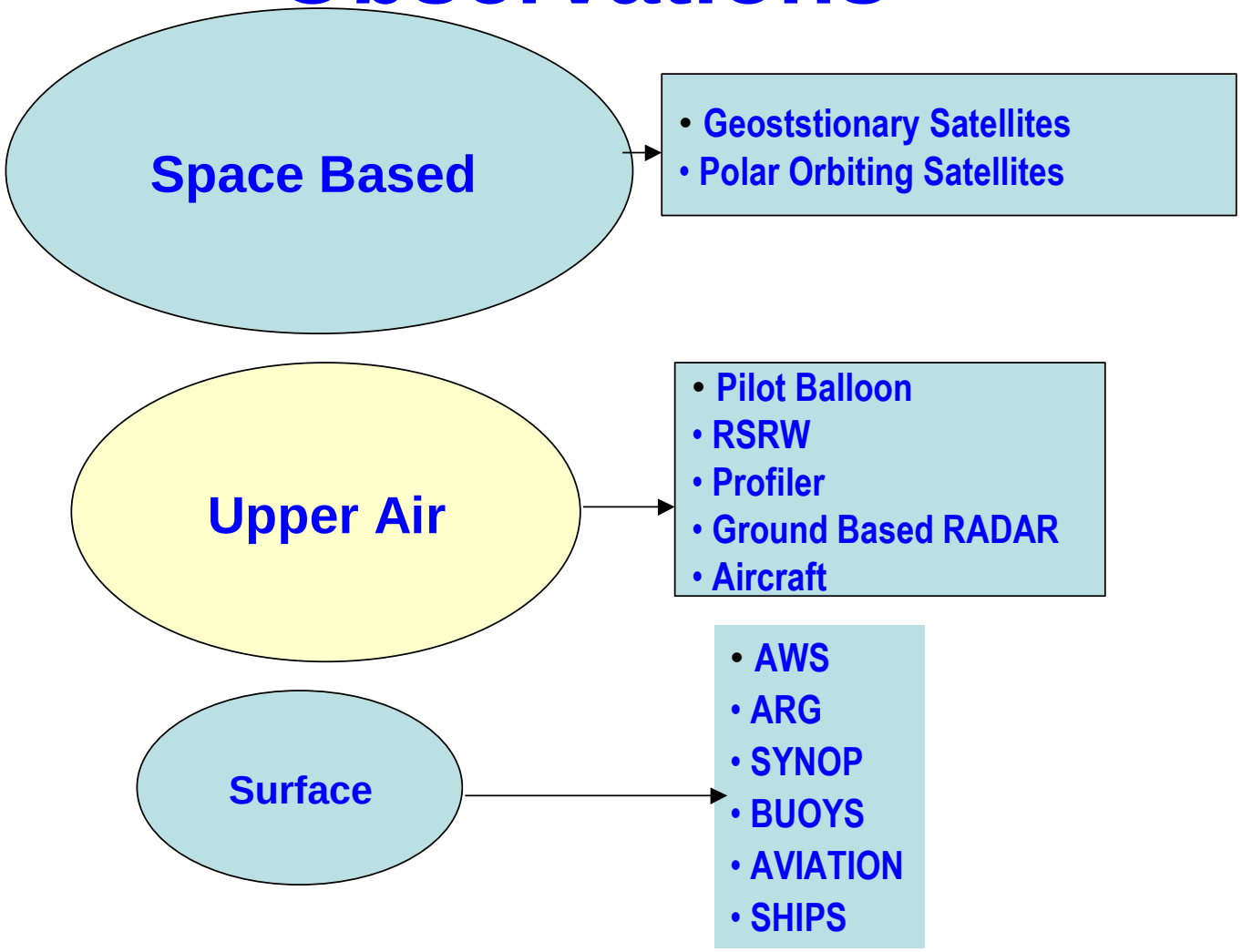
- Surface observations
- Ocean Observations
- Upper Air Observations
- Satellite Data

Critical Cyclone Data Platforms

- Doppler Weather Radar Data
- Aircraft (reconnaissance and surveillance)

Cyclone Monitoring

Broad Classification of Observations



Surface Stations (manned) –

Departmental (203)

Surface Stations (manned)

Non-Departmental (247)

675 Automatic Weather Stations

127 Agro-AWS

548 AWS

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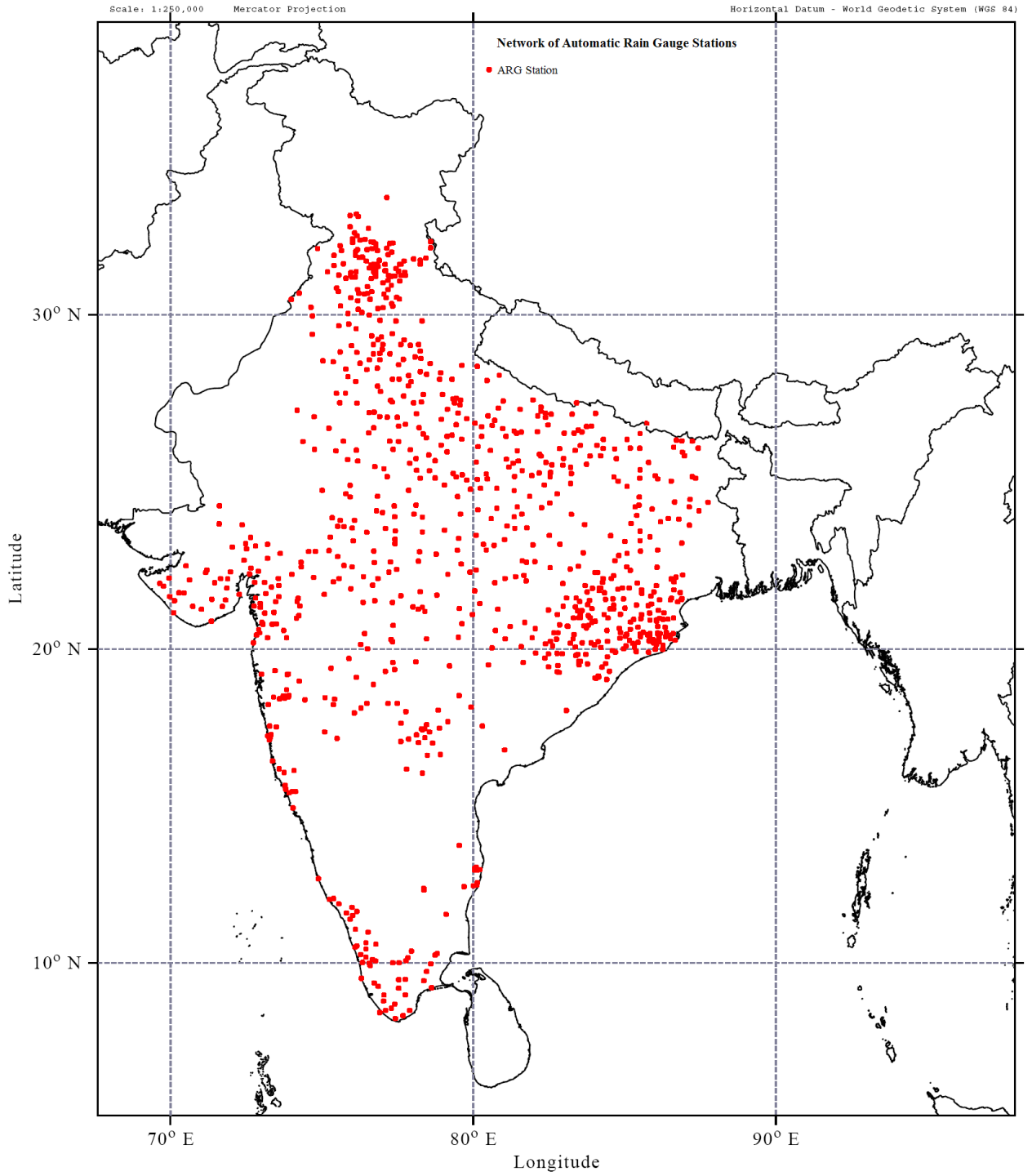
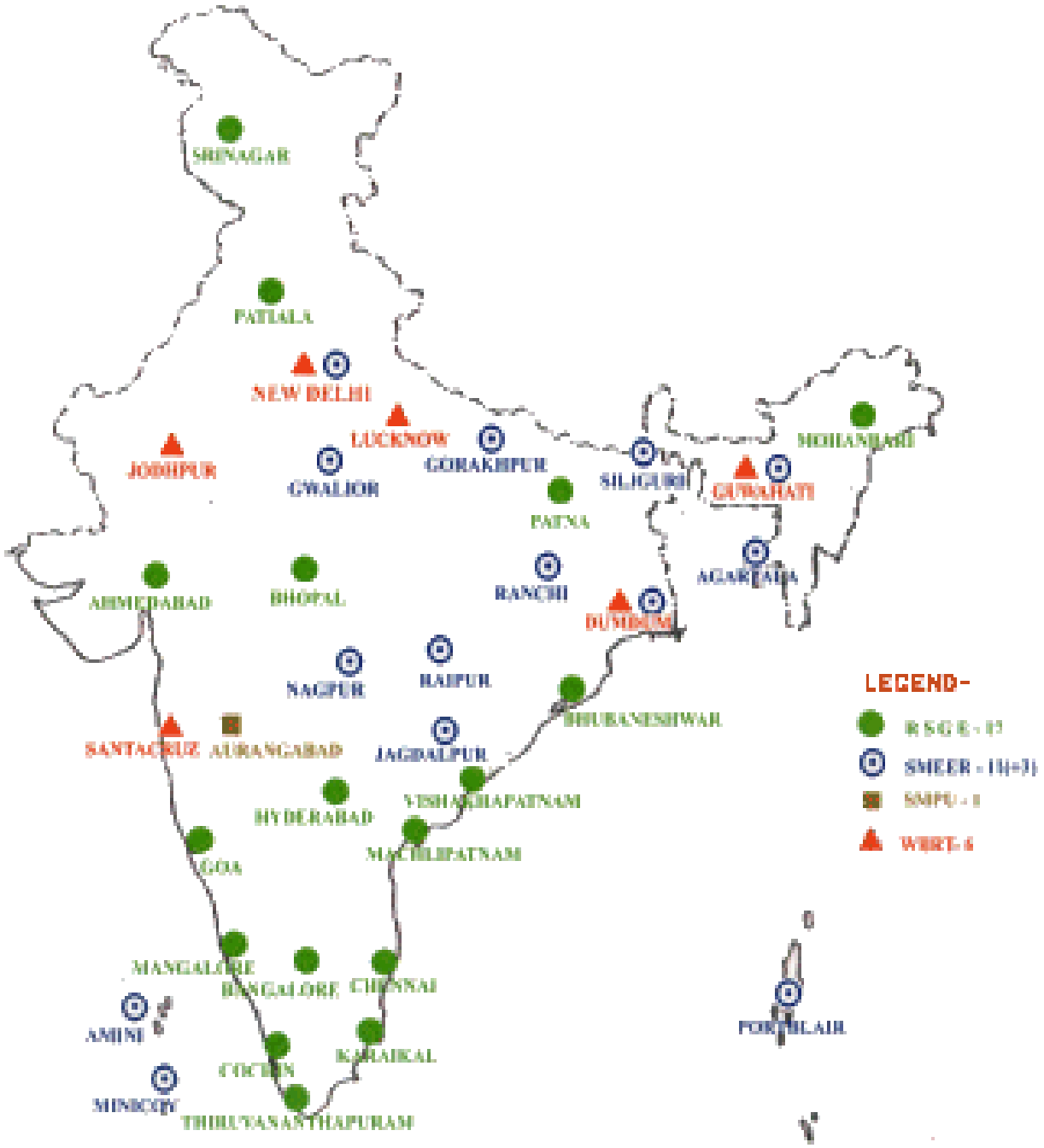
ARG

900


Scale: 1:250,000
Mercator Projection
Horizontal Datum - World Geodetic System (WGS 84)
Network of Automatic Rain Gauge Stations
ARG Station
30° N
20° N
10° N
Latitude
70° E
80° E
90° E
Longitude

RS/RW Network

Including 10 GPS based stations



PILOT BALLOON STATIONS (62)

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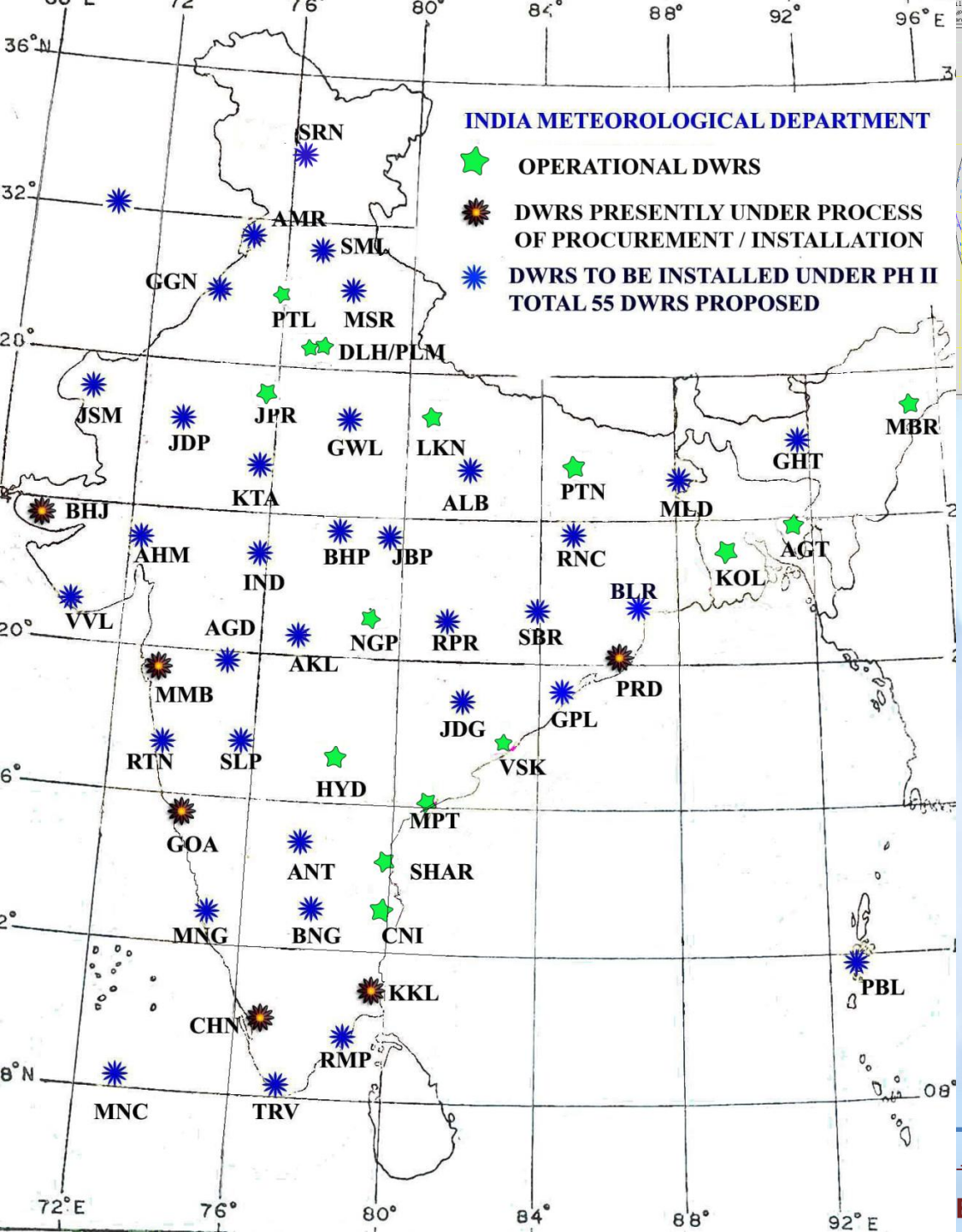
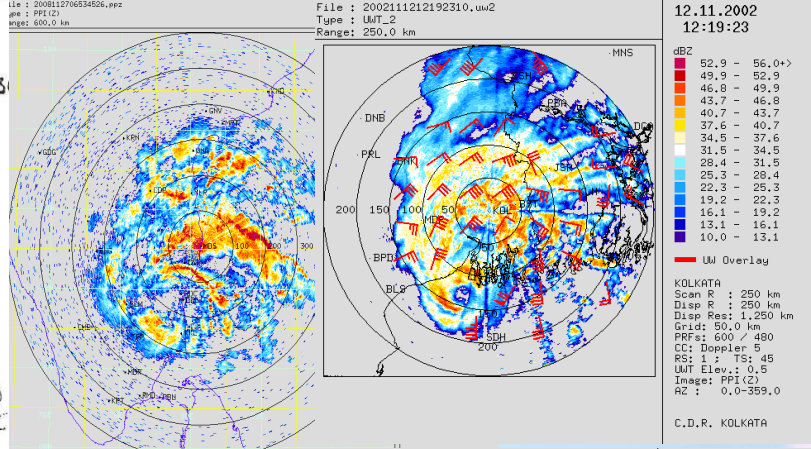
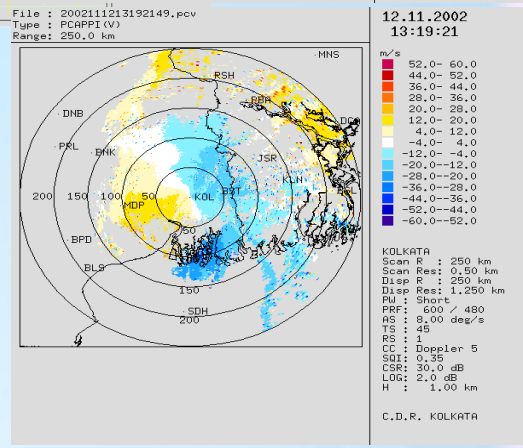
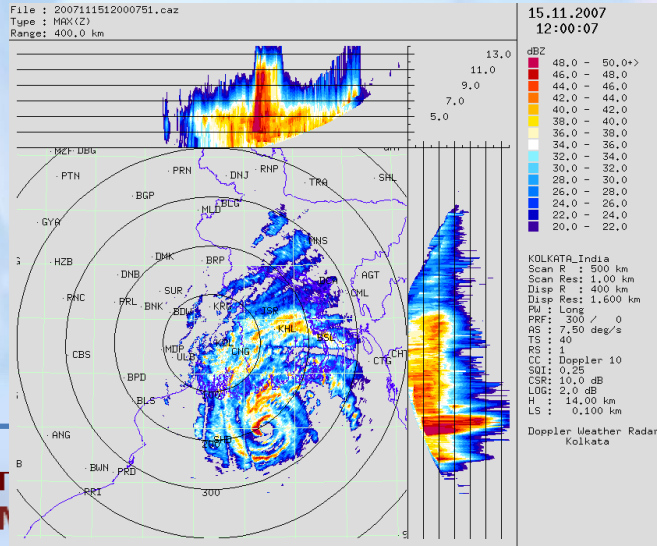

INDIA METEOROLOGICAL DEPARTMENT
OPERATIONAL DWRS
DWRS PRESENTLY UNDER PROCESS OF PROCUREMENT / INSTALLATION
DWRS TO BE INSTALLED UNDER PH II
TOTAL 55 DWRS PROPOSED
SRN
AMR
SML
GGN
PTL
MSR
DLH/PLM
JSM
JDP
JPR
GWL
LKN
KTA
ALB
PTN
MLD
GHT
MBR
BHJ
AHM
BHP
JBP
RNC
AGT
IND
KOL
BLR
VVL
AGD
NGP
RPR
SBR
AKL
PRD
MMB
JDG
GPL
RTN
SLP
VSK
HYD
MPT
GOA
ANT
SHAR
MNG
BNG
CNI
PBL
KKL
CHN
RMP
MNC
TRV
36°N
32°
20°
8°N
72°E
76°
80°
84°
88°
92°
96°E


File : 2002111212192310.uw2
Type : UWT_2
Range: 250.0 km
12.11.2002
12:19:23
dBZ
52.9 - 56.0+
49.9 - 52.9
46.8 - 49.9
43.7 - 46.8
40.7 - 43.7
37.6 - 40.7
34.5 - 37.6
31.5 - 34.5
28.4 - 31.5
25.3 - 28.4
22.3 - 25.3
19.2 - 22.3
16.1 - 19.2
13.1 - 16.1
10.0 - 13.1
UW Overlay
KOLKATA
Scan R : 250 km
Scan Res: 250 km
Disp Res: 1.250 km
Grid: 50.0 km
PRFs: 600 / 480
CC: Doppler 5
RS: 1 ; TS: 45
UWT Elev.: 0.5
Image: PPI(Z)
AZ : 0.0-359.0
C.D.R. KOLKATA

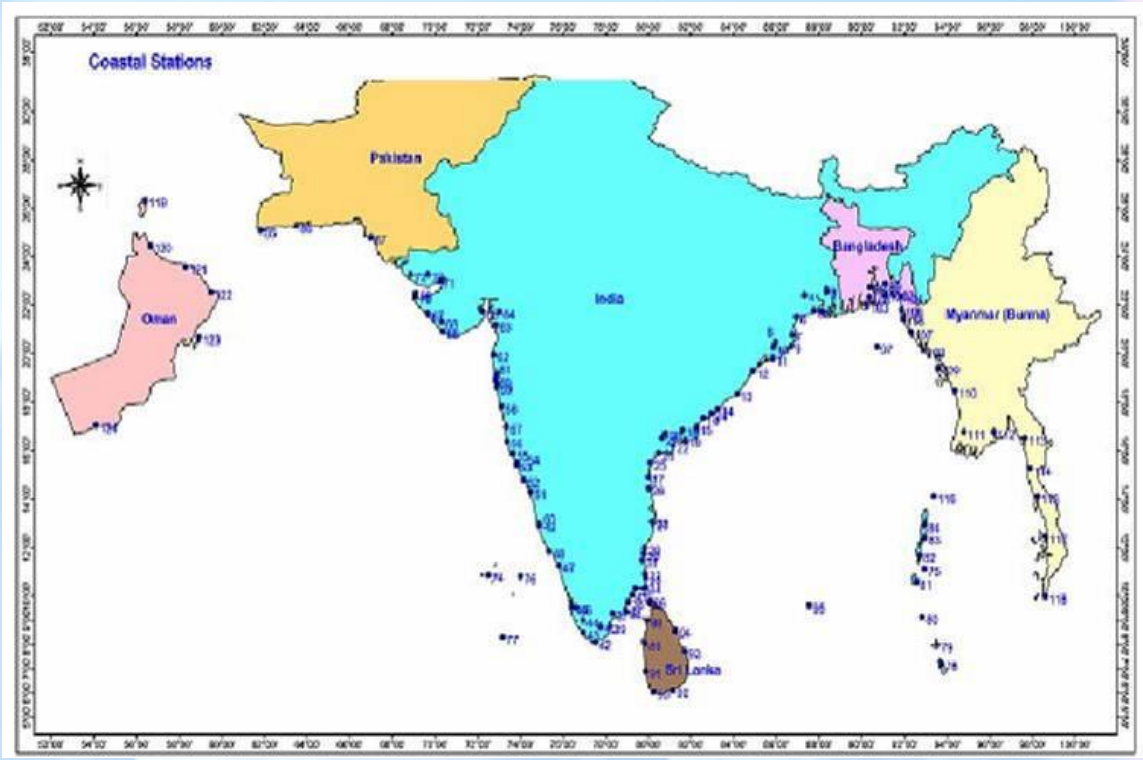

File : 2002111213192149.pcv
Type : PCAPPI(V)
Range: 250.0 km
12.11.2002
13:19:21
m/s
52.0- 60.0
44.0- 52.0
36.0- 44.0
28.0- 36.0
20.0- 28.0
12.0- 20.0
4.0- 12.0
-4.0- 4.0
-12.0- -4.0
-20.0--12.0
-28.0--20.0
-36.0--28.0
-44.0--36.0
-52.0--44.0
-60.0--52.0
KOLKATA
Scan R : 250 km
Scan Res: 0.50 km
Disp R : 250 km
Disp Res: 1.250 km
PW : Short
PRF: 600 / 480
AS : 8.00 deg/s
TS : 45
RS : 1
CC : Doppler 5
SQI: 0.35
CSR: 30.0 dB
LOG: 2.0 dB
H : 1.00 km
C.D.R. KOLKATA


File : 2007111512000751.caz
Type : MAX(Z)
Range: 400.0 km
15.11.2007
12:00:07
dBZ
48.0 - 50.0+
46.0 - 48.0
44.0 - 46.0
42.0 - 44.0
40.0 - 42.0
38.0 - 40.0
36.0 - 38.0
34.0 - 36.0
32.0 - 34.0
30.0 - 32.0
28.0 - 30.0
26.0 - 28.0
24.0 - 26.0
22.0 - 24.0
20.0 - 22.0
KOLKATA_India
Scan R : 500 km
Scan Res: 1.00 km
Disp R : 400 km
Disp Res: 1.600 km
PW : Long
PRF: 300 / 0
AS : 7.50 deg/s
TS : 40
RS : 1
CC : Doppler 10
SQI: 0.25
CSR: 10.0 dB
LOG: 2.0 dB
H : 14.00 km
LS : 0.100 km
Doppler Weather Radar
Kolkata

(High Wind Speed Recorder)

Seven HWSRs along the coast of India in the operational conditions

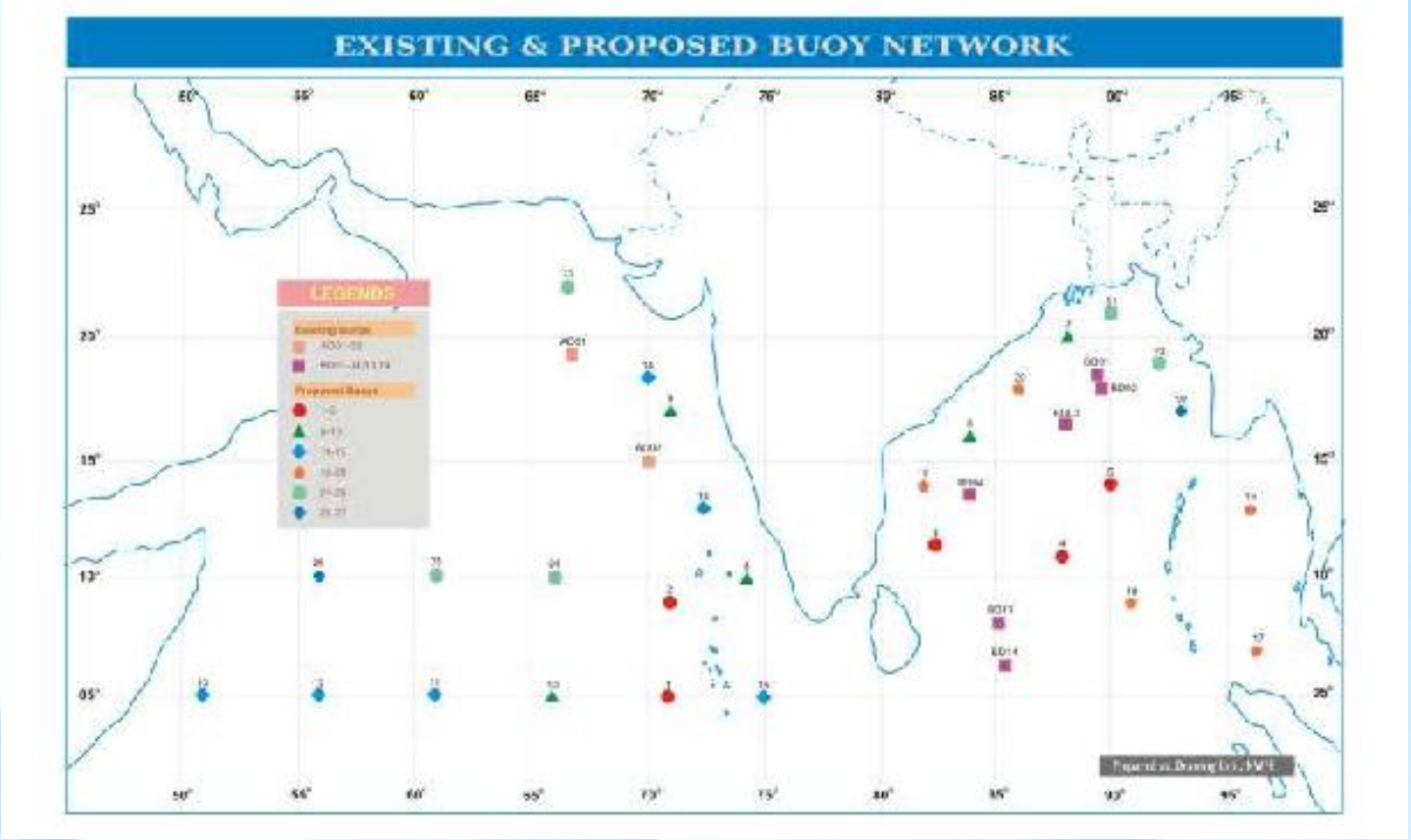
- Digha : West Bengal
- Visakhapatnam : AndhraPradesh
- Machilipatnam : AndhraPradesh
- Nellore : AndhraPradesh
- Chennai : Tamil Nadu
- Karaikal : Puducherry
- Mumbai. : Maharashtra



Four stations are likely to be operational during next 2-3 months

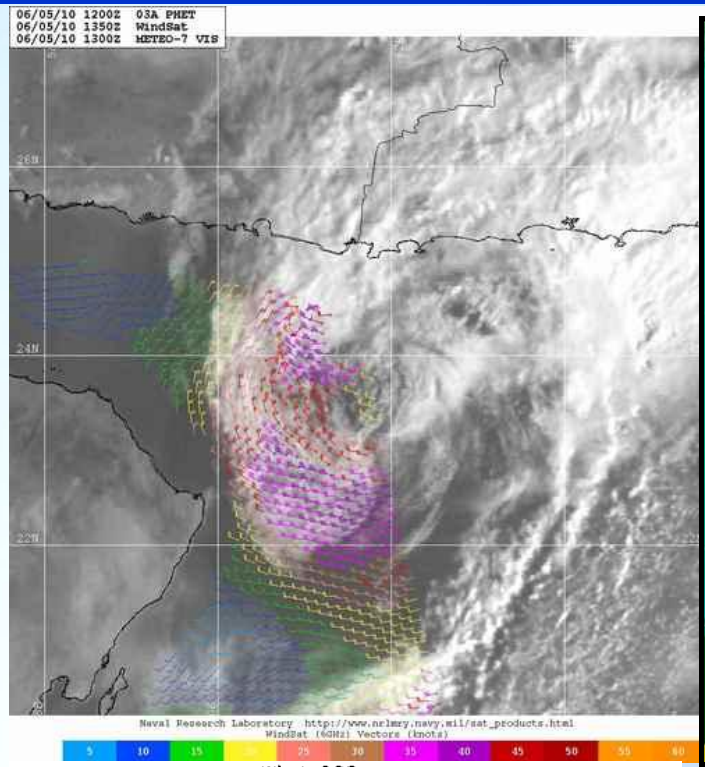
- Puri : Orissa
- Paradip : Orissa
- Gopalpur : Orissa
- Veraval : Gujarat

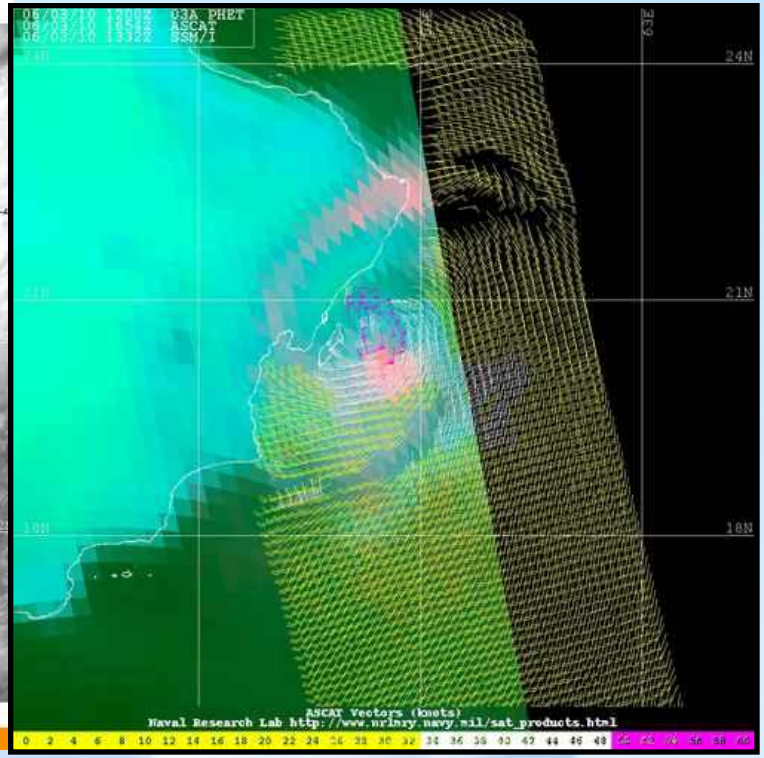
Buoys Network

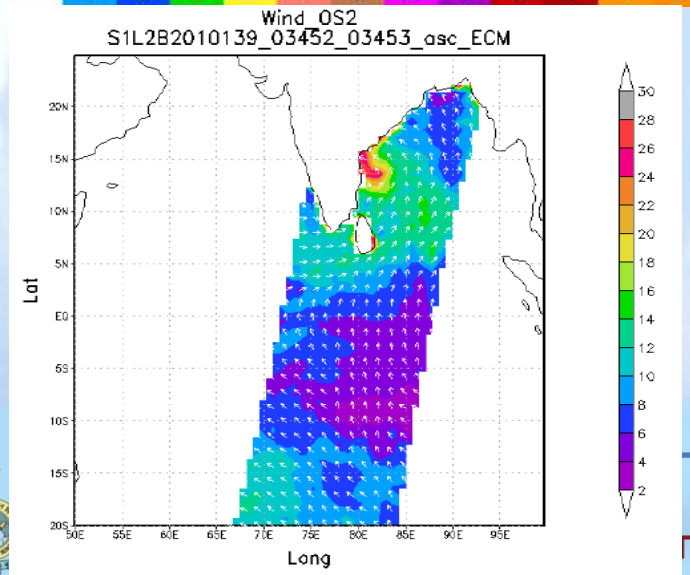


Government of India has established a National Data Buoy Programme (NDBP) at National Institute of Ocean Technology (NIOT), Chennai. Under this programme, twelve moored data buoys have been deployed from August'97 to February '98 at a sea depth of 20m to 4500m and spread over Bay of Bengal and Arabian sea. Since 2002, the number has increased to 25

Example of TC wind monitoring products







Scatterometry products

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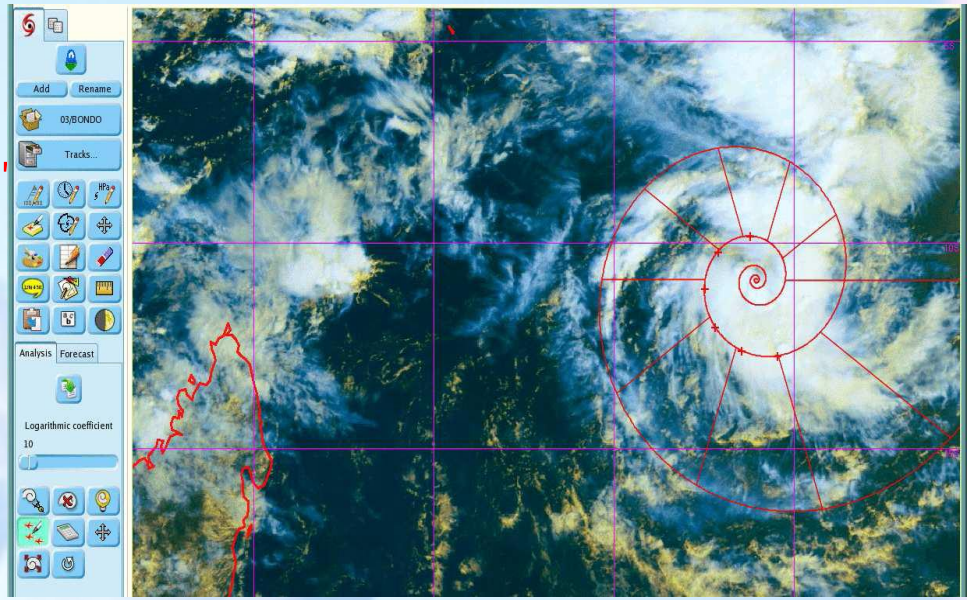
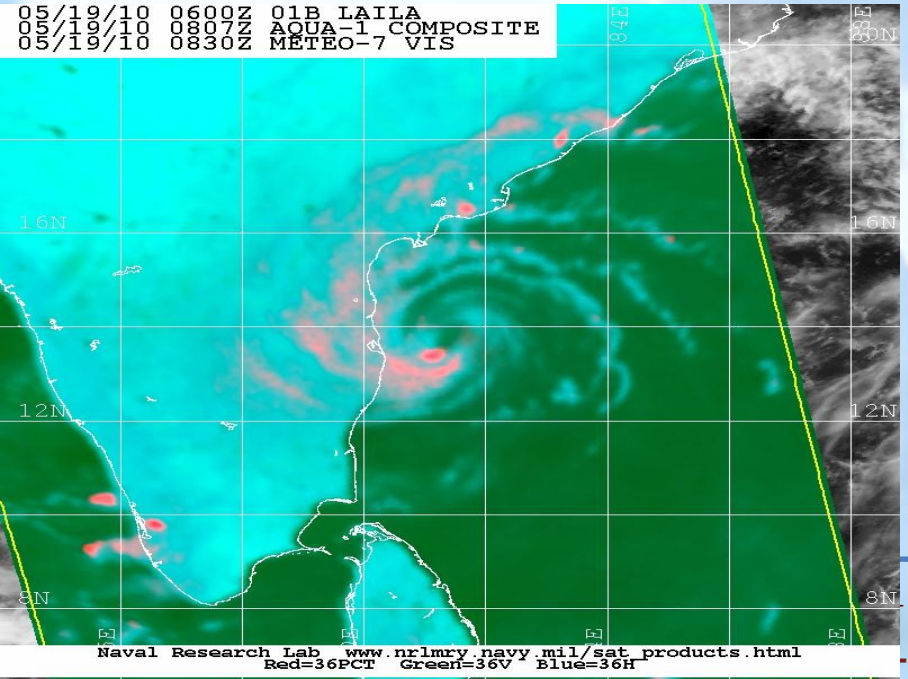
Basic Geostationary Imagery for Cyclone Monitoring

- **Visible**
  - Tracking (locating the centre)
  - For intensity analysis by Dvorak '
- **Infra-Red**
  - Tracking (locating the centre)
  - For structure analysis
  - For intensity analysis
- **Water Vapour**
  - For synoptic assessment of the storm environment



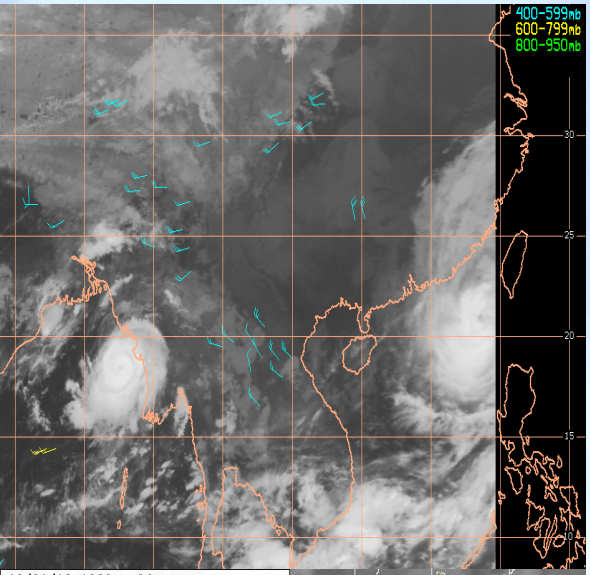
Satellite observations (Microwave) : -

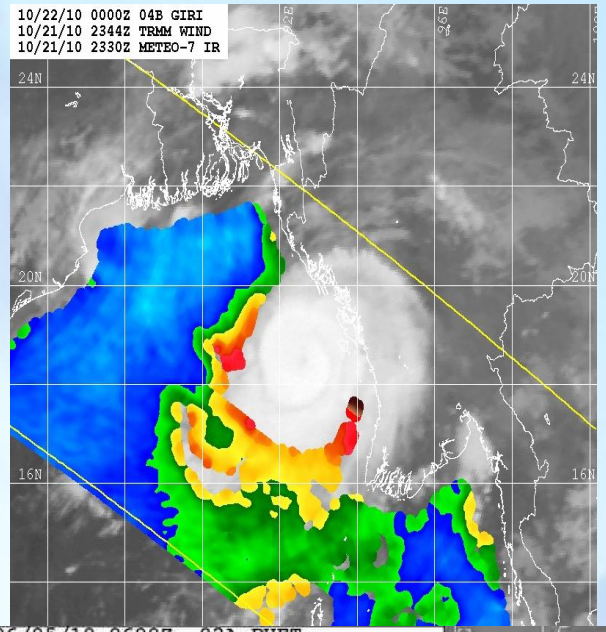
- Passive Microwave Imagers (PMW) for structure (eye wall and rain band)
- Microwave Sounders (MSU) (Intensity)
  AMSU-A oxygen band channels 5-8 (warm core temperature)
- Rain rate
  - TMI rain data
  - TRMM (Tropical Rainfall Measuring Mission) rain data

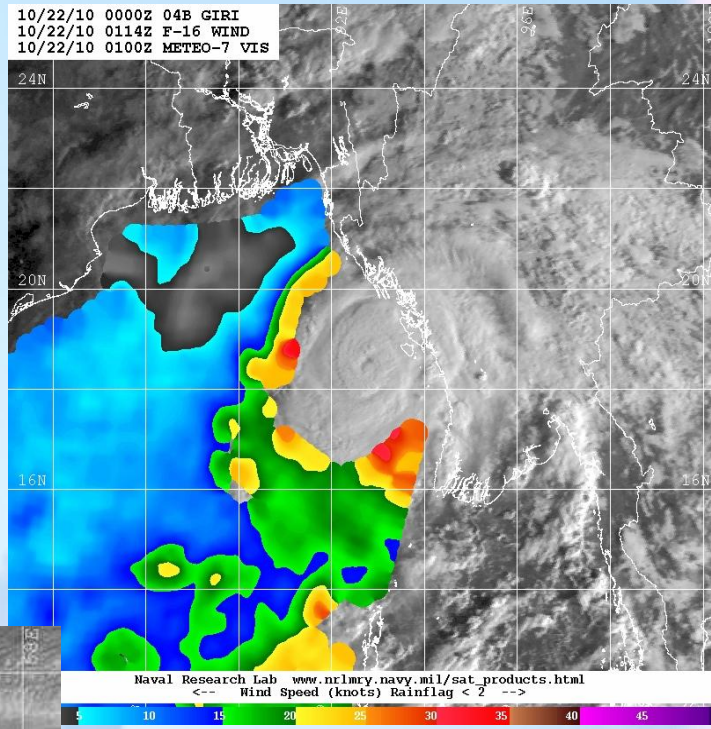


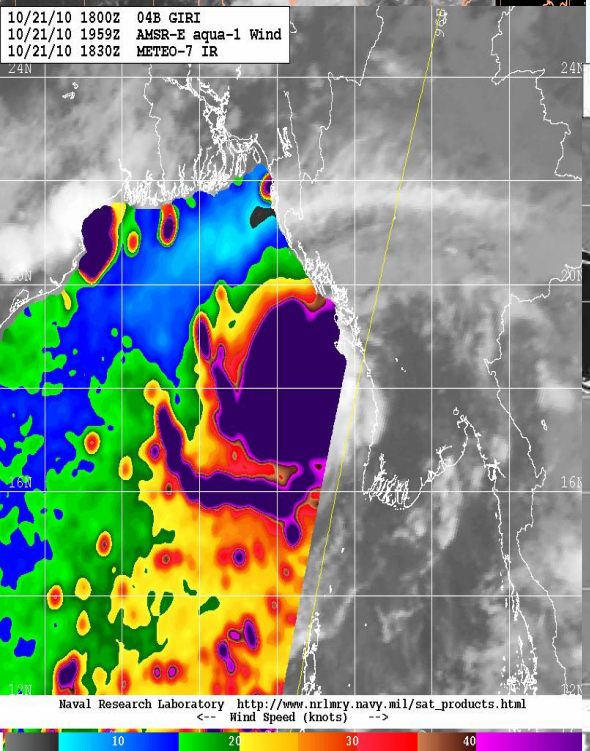
- Microwave imageries being used
- Tropical cyclone module
- Has been installed and will be utilised along with Navy NRL website to analyse microwave imageries.
- Available satellite derived products (high resolution AMVs; rapid scan winds; OLR; Oceansat and WINDSAT winds; local HRPT Temperature and moisture profiles from INCOIS; MODIS moisture data; TMI; SSMI and AMSU data sets etc.) for its utilization by the global and regional data assimilation-forecast systems of IMD and NCMRWF

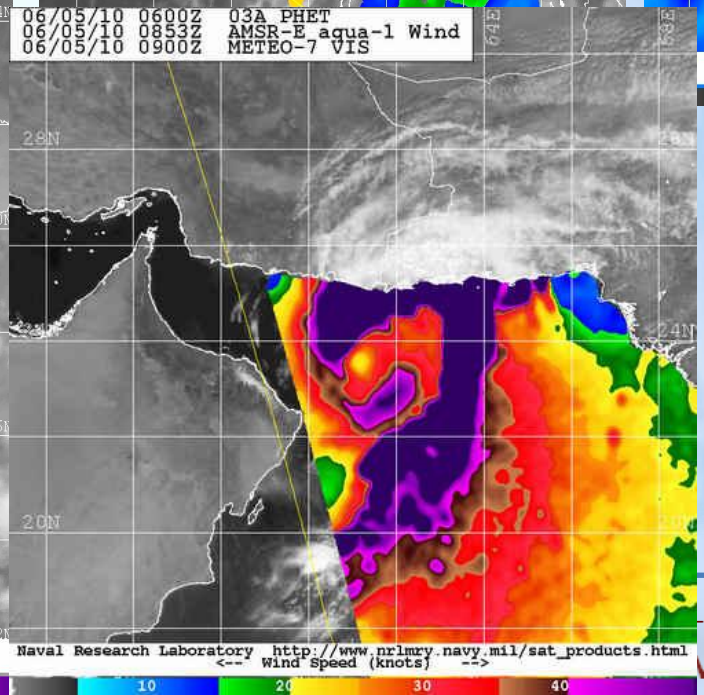
Example of TC wind monitoring products











Remotely sensed products

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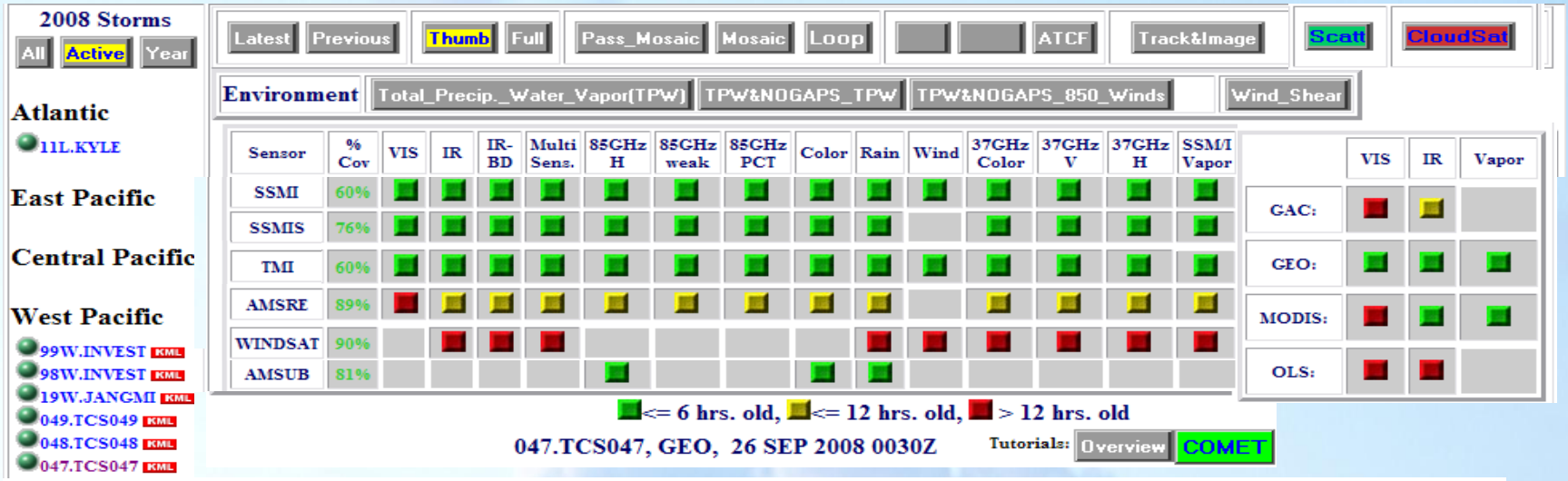
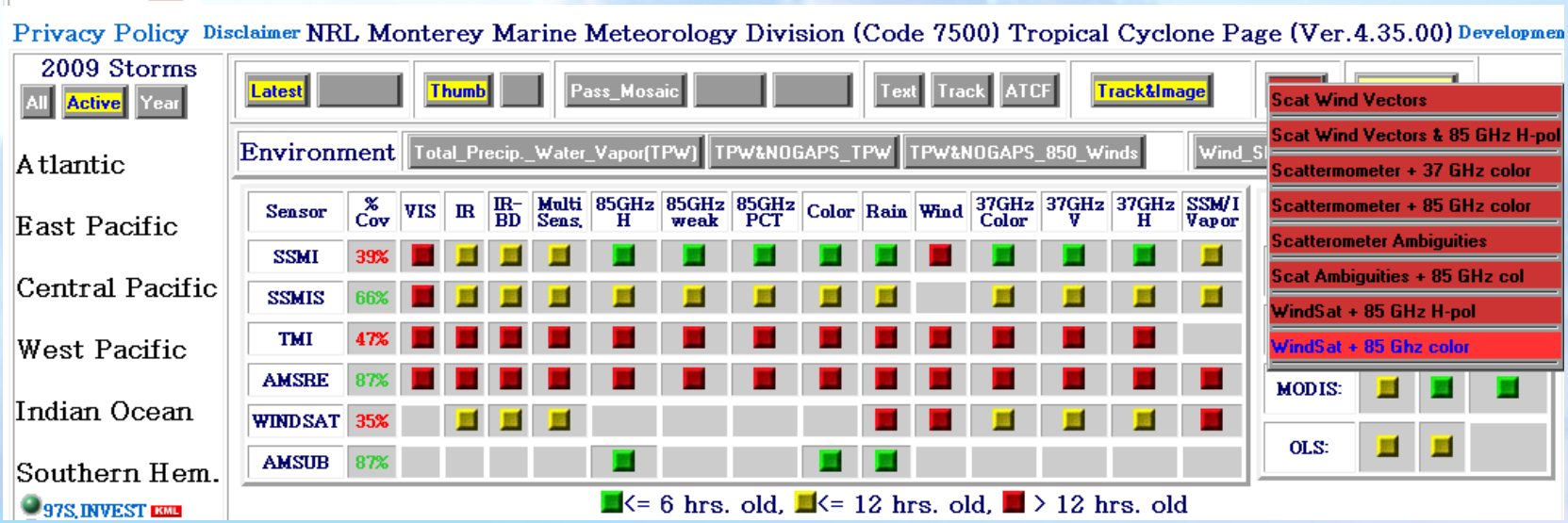
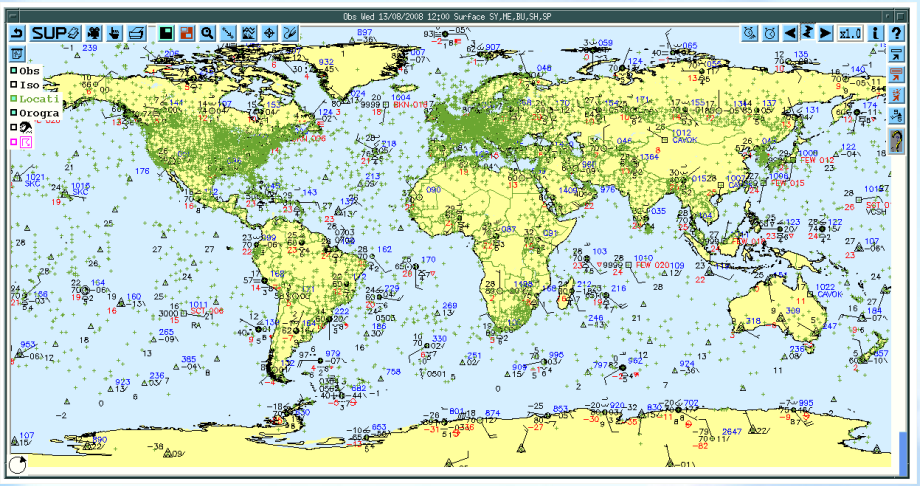
Unprecedented Real-Time Satellite Capabilities: Data Fusion

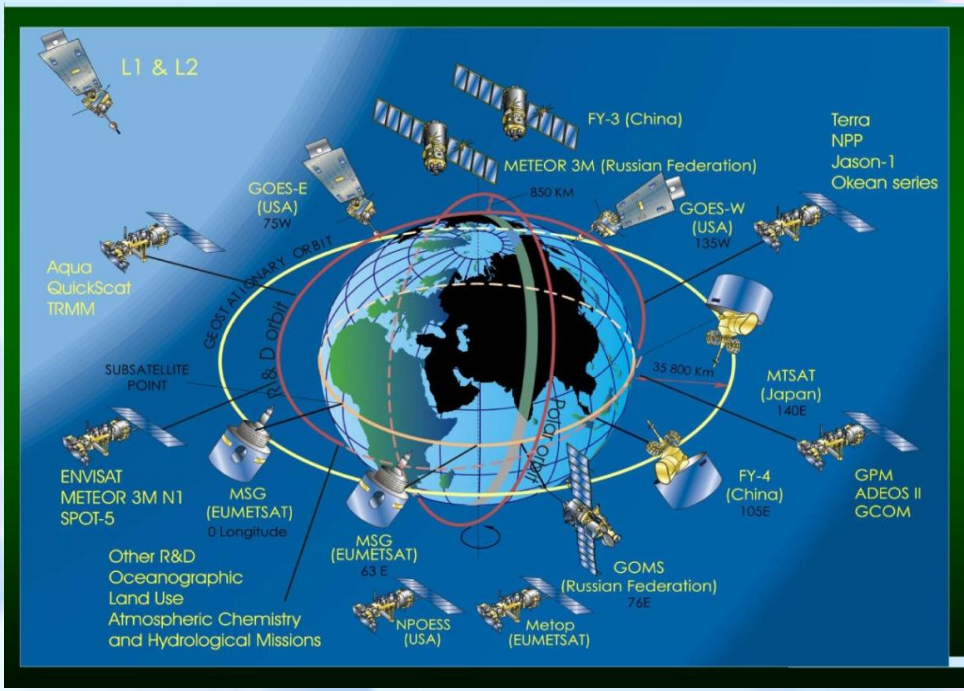


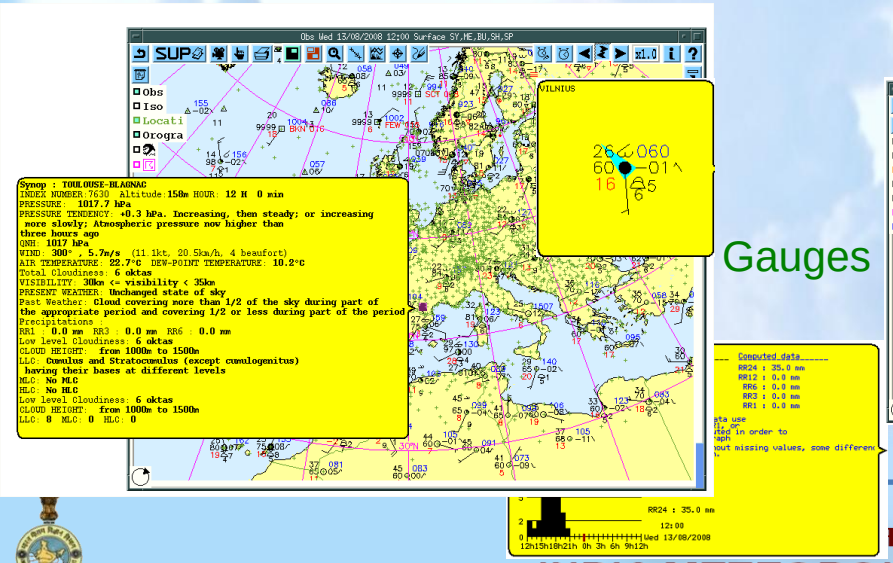


A typical daily synoptic products in Forecasting System of IMD

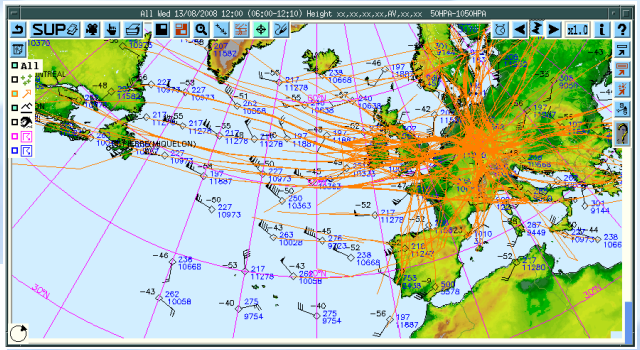


Global plotting





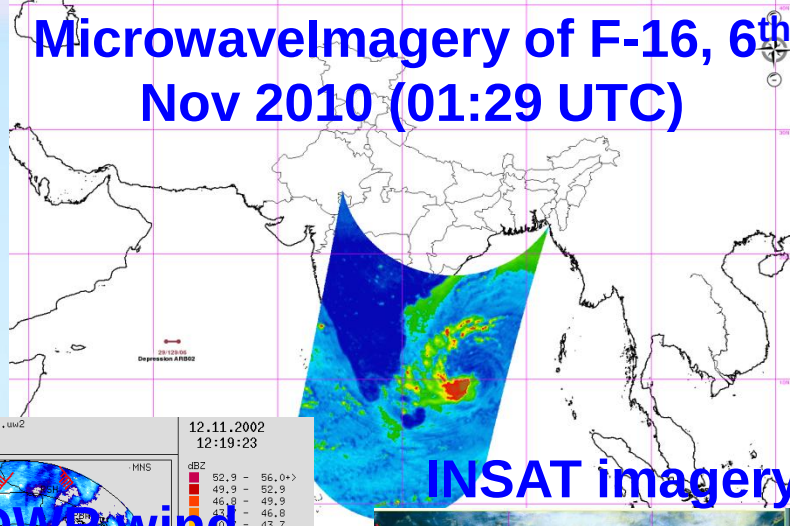
Gauges

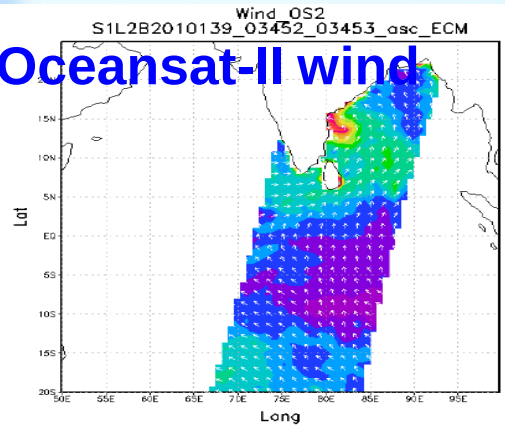


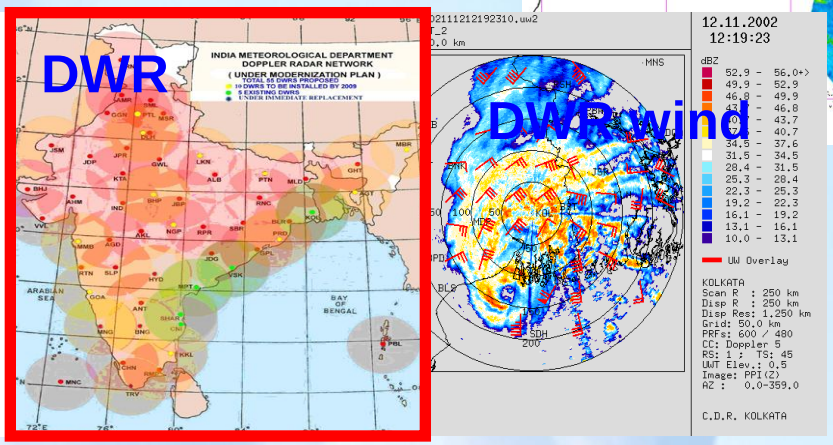
Plane trajectories

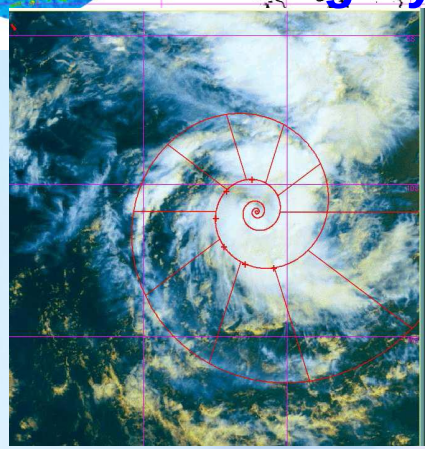
Tropical Cyclone Module

- It Has been installed and being utilised to various observation, satellite, radar abd NWP modeling products
- To general warning bulletins and products

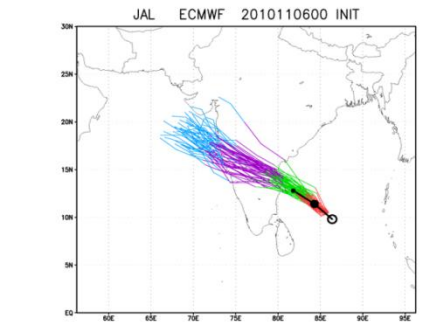


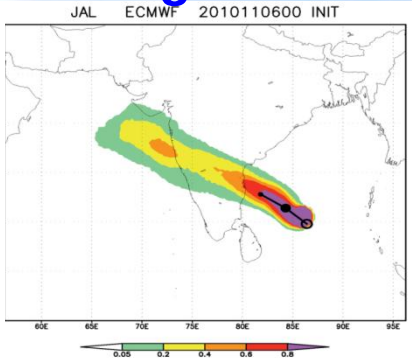


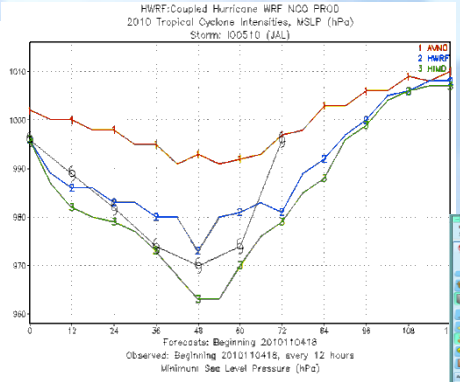




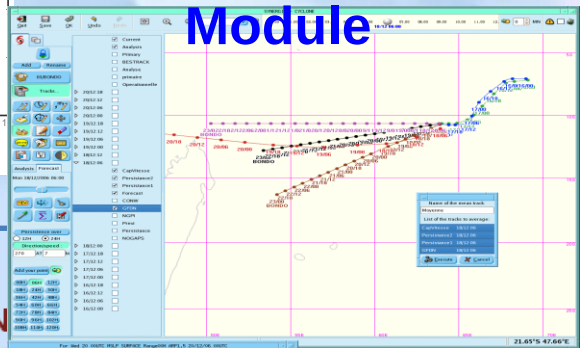
NWP model guidance







Decision making through Cyclone Module



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Cyclone genesis monitoring and forecasting

i) Dynamical Statistical Techniques
   i) Genesis potential parameter
   ii) MJO
ii) Synoptic Techniques – Empirical Techniques
iii) Satellite Techniques
iv) Radar Techniques
v) NWP Models

- Individual models (Global and regional)
- IMDGFS (382, 574), ARPEGE (MeteoFrance, ECMWF, JMA, UKMO, NCEP, WRF (IMD, IITD, IAF), HWRF (IMD), QLM
- MME (IMD) and MME based on Tropical Cyclone Module (TCM)
- EPS (Mean Track, Strike probability, Location specific probability)

Location of Centre

(a) Synoptic position

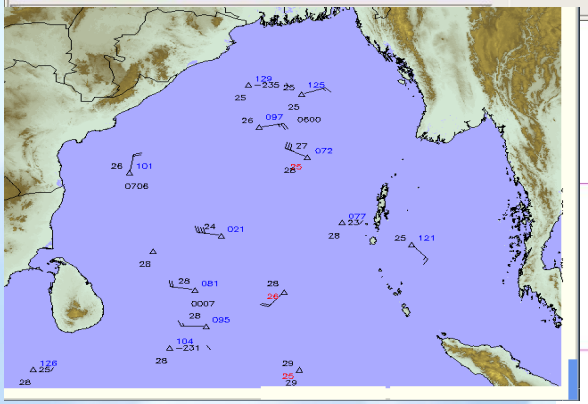
(b) Satellite:

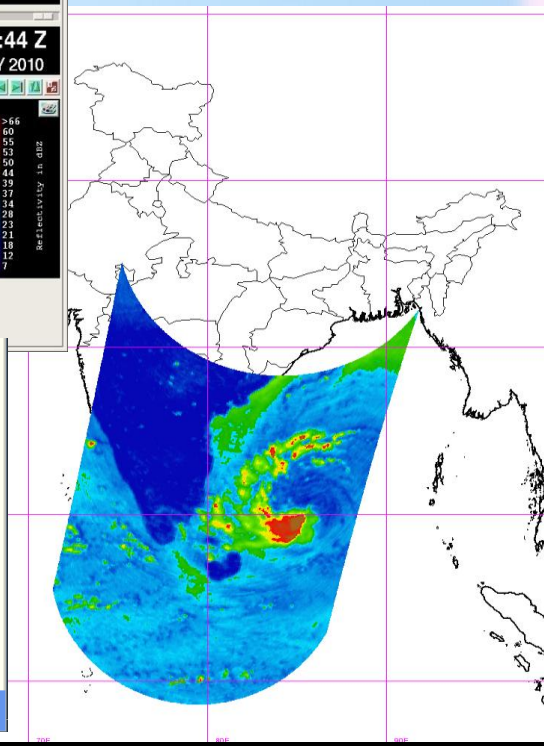
INSAT/METSAT position

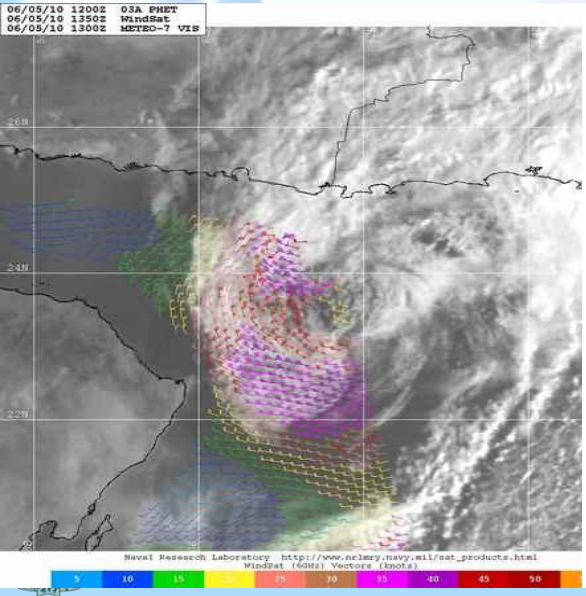
(c) Radar position :

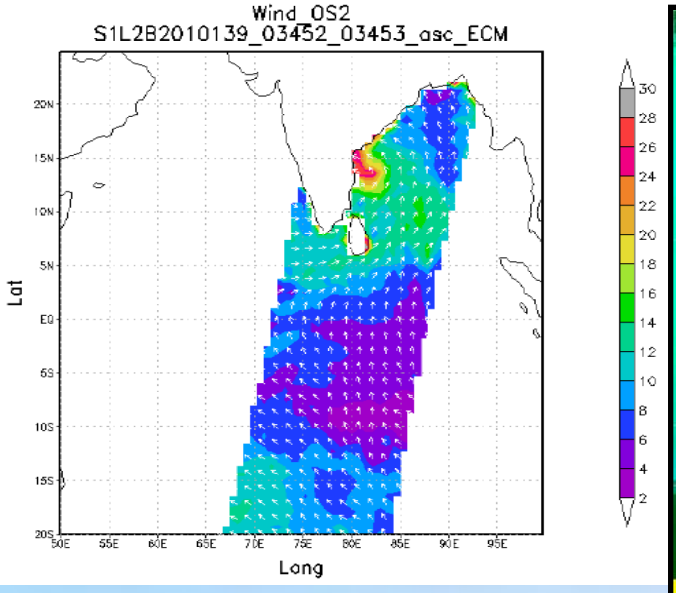
(d) Centre determined by other warning centres

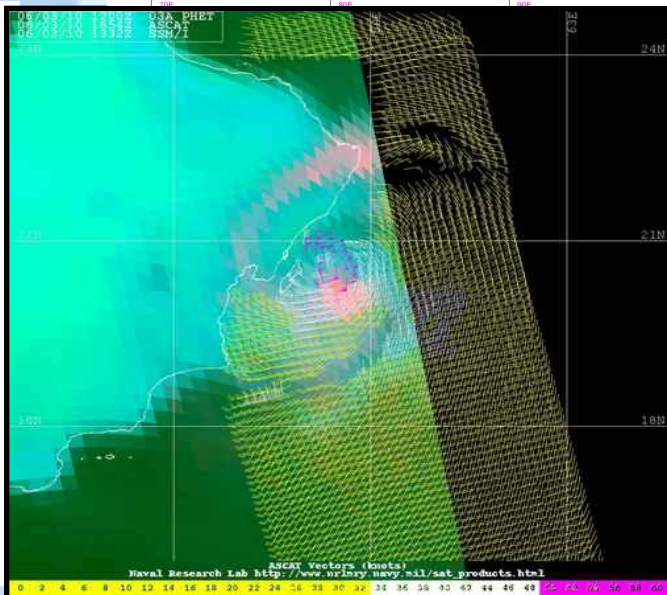
(e) Finally agreed official Position and Confidence











Intensity estimation:

(a) Satellite:

(b) INSAT/METSAT

(b) Radar

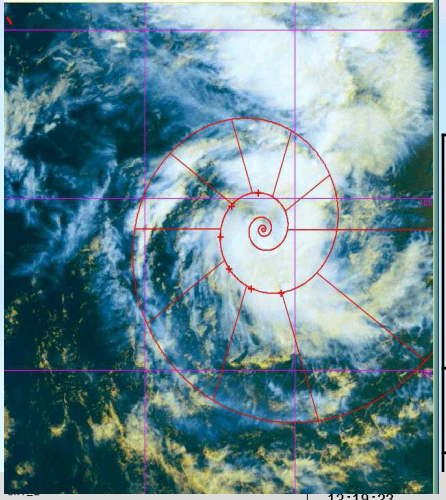
(c) Synoptic analysis

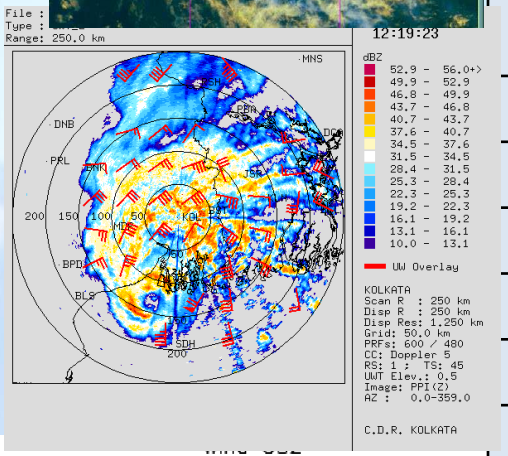
(wind observed by Buoys, Ships, Scatterometers)

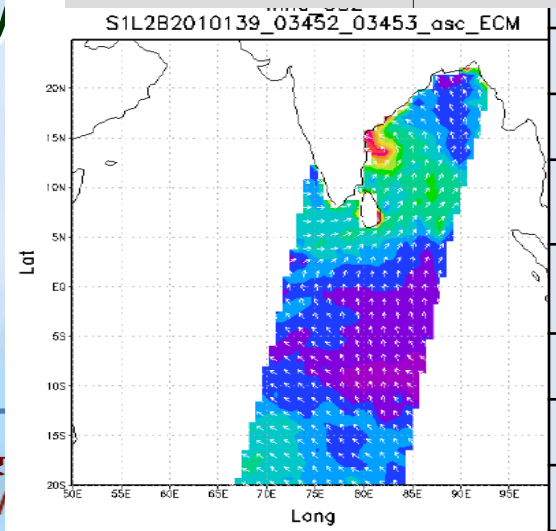
(d) Model analysis

(e) Intensity determined by other warning centres

(e) Finally agreed official intensity







C.I. Number	*Max. Wind Speed (knots)*	*Pressure depth (in mb)*
1	25	3.1
1.5	25	3.1
2	30	4.5
2.5	35	6.1
3	45	10.0
3.5	55	15.0
4	65	20.9
4.5	77	29.4
5	90	40.2
5.5	102	51.6
6	115	65.6
6.5	127	80.0
7	140	97.2
7.5	155	119.1
8	170	143.3

TC track forecasting methods

i) Statistical Techniques

Analogue, Persistence, Climatology, CLIPER,

i) Synoptic Techniques – Empirical Techniques

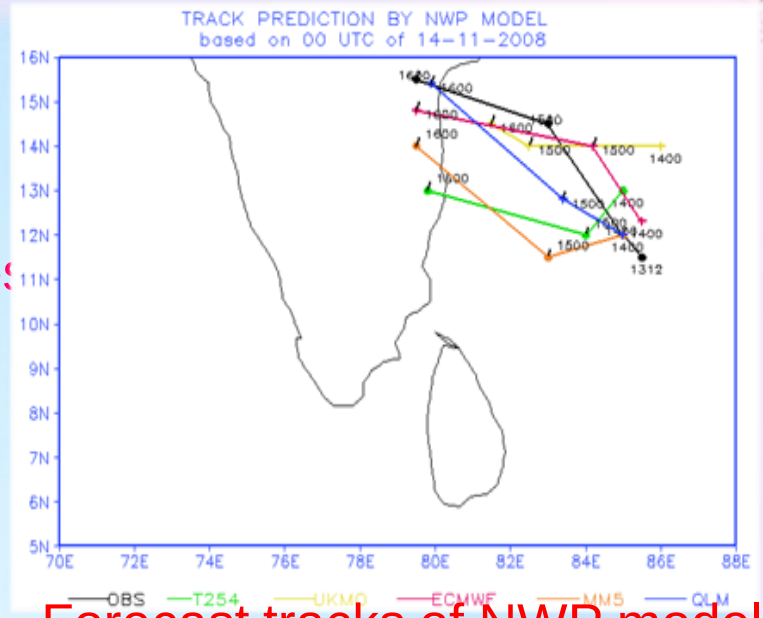
ii) Satellite Techniques Techniques

iii) Radar Techniques

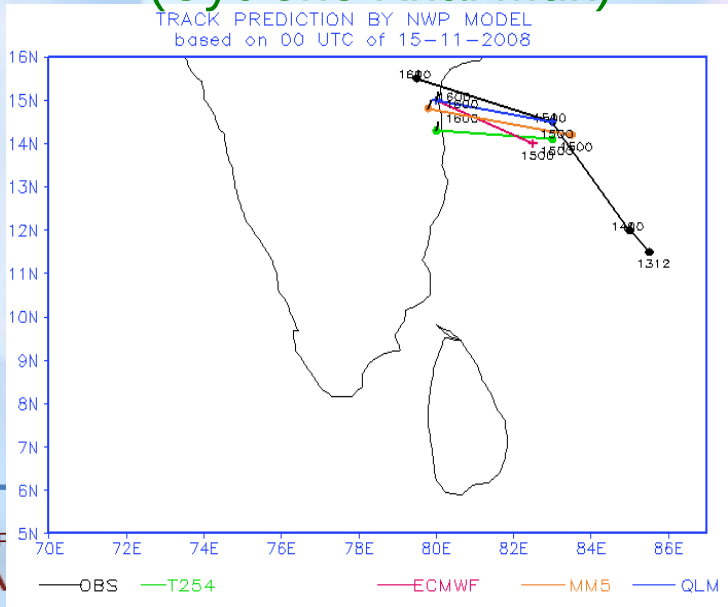
v) NWP Models

- Individual models (Global and regional)
- IMDGFS (382, 574), NCMRWF (254), ARP (MeteoFrance, ECMWF, JMA, UKMO, NCEP, WRF (IMD, IITD, IAF), HWRF (IMD), QLM
- MME (IMD) and MME based on Tropical Cyclone Module (TCM)
- EPS (Strike probability, Location specific probability

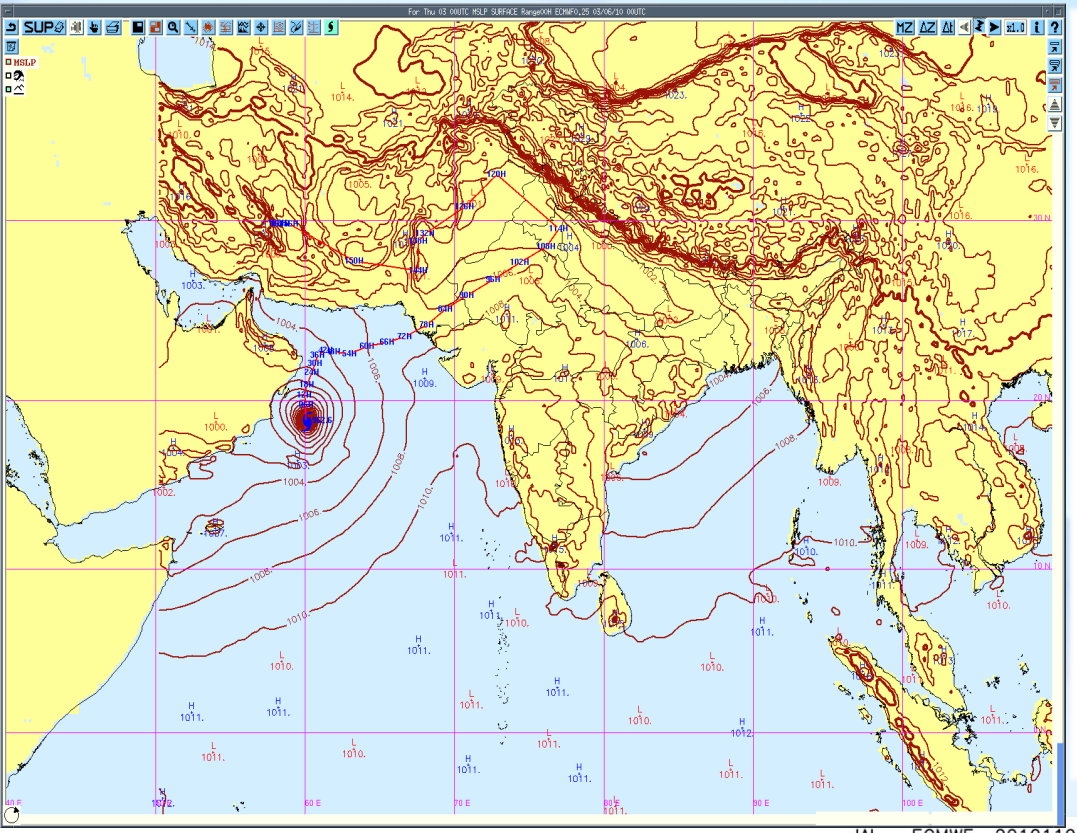
vi) Operational (Consensus) forecast

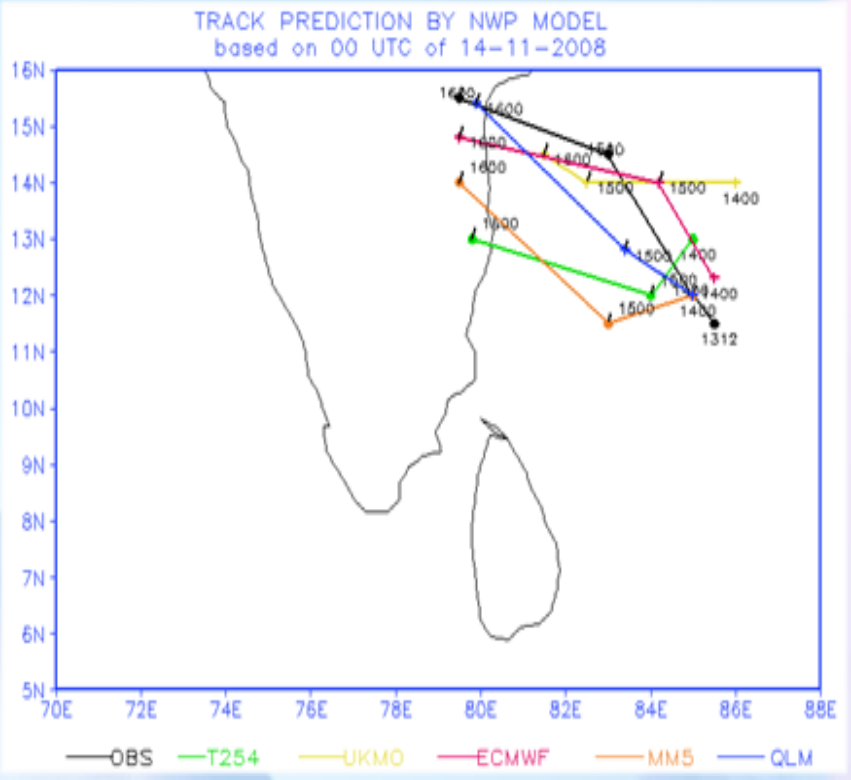


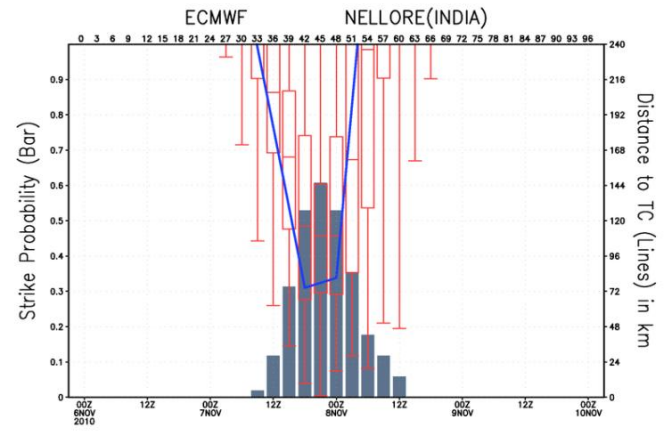
Forecast tracks of NWP model based on 0000 UTC of 14 and 15 November 2008 (Cyclone Khai Muk)

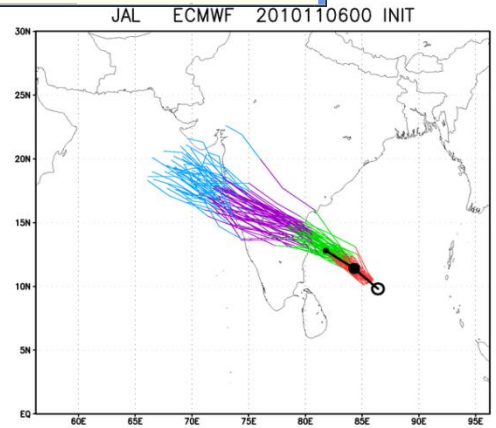


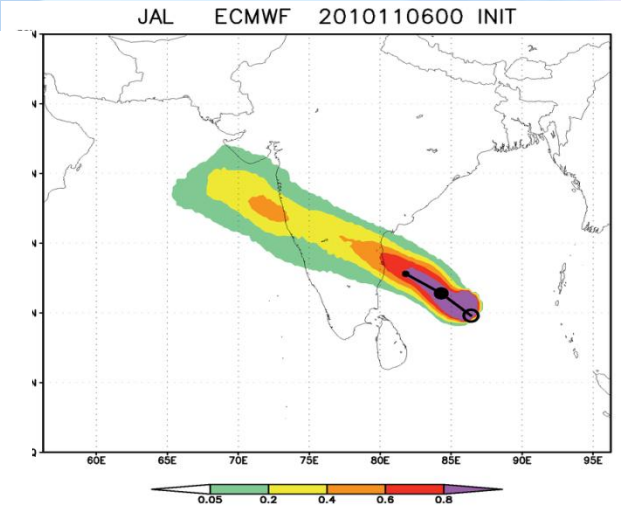
TC track forecasting methods











TC intensity forecasting methods

i) Statistical Techniques

Analogue, Persistence, Climatology

i) Synoptic Techniques

ii) Satellite Techniques

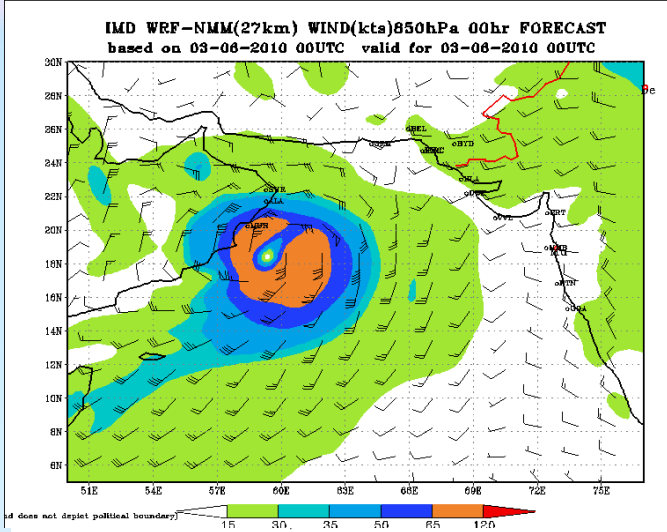
iii) Radar Techniques

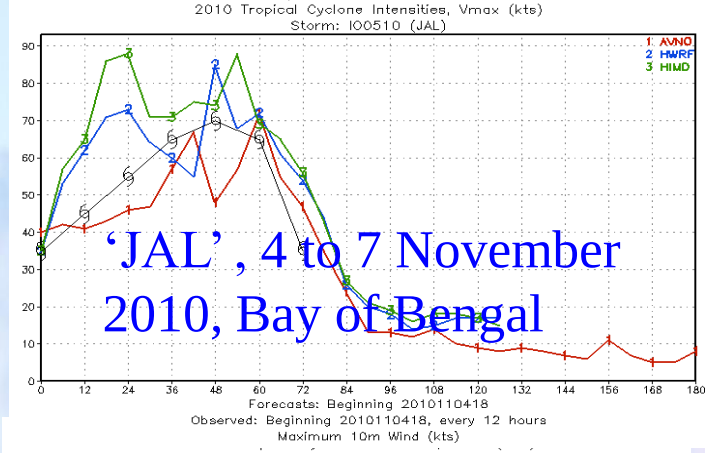
v) NWP Models

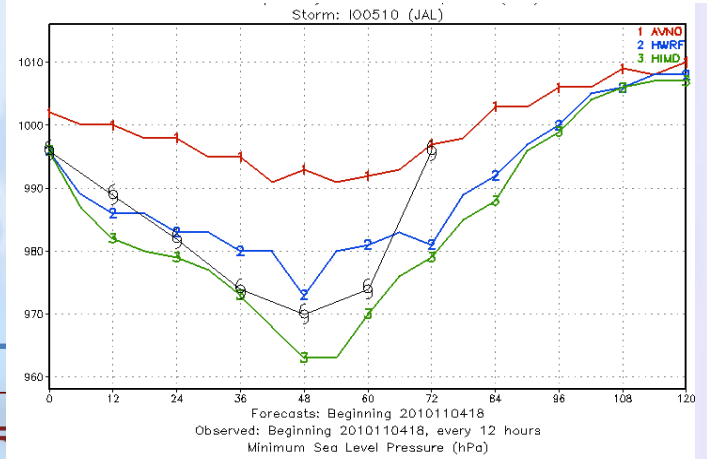
- Individual models (Global and regional)
- IMDGFS (382, 574), NCMRWF (254), ARP (MeteoFrance, ECMWF, JMA, UKMO, NCEP, WRF (IMD, IITD, IAF), HWRF (IMD), QLM

vi) Dynamical Statistical Model (SCIP)

Operational (Consensus) forecast

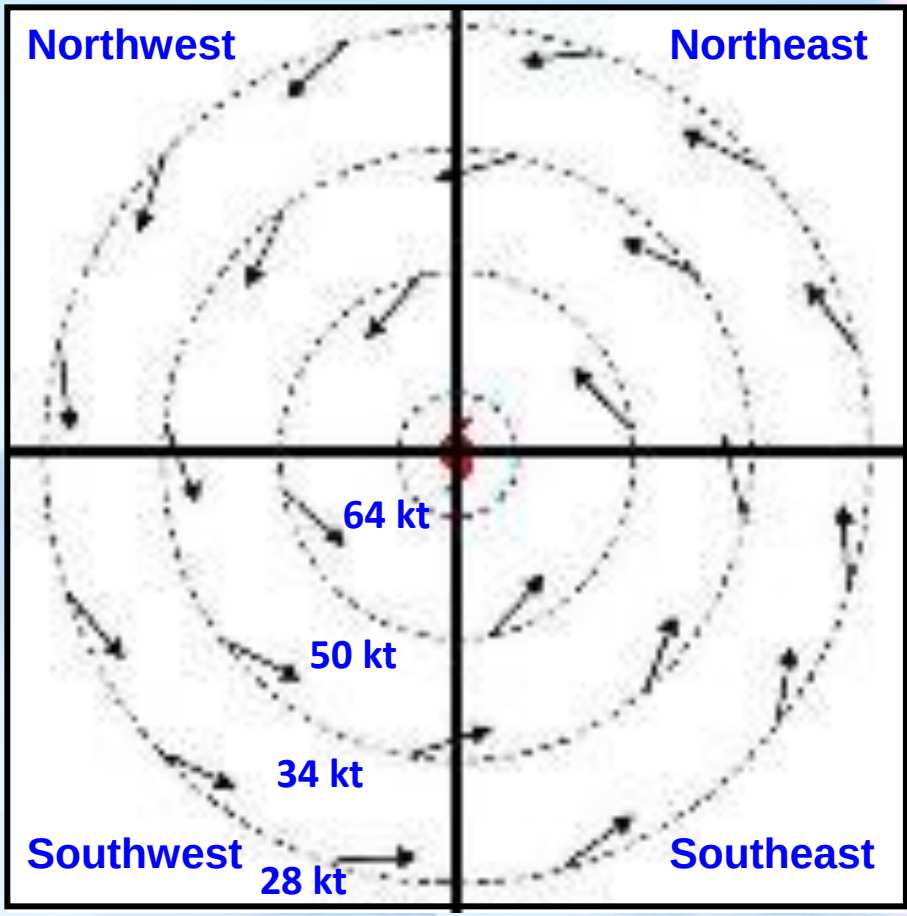


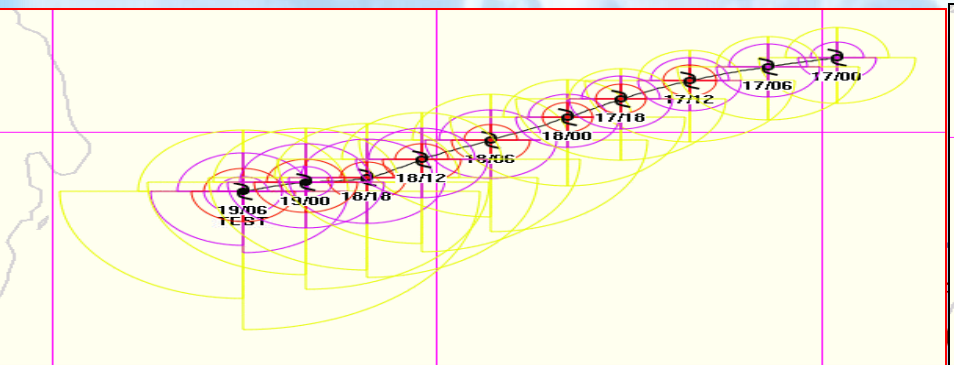


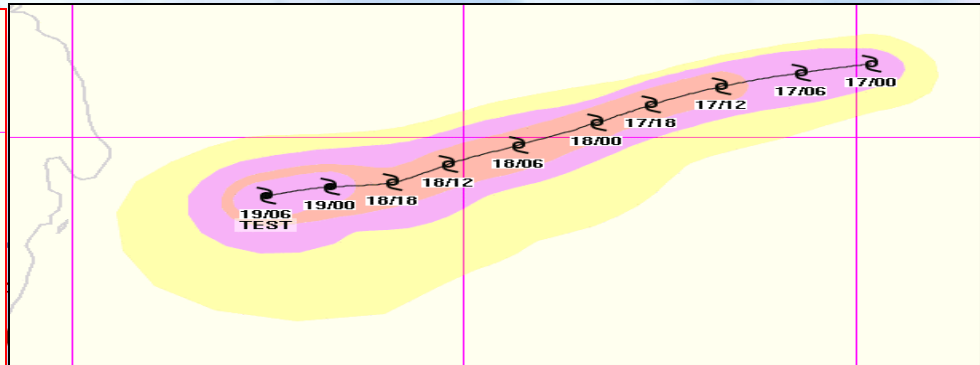


Quadrant wind radii monitoring and forecast

- Wind radii represents the maximum radial extent of winds reaching a threshold value in each quadrant.
- The wind radii forecasts are issued over the sea area only as per the requirement of the users.
- The TC wind radii forecasts are generated in terms of the radii of winds reaching 34kts, 50kts and 64kts value in four geographical quadrants around the tropical cyclone. In addition, radii of 28 kts is also added.

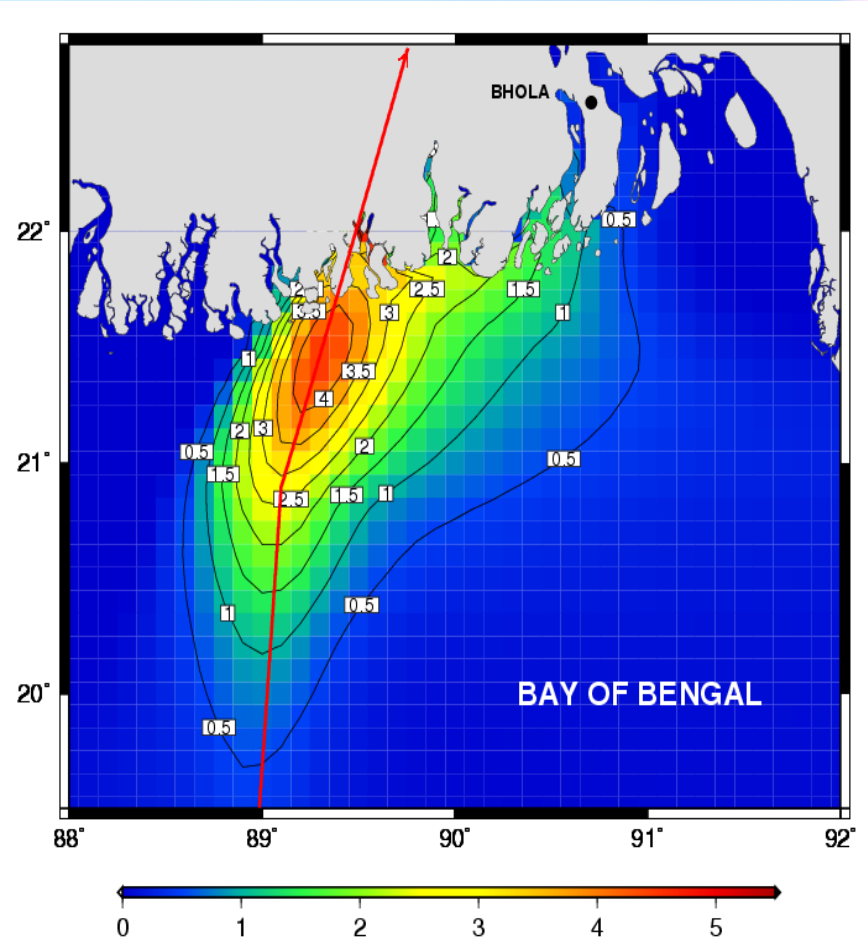






Disastrous weather forecasting

- Storm Surge prediction -
  - Nomograms
  - IITD model
- Strong wind
  - Satellite Method (Dvorak Technique)
  - DWR
  - Climatology (based on damage potential
  - NWP
- Heavy rainfall
  - Synoptic method
  - Climatological method
  - Satellite
  - Radar
  - NWP Method



FROM : RSMC-TROPICAL CYCLONES, NEW DELHI

TO : STORM WARNING CENTRES DHAKA, BANGKOK, COLOMBO, KARANCHI, MALE, MUSCAT, YANGOON

TROPICAL CYCLONE ADVISORY RSMC-TROPICAL CYCLONES, NEW DELHI TROPICAL STORM 'X' ADVISORY NO.---- ISSUED AT ----UTC OF ----2006 BASED ON -----UTC CHARTS.

CYCLONIC STORM 'X' OVER --------- MOVED WESTWARDS AND FURTHER INTENSIFIED INTO A SEVERE CYCLONIC STORM WHICH LAY CENTRED AT -----UTC NEAR LAT--/LONG--ABOUT -----KM (DIRECTION) OF 'P'.

SATELLITE IMAGERY (DESCRPTION OF CLOUD). CUURENT INTENSITY IS TN.N. ESTMATED CENTRAL PRESSURE -------- hPa. MAXIMUM SURFACE SUSTAINED WINDS --------- KTS GUSTING TO ----KT AROUND THE SYSTEM CENTRE.

FORECAST INTENSITY, TRACK WITH CONE OF UNCERTAINTY AND QUADRANT WIND

PHYSICAL REASONING:

TCAC Bulletin

DTG : 20080428/0000Z

TCAC: NEW DELHI

TC: NARGIS

NR: 01

PSN: N1300 E08530

MOV: NW05KT

C: 994HPA

Max Wind: 40KT GUSTING TO 50KT

FCST PSN +12Hrs: 281200 N 1330 E08500

Max Wind + 12hrs: 50KT

FCST PSN +18Hrs: 281800 N 1330 E 08500

Max Wind + 18hrs: 55KT

FCST PSN +24Hrs: 290000 N 1400 E 08500

Max Wind + 24hrs: 60KT

NEXT MSG: 20080428/0600Z

(SIGNATURE OF D.O.)

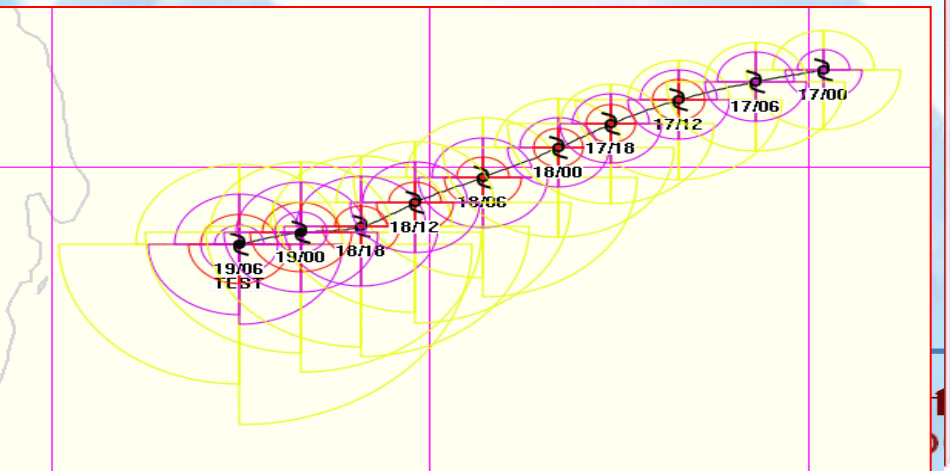
FROM: TCAC, NEW DELHI

TO: STORM WARNING CENTRE, DHAKA (BANGLADESH)
STORM WARNING CENTRE, YANGAON (MYANMAR)
STORM WARNING CENTRE, BANGKOK (THAILAND)
STORM WARNING CENTRE, COLOMBO (SRILANKA)
STORM WARNING CENTRE, KARACHI (PAKISTAN)
METEOROLOGICAL OFFICE, MALE (MALDIVES)
OMAN METEOROLOGICAL DEPARTMENT, MUSCAT (THROUGH RTH JEDDAH)

MWO's MUMBAI/ KOLKATA/ CHENNAI/ DHAKA/ MALE/ YANGON/MUSCUT/KARACHI/COLOMBO/ BANKOK
OPMET DATA BANK SINGAPORE
AFTN ADDRESS WSSSYMYX(VIA MET PALAM)

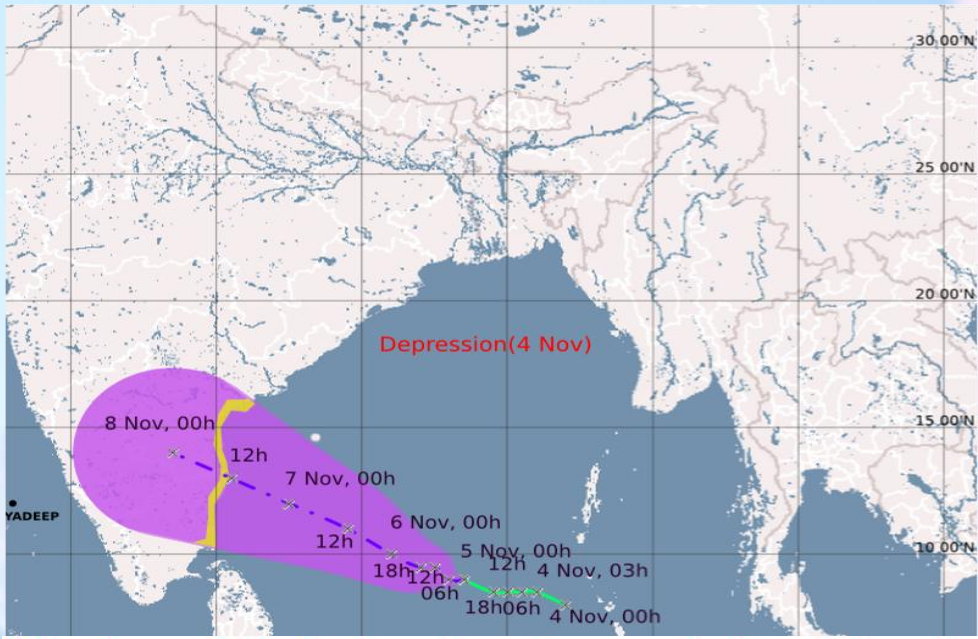
Products

- Improvement in lead period of forecast and warning
- The cyclone track, landfall, intensity and wind forecasts are now issued upto 72 hrs which was earlier issued for 24 hrs only.
- Value added services
- The cone of uncertainty in cyclone track forecast
- Cyclone wind forecast in different quadrant,
- Forecast map, Multi-hazard warning map of India

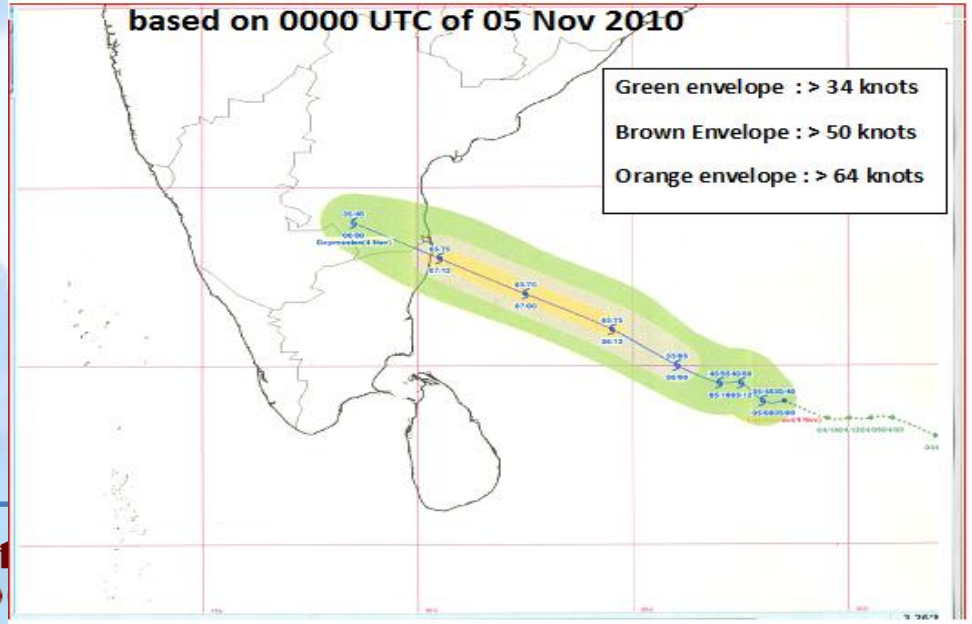


INDIA
METEOROLOGICAL DEPARTMENT

Observed and Forecast Track

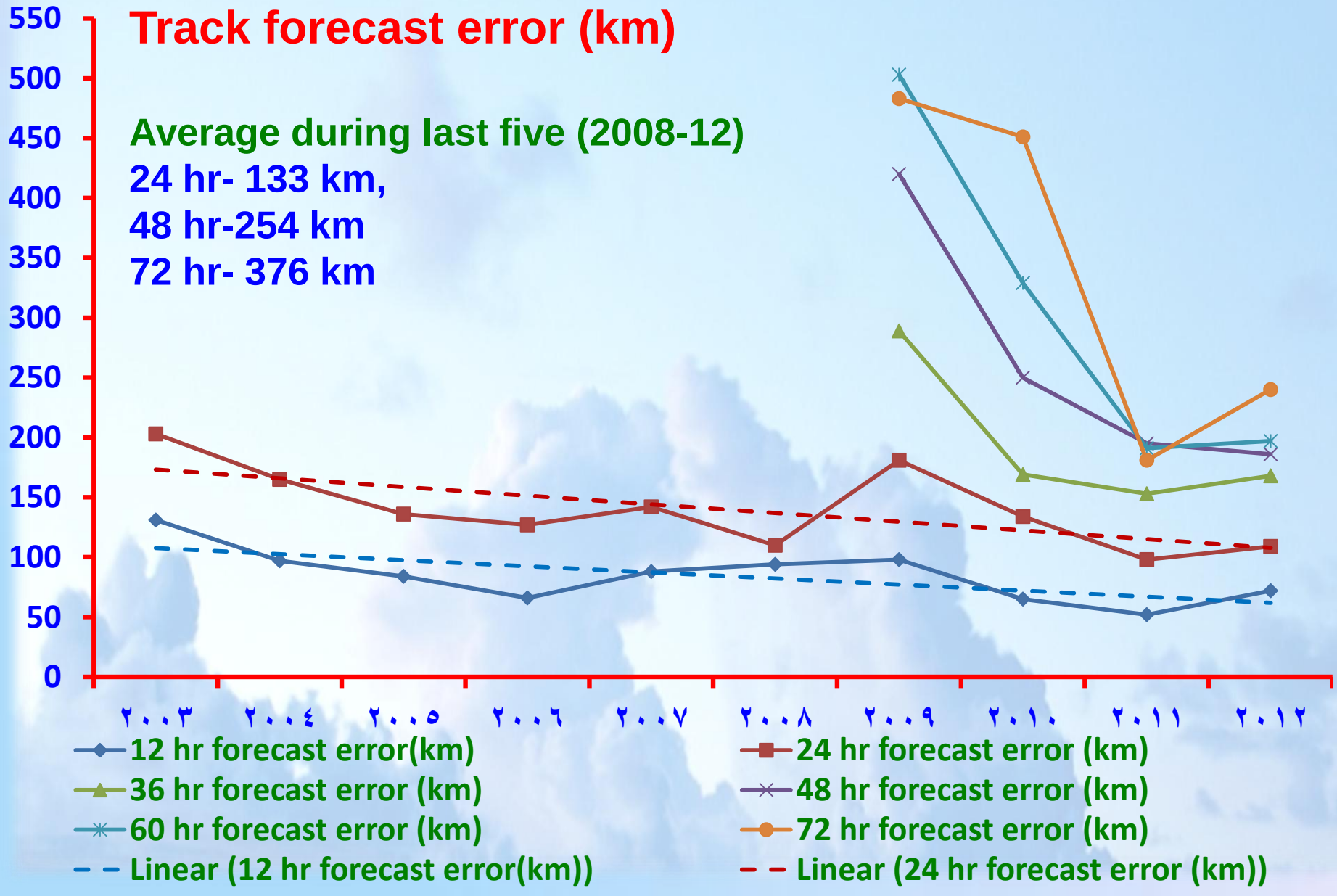


Wind forecast for the deep depression over the Bay of Bengal

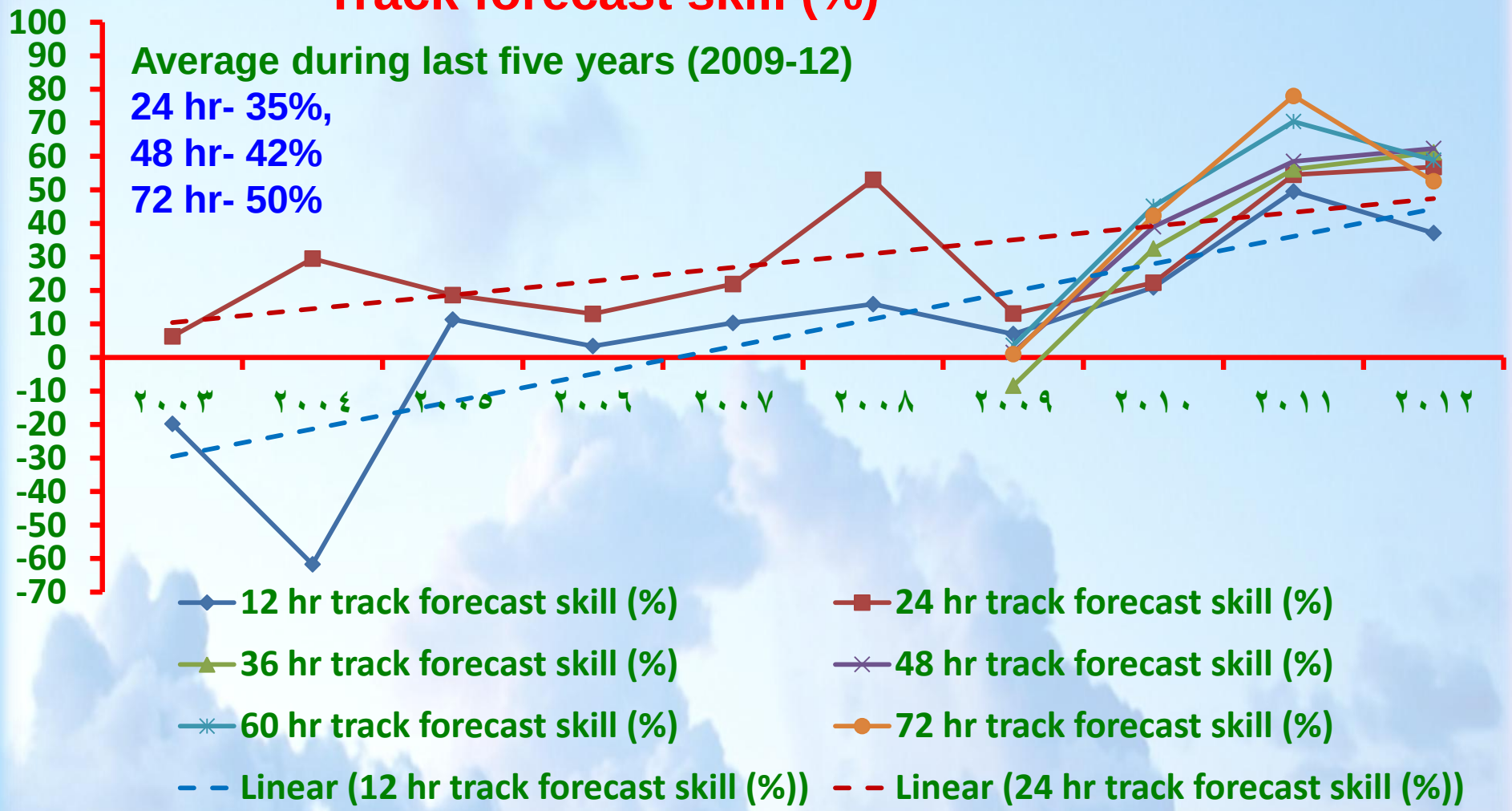


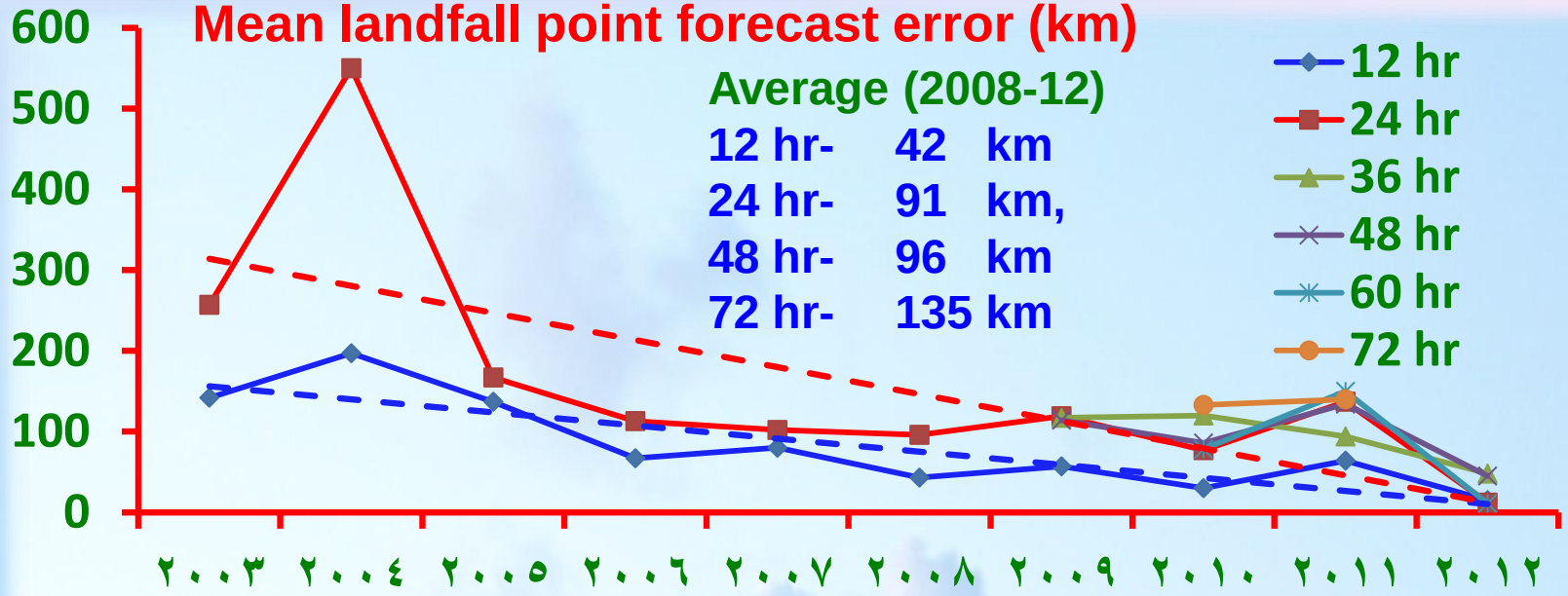
Track forecast error (km)

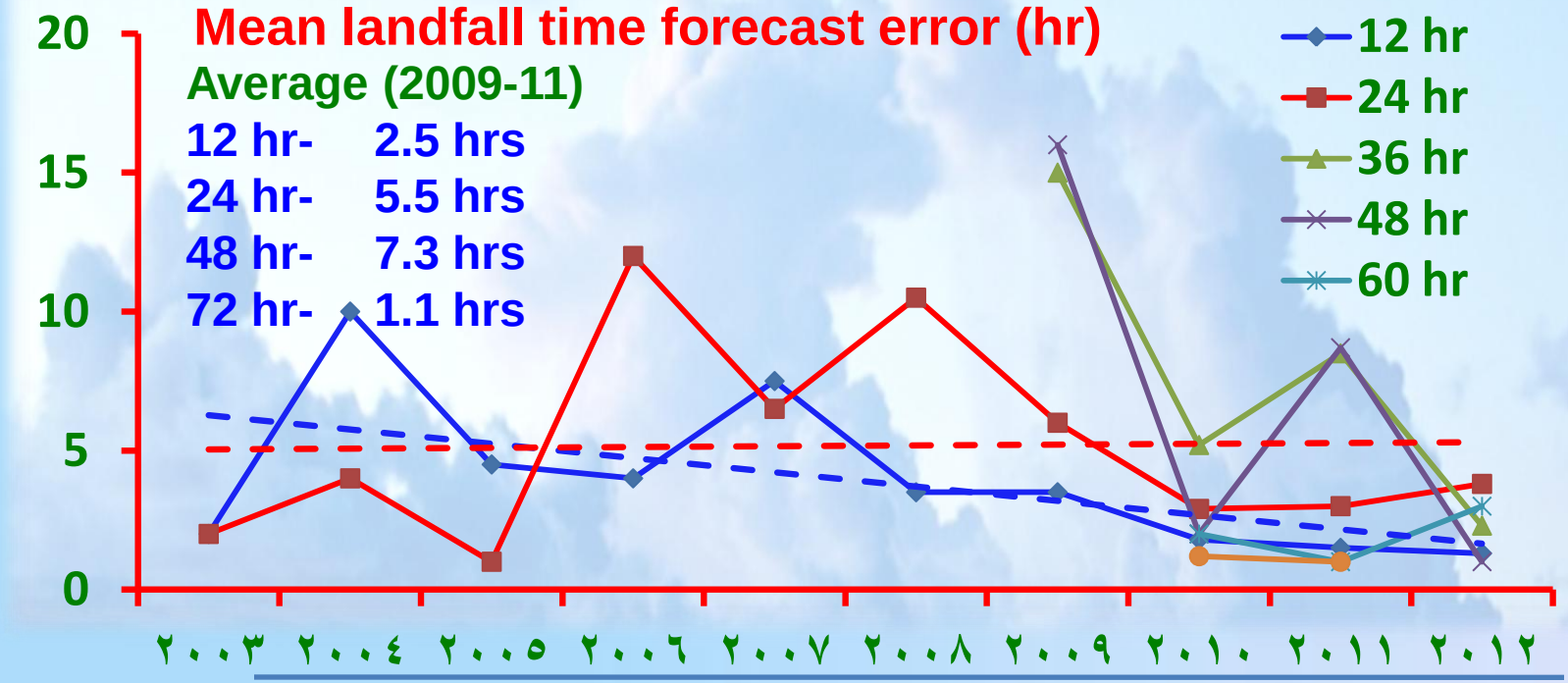
Average during last five (2008-12)
24 hr- 133 km,
48 hr-254 km
72 hr- 376 km



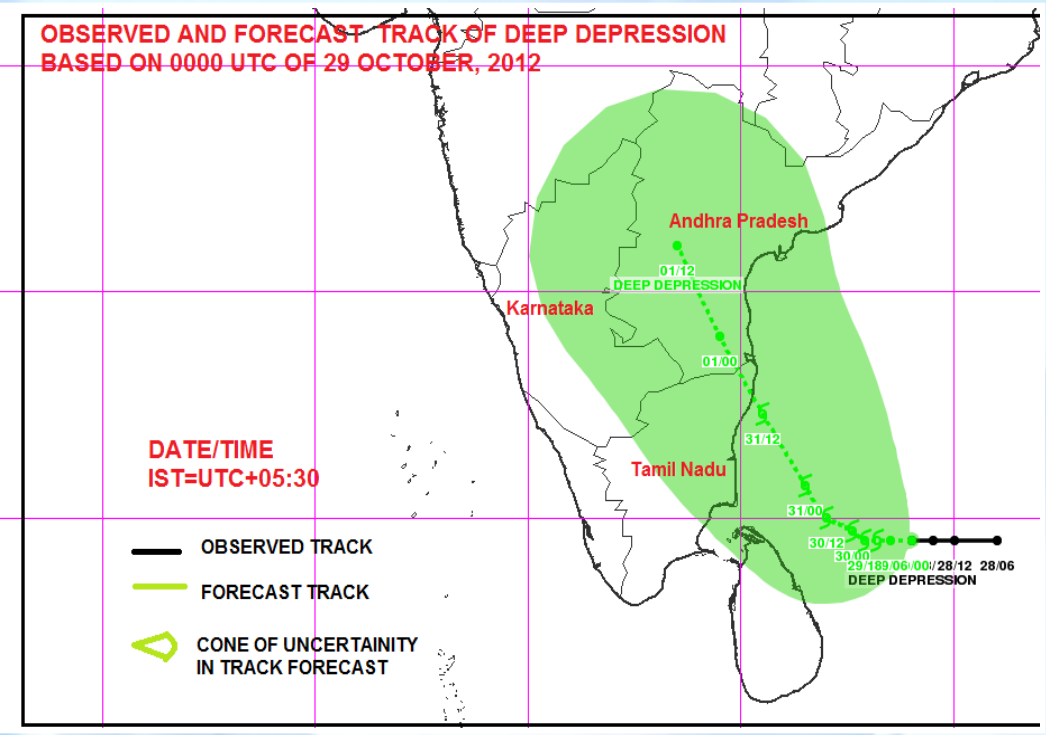
Track forecast skill (%)

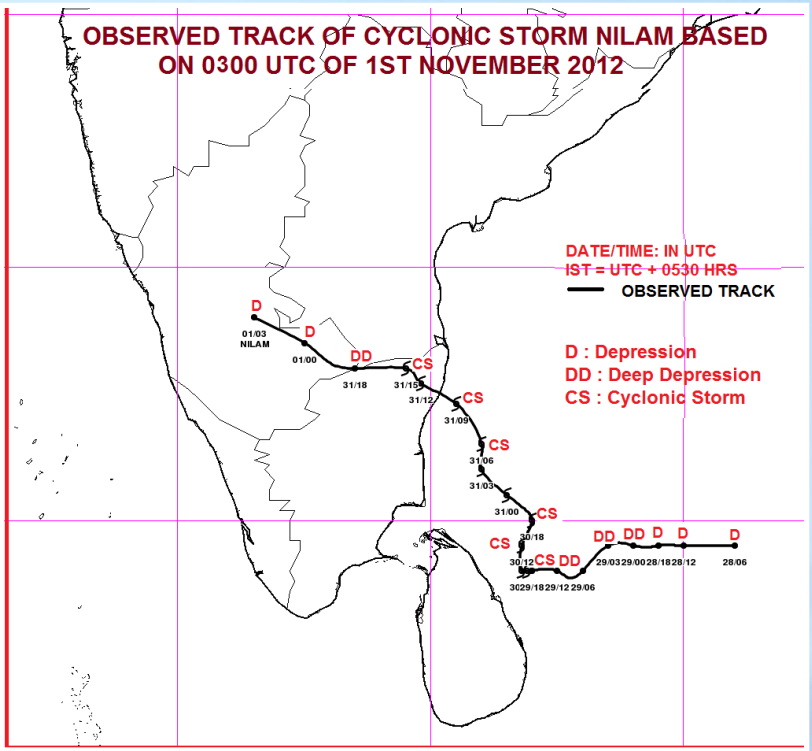



Mean landfall point forecast error (km)
Average (2008-12)
12 hr- 42 km
24 hr- 91 km,
48 hr- 96 km
72 hr- 135 km
12 hr
24 hr
36 hr
48 hr
60 hr
72 hr
600
500
400
300
200
100
0
٢٠٠٣ ٢٠٠٤ ٢٠٠٥ ٢٠٠٦ ٢٠٠٧ ٢٠٠٨ ٢٠٠٩ ٢٠١٠ ٢٠١١ ٢٠١٢


Mean landfall time forecast error (hr)
Average (2009-11)
12 hr- 2.5 hrs
24 hr- 5.5 hrs
48 hr- 7.3 hrs
72 hr- 1.1 hrs
12 hr
24 hr
36 hr
48 hr
60 hr
20
15
10
5
0
٢٠٠٣ ٢٠٠٤ ٢٠٠٥ ٢٠٠٦ ٢٠٠٧ ٢٠٠٨ ٢٠٠٩ ٢٠١٠ ٢٠١١ ٢٠١٢

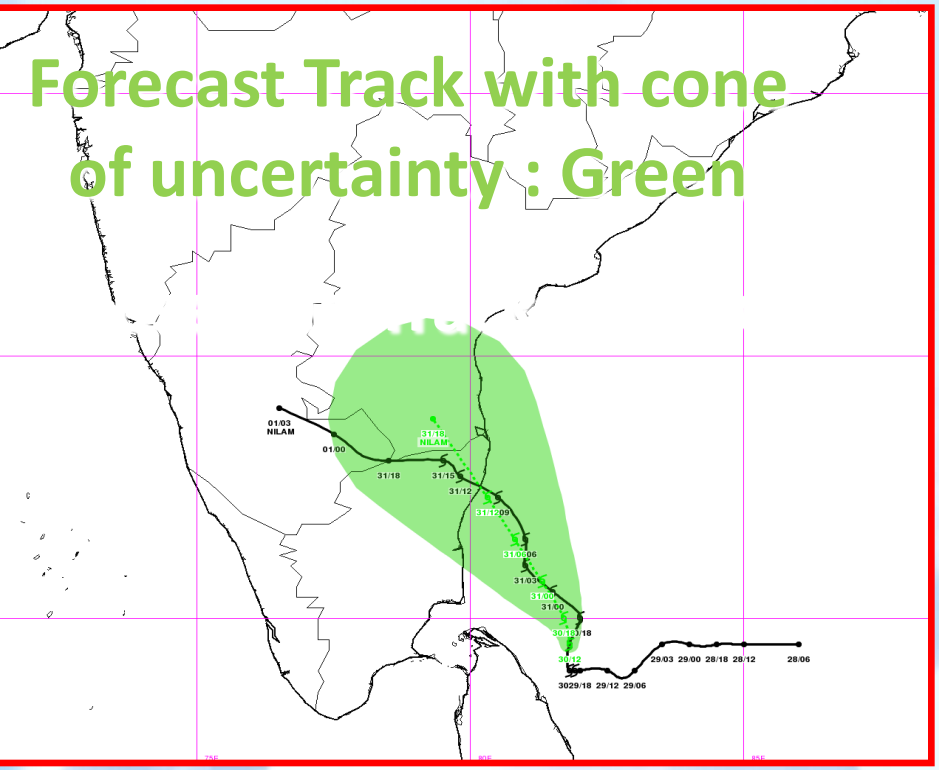
Track Forecast verification of Cyclonic Storm, NILAM (60 hrs in advance of landfall)





Actual place and time of landfall could be predicted 60 hours before the landfall near Chennai

Track Forecast verification of Cyclonic Storm, NILAM (24 hr in advance of landfall)



Avera Landfall orecast Error (km)

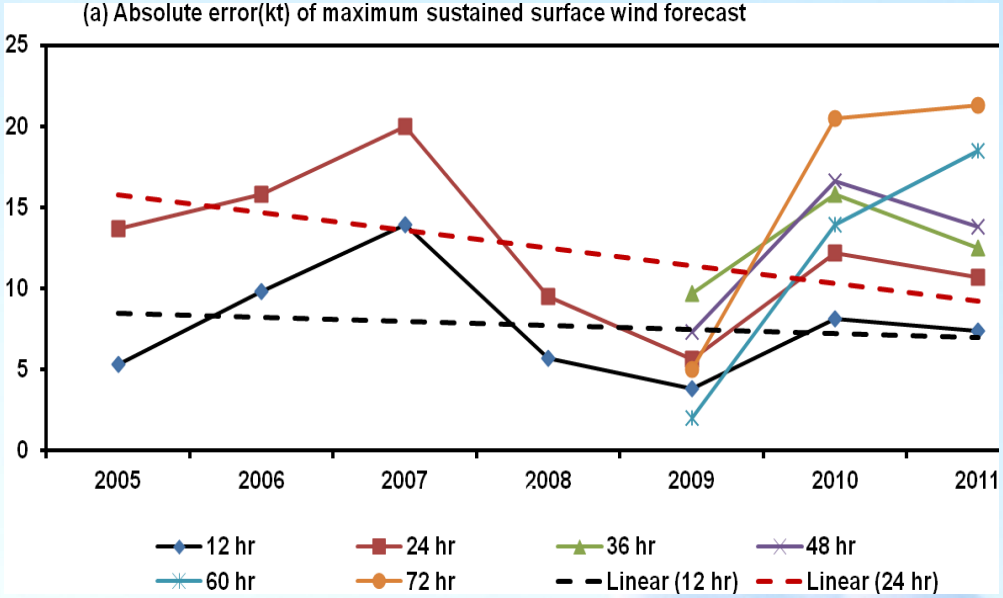
Lead Period (hrs) of forecast from the time of landfall	Landfall Point Forecast Error (km)	Landfall Time Forecast Error (hr)
12	16	1.5
24	11	2.0
36	74	3.0
48	45	1.0
60	11	3.0
72	Cyclone would move towards north Srilanka and Tamil Nadu Coast.	

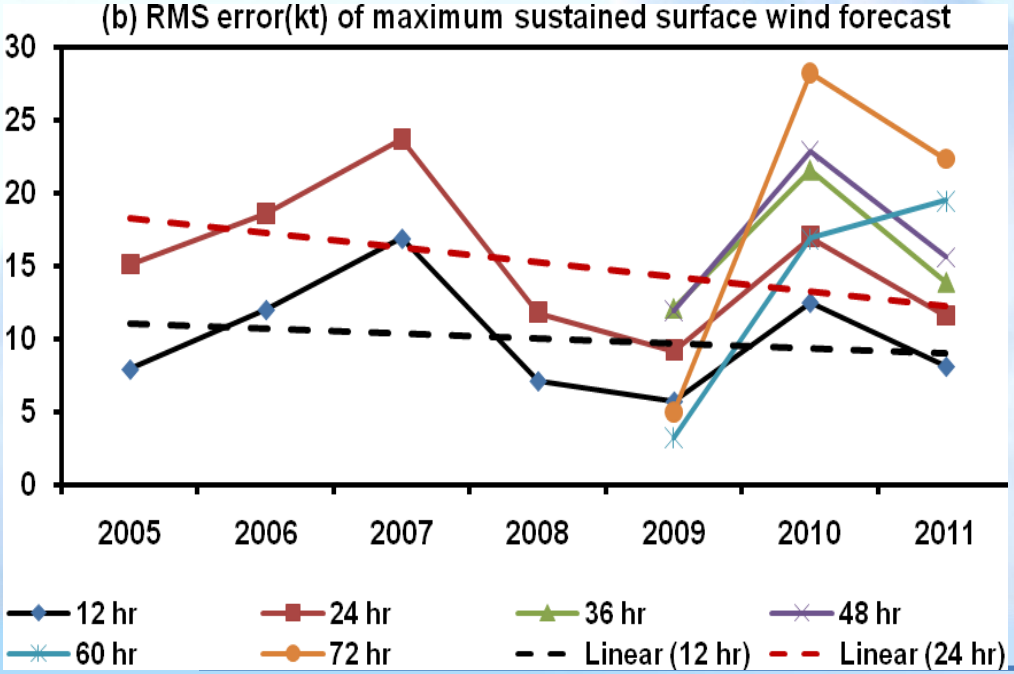
Avera Track Forecast Error (km)

Name of cyclone	Lead period in hours		
	24	48	72
Nilam	114	186	240
Average (2003-11)	148	262	385

Annual Average Track Forecast Error in 2012

Cyclone	Lead Period	Error in Km	No. of forecast
NILAM	12	70	11
	24	114	10
	36	145	7
	48	176	6
	60	172	4
	72	236	2
MURJAN	12	76	5
	24	92	3
	36	112	1
	48	-	-
	60	-	-
	72	-	-
AVERAGE	12	71.875	16
	24	108.9231	13
	36	140.875	8
	48	176	6
	60	172	4
	72	236	2





Average (2009-11)

	AE	RMSE
24 hr-	11 knot	14knot
48 hr-	14 knot	19knot
72 hr-	20 knot	26knot

Skill compared to persistence method

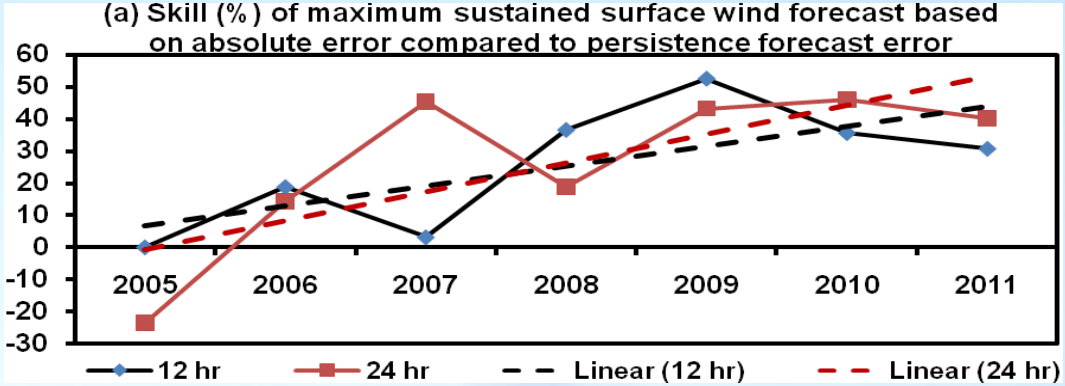
	AE	RMSE
24 hr-	44%,	48%
48 hr-	60%,	58%
72 hr-	60%,	65%

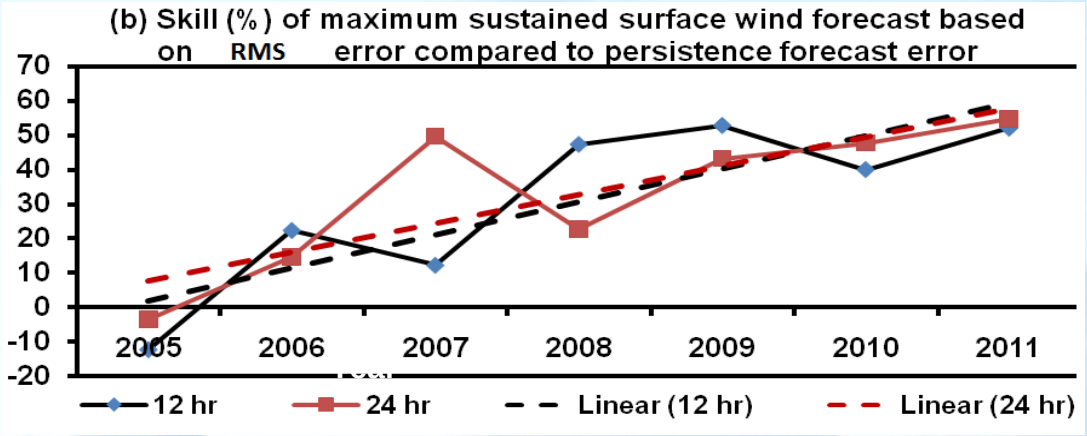
Trend in improvement in skill

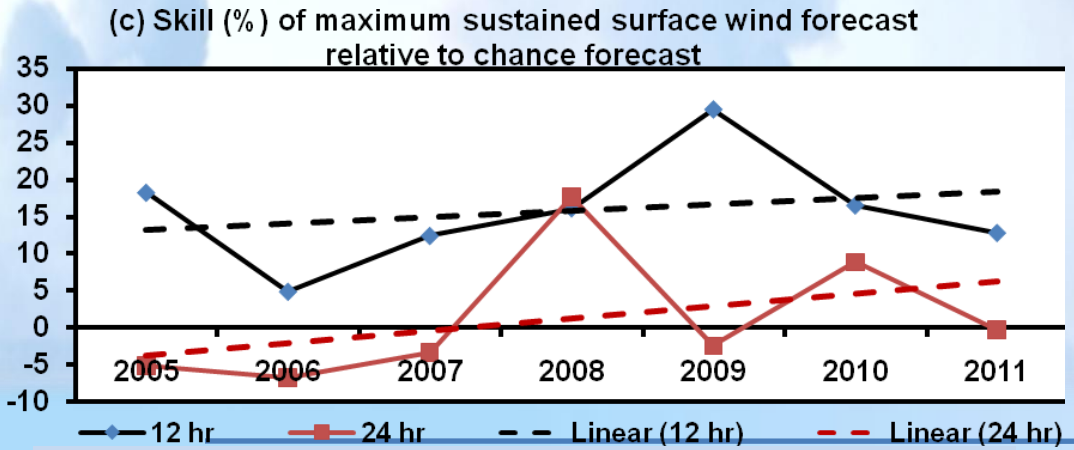
	AE	RMSE
12 hr-	06%,	10%
24 hr-	09%,	08%

Trend is similar to that over northwest Pacific and Atlantic Oceans

Mohapatra et al, 2012, Nat. Hazards







Average (2009-11)

	AE	RMSE
24 hr-	11 knot	14knot
48 hr-	14 knot	19knot
72 hr-	20 knot	26knot

Skill compared to persistence method

	AE	RMSE
24 hr-	44%,	48%
48 hr-	60%,	58%
72 hr-	60%,	65%

Trend in improvement in skill

	AE	RMSE
12 hr-	06%,	10%
24 hr-	09%,	08%

Trend is similar to that over northwest Pacific and Atlantic Oceans

Mohapatra et al, 2012, Nat. Hazards

Annual Average Intensity Forecast Error in 2012

Murjan	**Abs Error**	**RMS Error**	**No. od obsn**
	12	6.9	7.8	5
	24	6	6.4	3
	36	7.4	7.4	1
Nilam			
	12	5.7	6.9	11
	24	7.8	9.2	10
	36	6.8	8.4	9
	48	8.6	11.7	7
	60	7.9	8.5	5
	72	6.7	7.8	3
Annual			
	12	6.1	7.2	16
	24	7.4	8.7	13
	36	6.8	8.3	10
	48	8.6	11.7	7
	60	7.9	8.5	5
	72	6.7	7.8	3

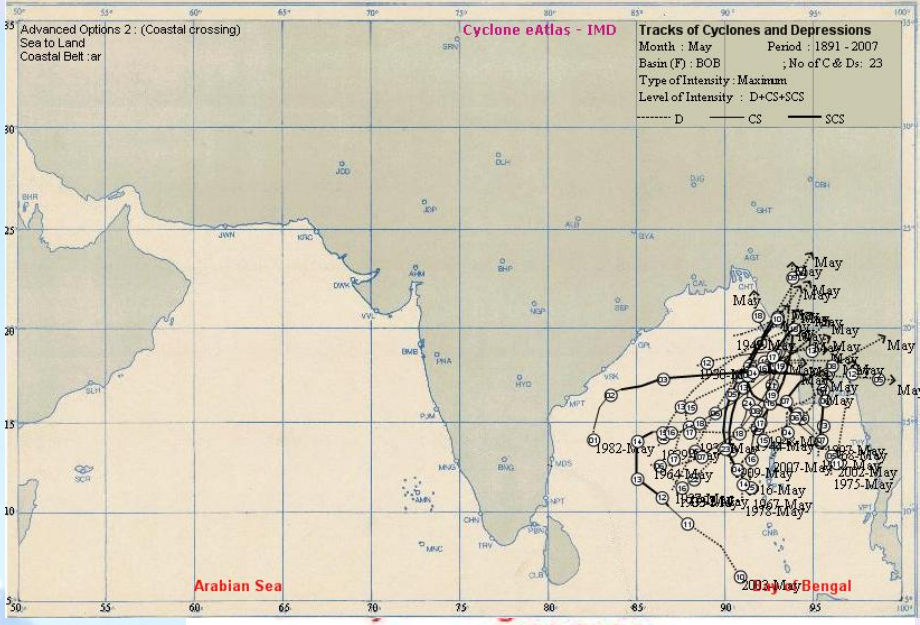
Regional Cooperation :
Real time Data and products

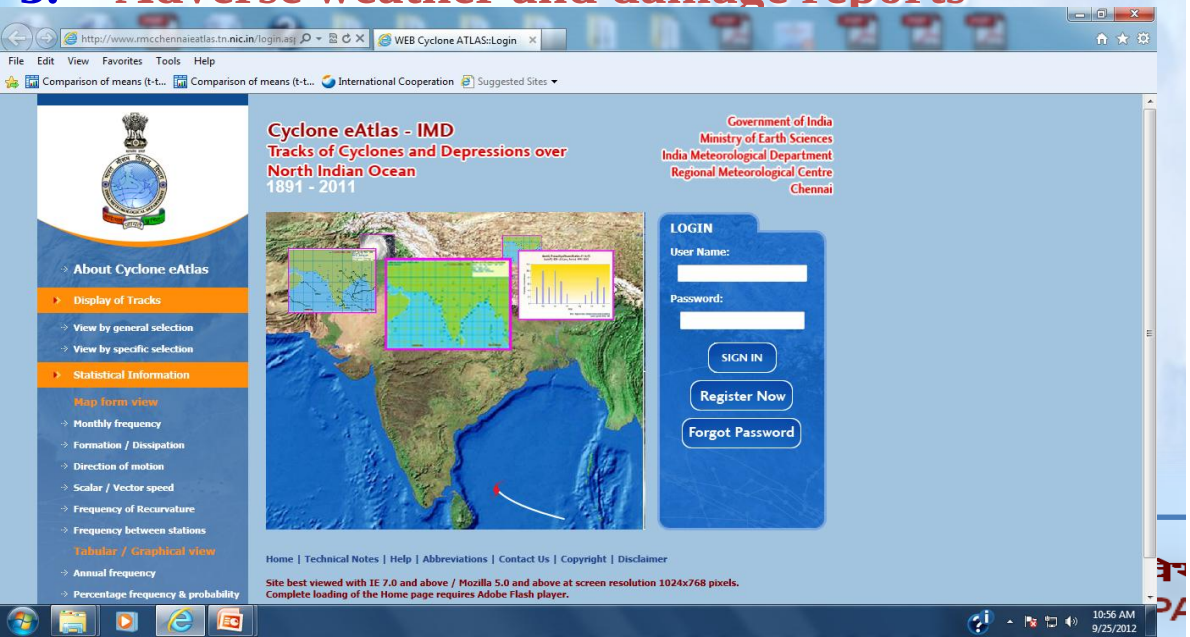
1. All the real time data and products are available in IMD website with open access (www.imd.gov.in)
2. It includes syrface, upper air, satellite and radar data and products
3. All NWP models analyses and forecasts are also available. It includes TC specific products also

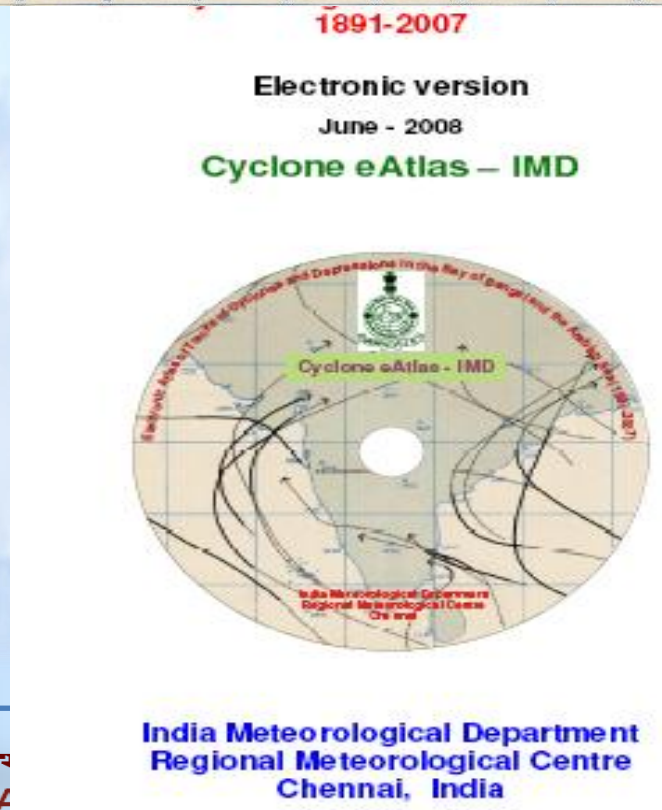
Regional Cooperation : Data Archival and R&D

1. Six hourly best track data of cyclones over north Indian Ocean since 1990 in digital form
2. 12 hourly data in cyclone Atlas during 1891-2009

   Data from 1877-1890 are also available in hard copies in 1979 edition of cyclone Atlas
3. Adverse weather and damage reports



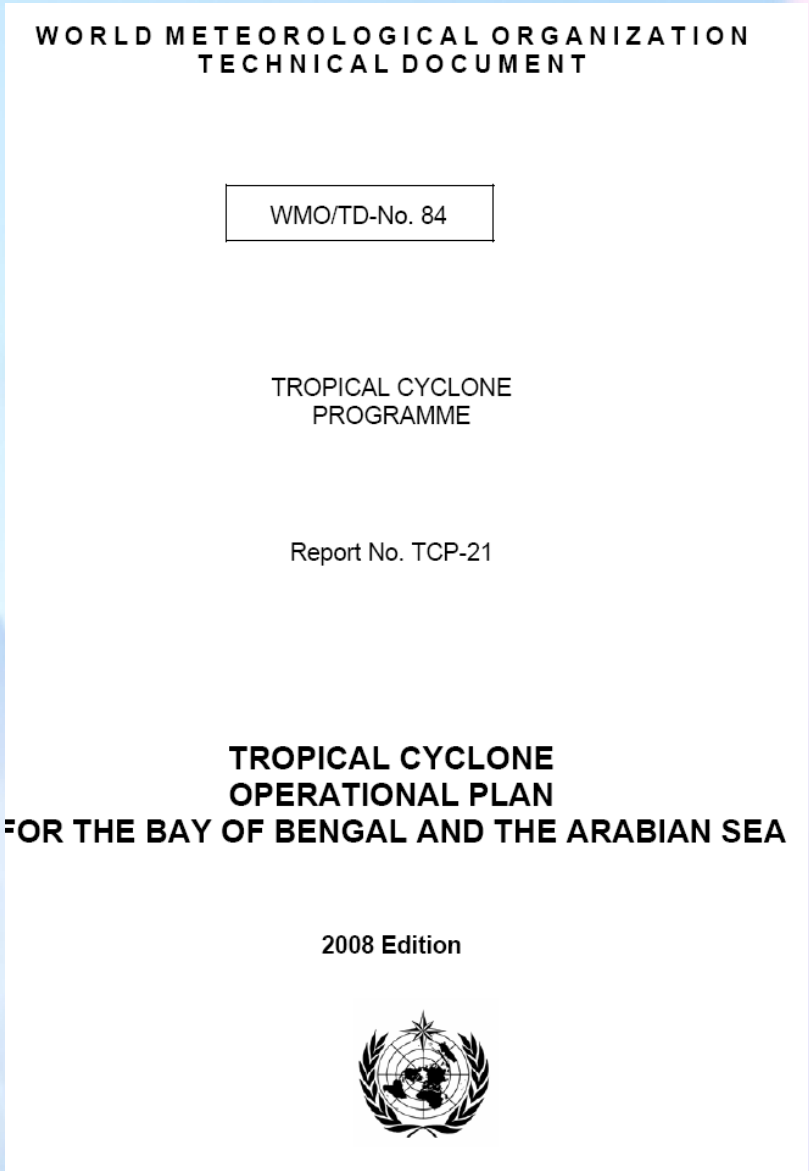




Regional Cooperation : Publications and Plans

- Reports
- Annual RSMC Report on Cyclonic Disturbances
- Annual Cyclone Review Report of WMO/ESCAP Panel countries
- Annual Tropical Cyclone Operation Plan (TCP-21)
- WMO/ESCAP Panel News
- Preliminary reports of cyclonic disturbances

- ❖ Met. Monograph
- ❖ SOPs
- ❖ Benchmarking
- ❖ Vision document


WORLD METEOROLOGICAL ORGANIZATION
TECHNICAL DOCUMENT

WMO/TD-No. 84

TROPICAL CYCLONE
PROGRAMME

Report No. TCP-21

TROPICAL CYCLONE
OPERATIONAL PLAN
FOR THE BAY OF BENGAL AND THE ARABIAN SEA

2008 Edition

Regional Cooperation : Training

- **RSMC, New Delhi is imparting training on cyclone warning to the WMO sponsored forecasters of various countries since 2005.**

Year	Name of Training	Period	Countries	No.of Trainees
2007	WMO cyclone forecasters training	12-23 Feb.	Bangladesh, Myanmar and Sri Lanka	03
2008	WMO cyclone forecasters training	14-25 Feb	Srilanka, Thailand	02
2009	WMO cyclone forecasters training	09-20 Feb.	Bangladesh, Maldives	02
2010	WMO cyclone forecasters training	1-12 feb.	Myanmar, Srilanka	02
2011	WMO cyclone forecasters training	28Feb.-11 March	Bangladesh, Oman, Myanmar	04
2012	WMO cyclone forecasters training	20 Feb-02 March	Thailand, Srilanka, Maldives	03

Regional Cooperation :RSMC Website

- IMD is developing a website exclusively for RSMC, New Delhi. It will be ready by March, 2013
- The data, forecast and products will be available to all the countries of the region through this website.
- There will be a discussion forum for exchange of real time views during TC period

Static information

RSMC

About RSMC

Publications

TROPICAL CYCLONE PROGRAMME Report No. TCP21(2008)

Report on Cyclonic Disturbances over North Indian Ocean during 2008

Cyclone Warning Division

About Cyclone Warning Division

Bulletins

Cyclone Warning Organisation

Tropical Cyclone Awareness

Frequently Asked Questions

Damage Potential of Tropical Cyclone

Port Warnings

Names Of Tropical Cyclones Over North Indian Ocean

Terminology on Cyclonic disturbances over the North Indian Ocean

Archives

Best Tracks Data (1990-2010)

Cyclone E-Atlas IMD

Preliminary Rrports

Vision (cyclone and storm surge)-2020

- Monitoring

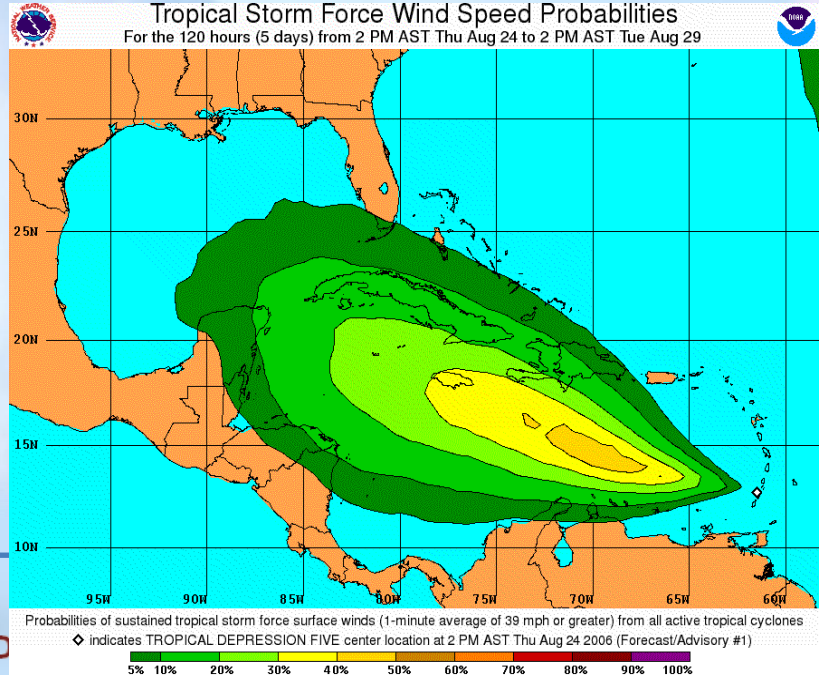
❖ Observational system should be upgraded so as to minimize the existing location error of 50 km to 40 km by 2015 and 30 km by 2020.

- Prediction

❖ More stress would be given to improve accuracy of forecast for smaller domain and longer lead times. Reduction of tropical cyclone track and intensity forecast errors at 12, 24, 36, 48, 72,…..,120 hours upto 20% by 2015 and 40% by 2020.

- Warning

❖ Generate probabilistic wind forecasts, local threat graphics



Vision (cyclone and storm surge)-Contd

- Generate probabilistic wind forecasts, local threat graphics and graphical display of official track /intensity.
- Nowcasting would be started for issuing high impact weather warnings. Real time data from the networking of Doppler Radars, satellites and Automatic Weather Stations would be used for analysis and NWP models.
- Warning should be generated for high impact weather events like heavy rainfall, gale wind and storm surge for smaller regions like blocks in a district and specific location at least 24 hrs in advance with reasonable accuracy.

Gap areas over the NIO Region

- Inadequate observational network:
  - Surface
  - Upper air
  - Radar
  - Nearly absent direct observations from TC field due to no aircraft reconnaissance
  - Inadequate buoy network
  - Ship data are gradually decreasing due to awareness of TC
- Unavailability of intense observation during TC period from the existing network
- Unavailability of real time data:
- Non-uniform TC analysis tools and techniques (varies from manual to digital forecasting work station)

Gap areas and strategy

- Scientific understanding:
- Improvements in forecasting require a better understanding of
  - Detailed structure and dynamics of tropical cyclones.
  - Interaction between cyclone and the ocean, the surrounding environment, high wind speed and
  - Internal physical and dynamical process in clouds.
- Forecast techniques:
  - Improvement of numerical modeling systems including improved numerical methods, ways of handling physical and sub-grid-scale processes, and increasingly sophisticated data assimilation methods with the use of targeted observations, especially from core of the cyclone with aircraft reconnaissance.

Future Plan : FDP on landfalling cyclone

- **Objective :**

  collect observations in the TC core environment using research aircraft and unmanned aerial vehicle (uav).

  Demonstrate the use of the drop soundings and uav data in providing improved numerical guidance for genesis, track and intensity prediction of the bay of bengal tropical cyclone

- **Project schedule :**

  Pre-pilot phase : 15 oct - 30 nov 2008-09

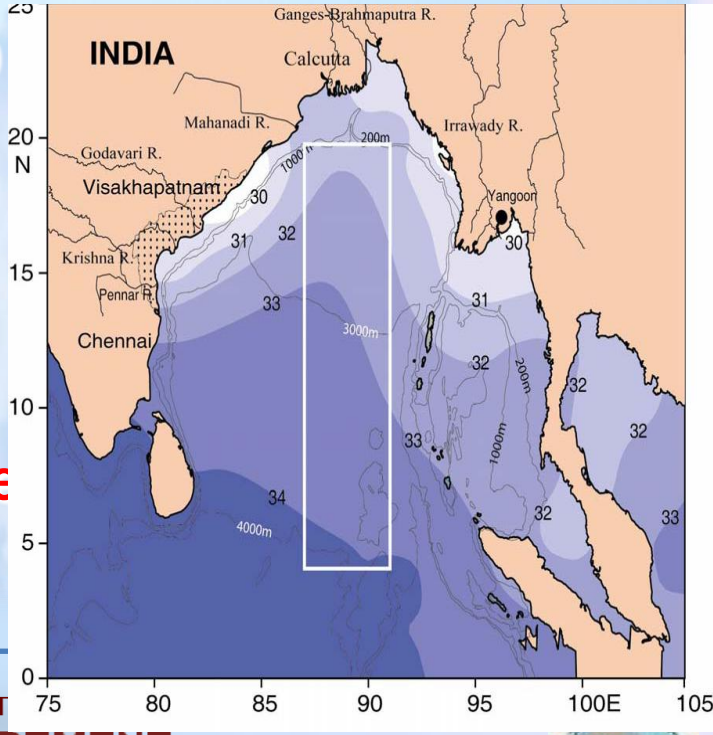
  Pilot phase : 15 oct - 30 nov 2010-12

  Final Phase: 15 OCT - 30 NOV 2013-14

  Region of study : Bay of Bengal

- **During FDP period, daily bulletins are prepared and shared with Panel countrie**

- **All bulletins and reports are available in IMD website**



Thank you