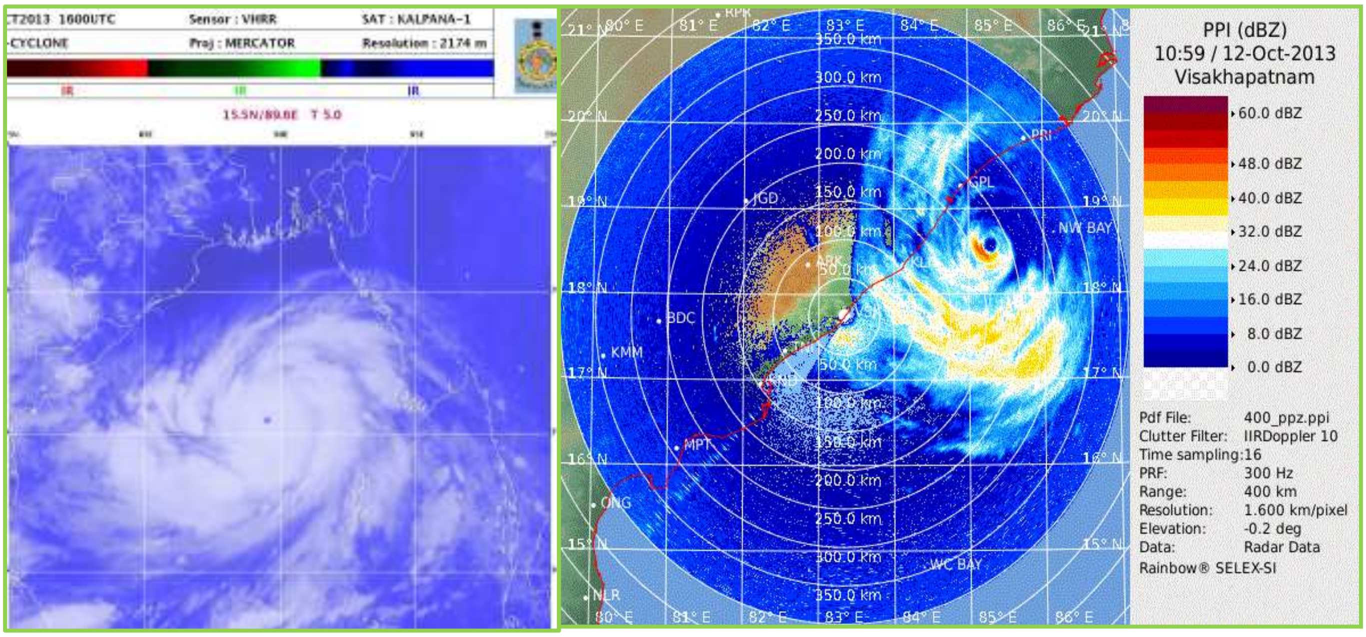
WMO/ESCAP
PANEL ON TROPICAL CYCLONES
ANNUAL REVIEW 2013



Satellite & DWR imageries of Very Severe Cyclonic Storm, 'PHAILIN'

WORLD METEOROLOGICAL ORGANISATION
AND
ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND THE PACIFIC

WMO

ESCAP

WMO/ESCAP

PANEL ON TROPICAL CYCLONES
ANNUAL REVIEW 2013

CONTENTS

PREFACE

First commenced in 1997, the publication of ***WMO/ESCAP Panel*** *- Annual Review* has entered **seventeenth** year of issue for the year 2013. Considerable efforts have gone into producing this document in order to make it useful scientifically and informative for the members of panel. Panel Members are encouraged to make more contributions for further improvement of this publication.

WMO and ***ESCAP*** have played a commendable role in disaster mitigation efforts in the Panel region through continued interaction with the governments of the member countries. There is increasing realization that disaster mitigation effort must encompass all spheres including scientific research on natural hazards, establishment of integrated-all-hazard early warning system and most importantly, empowering communities to be self reliant for timely and proper response to warnings. Despite rapid technological advances made in the recent past, the problem of generating accurate weather forecasts and associated warnings/ advisories and their timely dissemination to the communities at highest risk continues to be a great challenge. In order to make the early warning system more effective, it is essential that the Panel Members take new initiatives. The basic aim of the panel is to improve the quality and content of cyclone warnings, devise methods for quick dissemination of warnings and flood advisories and ensure proper response by concerned agencies and the community.

This review highlights the achievements made during the year, 2013 in the region in pursuance of the goals set out by the ***WMO / ESCAP*** *Panel* and the activities of other international and national organisations in support of the above tasks, within the overall objective of mitigating the impact of natural hazards. I would like to express my sincere thanks to all the Panel Members for their valuable inputs and contributions and hope for the same in future.

B.K. Bandyopadhyay
Chief Editor

WMO AND THE WMO / ESCAP PANEL ON TROPICAL CYCLONES

WORLD METEOROLOGICAL ORGANIZATION (WMO)

The World Meteorological Organisation (WMO), of which 185 States and Territories are Members, is a specialised agency of the United Nations. The objectives of the organisation are:

- To facilitate international co-operation in the establishment of networks of Stations and Centres to provide Meteorological and Hydrological services and observations;
- To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;
- To promote standardisation of meteorological and related observations and ensure the uniform publication/circulation of observations and statistics;
- To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities;
- To promote activities in operational hydrology and to further close co-operation between Meteorological and Hydrological Services and
- To encourage research and training in meteorology and, as appropriate, in related fields and to assist in co-ordinating the international aspects of such research and training.

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC (ESCAP)

The Economic and Social Commission for Asia and the Pacific (ESCAP) aims to initiate and participate in measures for concerted action towards the development of Asia and the Pacific, including the social aspects of such development, with a view to raising the level of economic activity and standards of living and maintaining and strengthening the economic relations of countries and territories in the region, both among themselves and with other countries in the world. The commission also:

- Provides substantive services, secretariats and documentation for the Commission and its subsidiary bodies;
- Undertakes studies, investigations and other activities within the commission's terms of reference;
- Provides advisory services to Governments;
- Contributes to the planning and organisation of programmes of technical co-operations and acts as executing agency for those regional projects decentralised to it.

WMO / ESCAP PANEL ON TROPICAL CYCLONES

Huge loss of human life, damage to property and unbearable sufferings of human beings caused by tropical cyclones in coastal areas in various parts of the globe like Atlantic, Pacific, China Sea and North Indian Ocean (NIO) coast are regular features.

The disaster potential due to cyclones is particularly high in the NIO comprising of the Bay of Bengal & the Arabian Sea region, which is being associated with high storm surge, which is the greatest killer in a cyclone. This region has the distinction of having experienced the world's highest recorded storm tide of 41 feet (1876 Bakherganj cyclone near Megna estuary, Bangladesh) followed by 13 metres over West Bengal coast on 7th October, 1737 in association with another super cyclone . Past records show that very heavy loss of life due to tropical cyclones have occurred in the coastal areas surrounding the Bay of Bengal. In the recent past, during the year 1998, the state of Gujarat in India experienced the impact of a very severe cyclonic storm, which crossed coast north of Porbandar (42830) on June 9, 1998 and caused huge damage to public property near Kandla Port (42639). A Super Cyclonic Storm that crossed east coast of India near Paradip (42976) in Orissa state on October 29, 1999 took a toll of 9885 lives and caused huge damage to property in 12 districts of the state. Apart from causing large-scale devastation to agriculture and plantation crops, it also affected entire infrastructure on communication, power and transport. The storm surge of 5-6 m height was experienced in areas close to and southwest of Paradip. This cyclone was century's most intense cyclone and its unusual feature was that it remained practically stationary after crossing coast and battered the State of Orissa for 36 hours. In June, 2007 another super cyclone 'Gonu' developed over southeast Arabian Sea, moved north-westward, crossed Oman coast and then entred into Gulf of Oman and made second landfall over Iran coast. It caused huge damage to the property and loss of lives in Oman and Iran. The very severe cyclonic storm, 'Nargis' crossed Myanmar coast near Irrawaddy delta on 2nd May 2008 and caused loss of about 138,000 lives in Myanmar.

Realising the importance of an effective cyclone warning and disaster mitigation machinery in the region, WMO and ESCAP jointly established the Panel on Tropical Cyclones (PTC) in 1972 as an inter-Governmental body. Its membership comprises the countries affected by tropical cyclones in the NIO. Its Member countries are Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand.

The Panel is one of the six regional tropical cyclone bodies established as part of the WMO Tropical Cyclone Programme (TCP) namely Miami, Honolulu, Tokyo, New Delhi, La Reunion and Nadi that aims at promoting and co-ordinating the planning and implementation of measures to mitigate tropical cyclone disaster.

It also aims to initiate and participate in measures for concerted action towards the development of Asia and the Pacific including social aspects of such developments, with a view to raising the level of economic activity and standards of living and maintaining and strengthening the economic relations of countries and territories in the region, both among themselves and with other countries in the world.

The first session of WMO/ESCAP Panel on Tropical Cyclones was convened in Bangkok, Thailand in January 1973. The functions of the Panel are:

- ► To review regularly the progress in various fields of tropical cyclone damage prevention;
- ► To recommend to the member countries plans and measures for the improvement of community preparedness and disaster prevention;
- ► To promote, prepare and submit to member countries plans for co-ordination of research programmes and activities on tropical cyclones;
- ► To facilitate training of personnel from member countries in tropical cyclone forecasting and warning, flood hydrology and its control within the region;
- ► To plan for co-ordination of research programmes and activities concerning tropical cyclones within member countries;
- ► To prepare and submit, at the request and on behalf of the member countries requests for technical, financial and other assistance offered under United Nations Development Programme (UNDP) and by other organisations and contributors and
- ► To consider, upon request, possible sources of financial and technical support for such plans and programmes.

In carrying out these functions, the PTC committee maintains and implements action programmes under the five components of meteorology, hydrology, disaster prevention and preparedness, training and research with contributions and co-operation from its Members and assistance by the UNDP, ESCAP, WMO and other agencies.

The Panel at its twelfth session in 1985 at Karachi (Pakistan) adopted a comprehensive cyclone operational plan for this region. The basic purpose of the operational plan is to facilitate the most effective tropical cyclone system for the region with existing facilities. The plan defined the sharing of responsibilities among Panel countries for the various segments of the system and recorded the co-ordination and co-operation achieved. The plan also recorded the agreed arrangements for standardization of operational procedures, efficient exchange of various data and its archival related to tropical cyclone warnings, issue of a tropical weather outlook and cyclone advisories from a central location having the required facilities for this purpose, for the benefit of the region and strengthening of the operational plan. Further the Panel agreed upon the issue of tropical cyclone advisory bulletin for use of aviation as per recommendation No. 1/21 of International Civil Aviation Organisation (ICAO) in its 12th meeting of 161st session held at Montreal, Canada during 09-26 September, 2002

The operational plan is evolutionary in nature. Its motivation is to update or raise the text of the plan from time to time by the Panel and each item of information given in the annexes of the plan to be kept up to date by the member country concerned.

RSMC- Tropical Cyclone, New Delhi:

Regional Specialized Meteorological Centre (RSMC) - Tropical Cyclones, New Delhi, which is co-located with Cyclone Warning Division of IMD came into the existence in 1988 as per the recommendation of first session of WMO/ESCAP Panel on Tropical cyclones held in January,1973. It has the responsibility of issuing Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of the countries in the World Meteorological Organization (WMO)/ Economic and Social Co-operation for Asia and the Pacific (ESCAP) Panel region bordering the Bay of Bengal and the Arabian Sea, namely, Bangladesh, Maldives, Myanmar, Pakistan, Sultanate of Oman, Sri Lanka and Thailand. It has also the responsibilities as a Tropical Cyclone Advisory Centre (TCAC) to provide Tropical Cyclone Advisories to the designated International Airports as per requirement of International Civil Aviation Organization (ICAO).

The area of responsibility of RSMC- New Delhi covers Sea areas of north Indian Ocean north of equator between 45^0 E and 100^0 E and includes the member countries of WMO/ESCAP Panel on Tropical Cyclones viz. Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, Sultanate of Oman and Thailand

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

- Round the clock watch on 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 disturbances in the Bay of Bengal and the Arabian Sea.
- Running of numerical weather prediction models for tropical cyclone track and storm surge predictions.
- Interaction with National Disaster Management Authority and National Disaster Management, Ministry of Home Affairs, Govt. of India to provide timely information and warnings for emergency support services. RSMC-New Delhi also coordinates with National Institute of Disaster Management (NIDM) for sharing the information related to cyclone warning.
- Implementation of the Regional Cyclone Operational Plan of WMO/ESCAP Panel.
- Issue of Tropical Weather Outlook and Tropical Cyclone Advisories to the Panel countries in general.
- Issue of Tropical Cyclone advisories to International airports in the neighbouring countries for International aviation.

- Collection, processing and archival of all data pertaining to cyclonic disturbances viz. wind, storm surge, pressure, rainfall, damage report, satellite and Radar derived information etc. and their exchange with Panel member countries.
- Preparation of comprehensive annual reports on cyclonic disturbances formed over North Indian Ocean every year.
- Preparation of annual review report on various activities including meteorological, hydrological and disaster preparedness and prevention activities of panel member countries.
- Research on storm surge, track and intensity prediction techniques.

COMMITTEE ON WMO/ESCAP PANEL ON TROPICAL CYCLONES (2013 –14)

Chairman : Mr Md. Shah Alam (Bangladesh)
Vice-Chairman : Mr Ali Shareef (Maldives)
Chairman drafting committee: Mr Ali Shareef (Maldives)

TECHNICAL SUPPORT UNIT (TSU)
ISLAMABAD, PAKISTAN

Co-ordinator : Mr. Arif Mahmood
Meteorologist : Mr. Imran Akram

EDITORIAL BOARD FOR THE 2013 ANNUAL REVIEW

WMO SECRETARIAT FOR
TROPICAL CYCLONE PROGRAMME (TCP)

Mr. Michel Jarraud : Secretary General
Dr. Tokiyoshi Toya : Regional Director for Asia and South-West Pacific
Dr. Taoyong Peng : Chief, TCP Division

UNITED NATIONS ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND THE PACIFIC (UNESCAP)

Mr Alf Blikberg	**Programme Officer/UN-ESCAP Disaster Risk Reduction Section of the ICT**
Mr Keran Wang	**Chief, Space Applications Section Information and Communications Technology and Disaster Risk Reduction Division, UNESCAP**

UNESCAP Secretariat, Bangkok, Thailand
Dr. Xuan Zengpei : Director, ICT & Disaster Risk Reduction

INTRODUCTION

Publication of "WMO/ESCAP Panel on Tropical Cyclones–Annual Review commenced with the review for the year 1997. This was as per the decision of the Second Joint Session of the WMO/ESCAP Panel on Tropical Cyclones and Typhoon Committee held at Phuket, Thailand 20-28, February 1997. The present Annual Review-2012 contains primary contribution from the Panel member countries.

Chapter I contains detailed information on national programmes and activities related to meteorology, hydrology, disaster prevention and preparedness, training and research as supplied by Panel Members. Technical and administrative support provided and activities undertaken by the Panel.

A summary of Tropical Cyclones during 2013 is given in the first part of Chapter II. Earlier, tropical cyclones were identified by their geographical locations. From post monsoon season 2004, the practice of naming each tropical cyclone individually has been adopted in the north Indian Ocean basin also. Tropical disturbances are classified as per the practice introduced at Regional Specialised Meteorological Centre (RSMC)– Tropical Cyclones New Delhi. The classification of disturbances is shown in the following Table. The term "Cyclone" used in the present text is a generic for the four categories of cyclonic disturbances (S.N. 4 to 7) in the Table.

Classification of low-pressure systems at RSMC–Tropical Cyclones, New Delhi

S No.	Maximum sustained surface wind Speed in knot (kmph)	Nomenclature
1.	Less than 17 (< 31)	Low Pressure Area (L)
2.	17 to 27 (31-49)	Depression (D)
3.	28 to 33 (50- 61)	Deep Depression (DD)
4.	34 to 47 (62 –88)	Cyclonic storm (CS)
5.	48 to 63 (89 – 117)	Severe Cyclonic Storm (SCS)
6.	64 to 119 (118 –221)	Very Severe Cyclonic Storm (VSCS)
7.	120 and above (≥ 222)	Super Cyclonic Storm (SuCS)

The second part of Chapter II contains a brief report on tropical cyclones affecting Panel countries during 2013. Based on the real time and climatological data available with India Meteorological Department (IMD), India, special features of the 2013 tropical cyclone season are highlighted. It also contains realized weather and the damages caused due to cyclones. All units used in the chapters are as per standard norms.

In the context of Chapter II, sustained winds refer to wind speeds averaged over a period of 3 minutes. Kilometer per hour (kmph) / knot is the unit used for wind speed as well as speed of movement of tropical cyclones. The S.I. unit of hecta-Pascal (hPa) is used for atmospheric pressure. Reference time used is primarily in Universal Time Coordinate (UTC). Wherever possible, station names contained in WMO Weather

Reporting-Observing Stations (WMO/OMM-No.9 Volume A) are used for geographical reference with code.

Chapter III consists of contributed articles / research papers on tropical cyclones received from Member countries and scientists from various organizations.

Chapter IV contains outlines of Activities of PTC Secretariat during the Intersessional Period 2013-2014

CHAPTER-I

WMO/ESCAP PANEL ACTIVITIES IN 2013

1.1 METEOROLOGICAL ACTIVITIES

Activities of member countries on WMO/ESCAP Panel for the year 2013 were presented at the forty first session of the WMO/ESCAP Panel on tropical cyclones held at Dhaka, Bangladesh from 2-6 March 2014. Under this item, matters relating to the basic observational network, the telecommunication links and data-processing systems established in the region to fulfill the requirements of WMO's World Weather Watch Programme were reviewed. The Panel reviewed the activities under the meteorological component of the Members during the past year. These are briefly summarized below:

1.1.1 Bangladesh

1.1.1.1 Surface Observation

There are 35 surface observatories in Bangladesh Meteorological Department (BMD).

Bangladesh Meteorological Department is in the process of strengthening of its observational network:

- Introduction of advanced technology for observational systems with induction of Automatic Weather Station (AWS).
- BMD has installed Two Doppler Weather Radar at Cox's Bazar & Khepupara for Tropical Cyclone monitoring.
- BMD has installed one Doppler Weather Radar at Mowlvi Bazar, North-eastern part of Bangladesh for flash flood warning.
- There are another two Weather Radar at Dhaka and Rangpur for monitoring severe local thunder storm.
- 24 AWS will be installed under SAARC STORM programme at different places for Nor'westers.

1.1.1.2 Upper Air Observation

GPS based Radiosode-3

1.1.2 India

A brief description of different types of observational network of India Meteorological Department (IMD) and observations collected from networks are given below:

1.1.2.1 Surface Observatories

The network of surface meteorological observatories consists of total 709 Stations. The break-up of various categories is as follows:

CATEGORY OF DEPARTMENTAL OBSERVATORIES

CLASS	RMC DELHI	RMC CHENNAI	RMC KOLKATA	RMC MUMBAI	RMC NAGPUR	RMC GUWAHTI	*TOTAL*
I , II (a), IV, VI & SMO (Deptt.)	57	53	31	29	17	17	204
II (b), II (c), II (d), III & IV, V, VI Io & EMO (Non Deptt.)	106	71	47	30	47	25	326
V (Non Deptt. HMO)	64	17	54	21	12	11	179
TOTAL	**227**	**141**	**132**	**80**	**76**	**53**	**709**

1.1.2.1.1 Airport Meteorological Instruments

There are about seventy airports where meteorological instruments have been provided. The international and national airports are equipped with additional instruments such as:

1) Laser Ceilometers
2) Transmissometer
3) Current Weather Instrument System
4) Distant Indicating Wind Equipment

1.1.2.1.2 High Wind Speed Recorders (HWSRs)

HWSR systems have been installed and operational at 13 coastal stations. These are Digha, Vishakapatnam, Chennai, Nellore, Machilipatnam, Karaikal, Puri, Balasore, Gopalpur, Mumbai (Colaba), Goa, Veraval & Dwarka,

This system is not functional at Balasore. All HWSR stations are being equipped with GPRS modems so that the data in real time is available at website "imdaws.com". Real time HWSR data from Karaikal, Goa & Veraval is already available through above website.

1.1.2.1.3 Radiation Network

The Radiation network consists of a total of 45 stations. There are 20 principal radiation stations where measurement of direct solar radiation – (either continuous or spot readings). Global Solar Radiation, Diffuse Sky Radiation, and Sunshine hours are made. Remaining radiation stations measure only one or two of these parameters and the duration of sunshine. Central Radiation Laboratory at Pune is maintaining this network of radiation measuring stations. It includes maintenance of the absolute standards and transfer standards, repairing and calibration of sensors, calibration and maintenance of network instruments, etc. Inter comparison of regional standard Pyrheliometer is done with international standards once in five years.

Central Radiation Laboratory, Pune, is a National Centre for India and also designated as Regional Radiation Centre for RA-II by WMO.

A radiation measuring station is also functioning at Maitri, Antarctica for last many years, recording global radiation, diffuse radiation and sun photometer measurements.

A project scheme to augment the radiation network with additional sensors and satellite communication of data is completed. All the stations were equipped with satellite link data logger and additional sensor for UV-A & Terrestrial radiation. Armstrong pyrheliometer is replaced with thermoelectric pyrheliometer on solar tracker at 13 stations for continuous recording of Direct Radiation. UV B radiometers have been installed and interfaced to data loggers at twenty three network stations. Data loggers at these stations are also interfaced to GPRS modems, which acquire data from the data logger and transmit it on the website, at 10 minutes interval which can be accessed at any location.

1.1.2.1.4 AWS Network

One hundred SUTRON make AWS systems and 25 ASTRA make AWS systems along with PRBS earth station were procured during June 2006. Under project 550 AWS, a TDMA earth station along with 550 AWS has been installed. All AWS systems have been installed. Data from AWS sites are being received at Pune Receiving Earth Station. From Pune Receiving Earth Station, hourly data is being sent to AMSS Mumbai through dedicated lease line for onward transmission through GTS to different users. Quality of AWS data from new AWS stations is under evaluation. Under the project 1350 ARGs, 1098 ARGs have been installed.

1.1.2.1.5 Moored Met Ocean Buoys

The 12 Buoy Network performed successfully during April 2011 to March 2012 and provided valuable data. The 12 buoy network was maintained, out of which six were OMNI buoys and six were Met-Ocean buoys.

1.1.2.1.6 Recent Achievements

1. Completion of 550 AWS Project in February 2013.
2. Augmentation of surface ozone network: Installation of Surface Ozone Instruments at 10 stations.
3. Comparison of AWS data received through Kalpana – 1 Satellite with Co- located obsy. data is in progress.
4. Installation of sky radiometers at 13 stations.
5. GPRS based modules interfaced with Sutron data logger at 15 radiation stations to facilitate transmission of the data on the website. Thus real time data can be accessed at any location on the website.
6. A new Wind Tunnel having a speed range of 0-70 mps has been installed at AWS lab, IMD, Pashan, Pune during May 2013 for calibration of Wind sensors and anemometers.

7. 15 stations under RMC Mumbai have been equipped with Hand held Data Loggers under the 'Automation of surface observatories; (HHDL project) for transmissions of SYNOP data via GSM SIM cards from observatories to RMC Mumbai. The systems are under trial.
8. AWS observatories at Pahalgam, Chandanwadi and Baltal tenroute Shri Amarnathji Yatra were established during April 2013 as per Supreme Court order.
9. Aviation Weather Observation System (AWOS) has been installed at Juhu heliport for helicopter operations. The system is kept under trials.

1.1.2.1.7 Future Plan 12th Five Year Plan (2012-2017)

1.1.2.1.7.1 Under the projects AOSN

I. Annual Maintenance Contract for Astra make Automatic Weather Station (550 Nos)
II. Annual Maintenance Contract for Automatic Rain Gauge Station (1350 Nos)
III. Annual Maintenance Contract for TDMA type data receiving Earth Station
IV. Test Equipments and travelling standards for AWS
V. QA/QC system for AWS and ARG
VI. Procurement of high accuracy GNSS receivers (8 Nos.) for survey of AWS and ARG stations.
VII. Commissioning of TDMA type receiving Earth Station at IMD Pune
VIII. Augmentation of Radiation Network.
IX. Procurement of Digital Station Barometers (500Nos.).

1.1.2.1.7.2 Projects under Weather Services - Aviation

1.1.2.1.7.2.1 Airport Meteorological Instruments (AMI)

I. Commissioning of Automatic Weather Observing System (AWOS) at 56 airports including 10 new Greenfield airports.
II. Commissioning of Automatic Weather Observing System for safety of helicopter operations at 20 heliports.
III. Procurement of spares for in house maintenance of AMIs, such as Current Weather Instrument System, ceilometers and Transmissometers.
IV. Commissioning of 20 additional transmissometers at some international airports

1.1.2.2 Upper Air observatories

(a) 11 Nos. of GPS based Upper Air Sounding systems installed/ commissioned at RS/RW Chennai, Hyderabad, Goa, Thiruvananthapuram, Vishakhapatnam, Amini, Minicoy, Portblair, Mohanbari, Patna, Srinagar. A total of 17 GPS stations are working at present.

(b) Implementation of MK-IV modified radiosonde by using digital pressure sensor in place of barrow-switch, at RS/RW stations of Gwalior, Gorakhpur, Jaipur, Siliguri, Mumbai, Jagdalpur, Raipur, Machilipatnam, Karaikal, Mangalore done.

(c) Indigenous GPS based radiosonde developed with M/S SAMEER, Mumbai. Procurement of different components initiated and production will start on receipt of material.

1.1.2.2.1 Status of Doppler Weather Radar Network of IMD

Under phase I of modernization, IMD is in the process of replacing many old and obsolete Analogue Radars with the state of art Doppler Weather Radars (DWRs) at 16 locations around the Country, viz., Patiala, Delhi IGI Airport, Lucknow, Bhopal, Nagpur, Mumbai, Bhuj, Karaikal, Paradip, Goa, Mohanbari, Agartala,Patna, Hyderabad, Delhi IMD HQs and Jaipur. Out of these 16, two are C band Polarimetric Doppler Weather Radars, which are installed at Delhi IMD HQs and Jaipur Airport. These are capable to provide additional information on shape, size and classification of hydrometeors & 8 S-band DWRs have also been commissioned at Delhi (Palam), Hyderabad, Nagpur, Agartala, Patna, Lucknow, Patiala, Mohanbari and Bhopal. Remaining 5 are under process of Installation/ commissioning. Commissioning of Mumbai DWR is pending due to non-completion of SAT and thereafter Bhuj SAT will be conducted. Installation work will be started at the coastal stations Paradip, Goa, & Karaikal after getting Security, Audit Clearance Report.

In the Phase II of modernization, 34 DWRs are originally proposed to be procured and installed at various locations throughout India. Approval for Modernization of Phase-II is under progress. After approval of competent authority, infrastructure development requires 2-3 years period and further 3-4 months are required for commissioning. All of these radars have been proposed to be Polarimetric Doppler Weather RADARs. As per this plan on completion of modernization programme, entire Country will be under the coverage of 55 DWRs. However. MoES has constituted a high level national committee to review the locations, types and total numbers of DWRs to be installed. The report of the committee is awaited.

1.1.2.2.2 Satellite Meteorology

1.1.2.2.2.1 Satellite Monitoring

1.1.2.2.2.1.1 Current status

At present IMD is receiving and processing meteorological data from three Indian satellites namely Kalpana-1, INSAT-3A & INSAT-3D. Kalpana-1 was launched on 12th September, 2002 and is located at 74.0° E. INSAT-3A was launched on 10 April, 2003 and is located at 93.5° E. INSAT-3D has been launched on 26 July 2013. Kalpana-1 and INSAT-3A both have pay load of Very High Resolution Radiometer (VHRR) for imaging the earth in three channels viz. Visible (0.55-0.75 µm), Infra-Red (10.5-12.5µm) and Water vapour (5.7-7.1µm) having resolution of 2X2 km in visible and 8X8 km in Water vapour (WV) and Infra red (IR) channels. In addition, the INSAT-3A has a three channel Charge Coupled Device (CCD) payload for imaging the earth in Visible (0.62- 0.69um), Near IR (0.77-0.86µm) and Short Wave IR (1.55-1.77µm) bands of Spectrum. The Resolution of CCD payload in all the three channels is 1KmX 1 Km. INSAT-3D has an advanced imager with six imagery channels (VIS, SWIR, MIR, TIR-1, TIR-2, & WV) and a nineteen channel sounder (18 IR &1 Visible) for derivation of atmospheric temperature and moisture profiles. It provides 1 km. resolution imagery in visible band, 4 km resolution in IR band and 8 km in water vapour channel.

At Present about 48 nos. of satellite images are taken daily from Kalpana-1, approximately 20 images are taken from INSAT-3A. Imaging from CCD is done 5 times during daytime only. Half hourly satellite imageries are also obtained from all the six imager channels and hourly images from the sounder channels of INSAT-3D satellite.

All the received data from the satellite are processed and archived in National Satellite Data Centre (NSDC), New Delhi. Indian Meteorological Data Processing System (IMDPS) is processing meteorological data from INSAT VHRR and CCD data and supports all operational activities of the Satellite Meteorology Division on round the clock basis. Cloud Imagery Data are processed and transmitted to forecasting offices of the IMD as well as to the other users in India and foreign countries.

The following products derived from the satellite are useful for monitoring of tropical cyclones

1. Outgoing Long wave Radiation (OLR)
2. Quantitative Precipitation Estimation (QPE)
3. Sea Surface Temperature (SST)
4. Cloud Motion Vector (CMV)
5. Water Vapor Wind (WVW)
6. Upper Tropospheric Humidity (UTH)
7. Temperature, Humidity profile
8. Value added parameters from sounder products
    a. Geo-potential Height
    b. Layer Precipitable Water
    c. Total Precipitable Water
    d. Lifted Index
    e. Dry Microburst Index
    f. Maximum Vertical Theta-E Differential
    g. Wind Index

Apart from generating half hourly cloud imagery, IMDPS produces derived products from the processed data as follows:

- Cloud Motion Vectors (CMV) are derived half hourly using Visible & IR
- images from the operational Kalpana-I Satellite.
- Water Vapour Winds (WVWs) are derived half hourly using IR & Water
- vapour images from the operational Kalpana-I Satellite.
- Sea Surface Temperatures (SST) are computed at 1° x 1° grid intervals from all Kalpana-I data on half hourly /daily /weekly/monthly basis.
- Outgoing Longwave Radiation (OLR) are computed at 0.25° x 0.25° grid intervals from all Kalpana-I data on half hourly /daily /weekly/monthly basis.
- Quantitative Precipitation Estimation (QPE) is generated at 1° x 1° Grid from Kalpana-1 imagery on half hourly/daily/weekly/monthly basis.
- Upper Tropospheric Humidity (UTH).

At present Dvorak technique is widely used but manually applied. Recently efforts have been made for automation of this technique. Automated Dvorak technique is running in experimental mode at Synoptic Application Unit, Satellite Meteorology Division. Satellite Application Unit is also using Microwave imageries operationally from NOAA, Metop's DMSP satellites for locating the tropical systems. Satellite Application Unit issues three hourly bulletins in general and hourly and half hourly bulletins in case of tropical cyclones and other severe weather events. The unit is modifying these bulletins from time to time.

With the Web Archival System developed at IMD, KALPANA/INSAT-3A data products, imageries and satellite bulletins are archived. The automatic script is being used to keep and update the images/products on the website for 1 month. These are available to all users.

On 23rd Sept 09, polar orbiting satellite OCEANSAT–II has been launched by Indian Space Research Organisation (ISRO) which carries a ku band pencil beam scatterometer to provide ocean surface winds at 10 m height for early detection of tropical cyclones. Winds from this satellite are used regularly for locating the centre and intensity of the tropical systems in the formative stage.

Space Application Centre (SAC), ISRO Ahmedabad has developed a technique to predict the formation of tropical cyclones over north Indian Ocean (Bay of Bengal & Arabian Sea) before 24-96 hrs lead time based on OCEANSAT-II Scatterometer wind. Satellite Division of IMD has acquired the software and validating the technique before making it operational.

On 12th October, 2011 another Polar orbiting satellite MEGHA TROPIQUES has been launched which covers the area 20º N to 20º S. MEGHA TROPIQUES has three payloads:

1. MADRAS: a microwave imager aimed mainly at studying precipitation and clouds properties,
2. SAPHIR: a 6 channels microwave radiometer for the retrieval of water vapour vertical profiles and horizontal distribution,
3. SCARAB: a radiometer devoted to the measurement of outgoing radiative fluxes at the top of the atmosphere.

The basic principles of the MEGHA-TROPIQUES mission are to provide simultaneous measurements of several elements of the atmospheric water cycle, water vapour, clouds, condensed water in clouds, precipitation and evaporation, measure the corresponding radiative budget at the top of the atmosphere, ensure high temporal sampling in order to characterise the life cycle of the convective system and to obtain significant statistics.

1.1.2.2.2.1.2. Digital Meteorological Data Dissemination

IMD transmits processed imagery, meteorological data and facsimile weather charts to field forecasting offices distributed over the country using the Digital Meteorological Data Dissemination (DMDD) facility, through INSAT in broadcast mode. The bulletins providing description of the cloud organization and coverage are also sent as advisory to forecasting offices every synoptic hour. When cyclones are detected in satellite imagery, these bulletins are sent every hour. Such advisories are also transmitted to the neighbouring countries.

Processed satellite imagery, analyzed weather charts and conventional synoptic data are up-linked to the satellite in C-band. Satellite broadcasts these data to DMDD receiving stations in S-band. DMDD receiving stations analyze weather imagery and other data to generate required forecast. There are 37 no. of DMDD stations installed in India. Three DMDD receiving stations are also operating in neighbouring SAARC countries at Sri Lanka, Nepal and Maldives. These stations are receiving direct broadcast of cloud imagery, weather facsimile charts and meteorological data on an operational basis. The frequency of transmission from ground to satellite (uplink) is 5886 MHz and that of downlink is 2586 MHz.

1.1.2.2.2.1.3 Future Plan

(1) There is a plan to develop state of art Satellite Data Centre.
(2) 25 numbers of GNSS stations network will be installed all over India by mid 2014.
(3) 4 nos. of DMDD systems to be installation in Afghanistan, Bhutan, Bangladesh & Myanmar.

(4) It has been planned to procure software for better monitoring & warning of severe weather events.
(5) Planning for automization of Advanced Dvorak Technique and tracking of thunderstorms.

1.1.2.2.2.2 Analysis and Prediction system

Cloud imageries from Geostationary Meteorological Satellites INSAT-3A and METSAT (KALPANA-1) and INSAT-3D are the main sources of information for the analysis of tropical cyclones over the data-sparse region of north Indian Ocean. Data from Oceansat-2 & scatteometry based satellites like ASCAT & WINDSAT and Ocean buoys also provide vital information. Ship observations are also used critically during the cyclonic disturbance period. When the system comes closer to the coastline, the system location and intensity are determined based on hourly observations from Radar as well as from coastal observatories. The AWS stations along coast are also very useful as they provide hourly observations on real time basis. The Water Vapor based Wind Vector (WVWV) and Cloud Motion Vectors (CMV) in addition to the conventional wind vectors observed by Radio Wind (RW) instruments are very useful for monitoring and prediction of cyclonic disturbance, especially over the Sea region. The direction and speed of the movement of a tropical cyclone are determined primarily from the three hourly displacement vectors of the centre of the system and by analyzing satellite imageries.

1.1.2.2.3.1 Prediction Models in operational use during the year 2013

NWP Division of India Meteorological Department (IMD) operationally runs three NWP models WRF (ARW), HWRF and Global model (GFS T574/L64) for short and medium range predictions (3-7 days). As a part of effort to translate research to operation, and to meet the need of the operational forecaster, IMD developed and implemented an objective NWP based Cyclone Prediction System for the operational cyclone forecasting work. The method comprises of five forecast components, namely (a) Cyclone Genesis Potential Parameter (GPP), (b) Multi-Model Ensemble (MME) technique for cyclone track prediction, (c) Cyclone intensity prediction, (d) Rapid intensification and (e) Predicting decaying intensity after the landfall.

Under NOAA-MoES collaboration program the HWRF model, which was operational at Environmental Modelling Centre (EMC), NCEP, USA was installed at IMD, New Delhi with nested domain of 27/ 9 km horizontal resolution and 42 vertical levels for Tropical Cyclone track and intensity forecast up to 5 days for North Indian Ocean (NIO) region for its operational requirements. Recently NCEP, USA upgraded HWRF modelling system version - 2013 with improved resolution (9/3 km), vortex initialisation, physical process and diagnostic tools. This new version is to be ported at IMD, New Delhi HPCS in February 2014 and customization and testing of the new code will be initiated. This new version is expected to be validated and made operational during the cyclone season – 2014. With the upgradation of the model, it is expected to improve further the Tropical Cyclones track and intensity forecasts over Indian Region.

As part of WMO Program to provide a guidance of tropical cyclone (TC) forecasts in near real-time for the ESCAP/WMO Member Countries based on the TIGGE Cyclone XML (CXML) data, IMD implemented JMA supported software for real-time TC forecast over North Indian Ocean (NIO) during 2011. The Ensemble and deterministic forecast products from UKMO (50+1 Members), NCEP (20+1 Members), UKMO (23+1 Members) and MSC (20+1 Members) are available near real-time for NIO region for named TCs. These Products includes: Deterministic and Ensemble TC track forecasts, Strike Probability Maps, Strike probability of cities within the range of 120 kms 4 days in advance. The JMA provided software to prepare Web page to provide guidance of tropical cyclone forecasts in near real-time for the ESCAP/WMO committee Members.

Recently NCEP, USA upgraded HWRF modelling system version - 2013 with improved resolution (27/9/3 km), vortex initialization, physical process and diagnostic tools. This new version is successfully ported at IMD, New Delhi HPCS. Customization and testing of the new code has been in progress. Presently HWRF model is coupled to POM-TC, a three-dimensional version of the POM modified for hurricane applications over the North Atlantic basin. Prior to implementation, many experiments were conducted over multiple hurricane seasons that clearly demonstrated the positive impact of the ocean coupling on both the track and intensity forecasts. The Ocean Model (POM-TC) and Ocean coupler requires the customization of Ocean Model for Indian Seas. In this regards, INCOIS, Hyderabad which is running the Ocean Models (POM)/Hybrid co-ordinate ocean model (HYCOM) is requested to help and support in porting the Ocean Model with Indian Ocean climatology and real time data of SST over Indian Seas. IMD NWP is already in consultation with INCOIS to implement the Ocean Coupling in HWRF in the present high resolution (27/9/3 km) HWRF model in collaboration with INCOIS/EMC by September 2014 and expecting to access the impact of the ocean coupling in the model and ultimately making operational.

1.1.2.2.4 Telecommunication Network in IMD

1.1.2.2.4.1 Present Status of Circuits in the GTS connected with RTH, New Delhi

India Meteorological Department has its National Meteorological Telecommunication Centre (NMTC) with an Automatic Message Switching computer System (AMSS) which is connected to WMO Centers on the GTS. The existing RTH switching system “TRANSMET” is the state-of-the-art technology system. It consists of two Separate Automatic Message Switching System (AMSS) for National and International data exchange. Each AMSS works in hot standby mode for 100% redundancy in case of any failure.

During the period 2013-2013 following new data sets were received from different circuit and submitted on GTS

- **(i)** BUFR data from Pakistan
- **(ii)** Storm Information, Forecast and Advisories messages from RSMC NEW Delhi in Text and Graphical form.
- **(iii)** ASCII AWS/ARG data received from SI, Pune and routed to GTS.
- **(iv)** BUFR AWS/ARG data reception is under progress.
- **(v)** Request has been sent for AIREP, AMDAR and ACARS data as per user requirement to the concerned Centres.
- **(vi)** Sixteen operational RADAR data are received in NETCDF and BUFR format and routed to users as per their requirement.
- **(vii)** Forecast for AMARNATH Yatra was received and disseminated via SMS to the concerned user through RTH.
- **(viii)** Warning messages such as Tsunami and Cyclone messages received from INCOIS and RSMC are disseminated via SMS as per the user requirement.
- **(ix)** Ocean Sat 2 wind data dissemination from Satmet division is under progress.
- **(x)** Data received from NAVY for Porbandar station and disseminated for FDP (CTCZ).

(xi) RMDCN link has been upgraded to 2Mbps which handles 4 circuits viz. Tokyo, Moscow, Beijing and Toulouse. This has improved the data exchange between these GTS centres.

(xii) MPLS VPN link at HQ New Delhi has been upgraded to 8 Mbps for smooth catering of data requirements to the national users w.e.f. 12-12-12.This will help in faster data reception at Head Quarter from DWR stations & NWP Centres to various users.

1.1.2.2.4.2 VPN Circuits

Fifty four, IMD stations are connected with IPVPN connectivity speeds ranging from 256 Kbps to 8 Mbps. These VPN circuits are connected with High Speed Data Terminals, Doppler Weather Radar Stations, AMSS Centres and Regional Centres.

1.1.2.2.4.3. IVRS

Popularly known as "Weather on telephone", the Interactive Voice Response System (IVRS) is functioning with effect from July, 2000. One can access current weather and forecast for major Indian cities by dialing Toll free number 1800 180 1717 (List of IVRS stations enclosed as Annexure III). Presently service is available for landline phone users due to excess bills. The mobile users also be provided restricted access to minimize expenditure.

1.1.2.2.4.4 VSATs

A network of 26 V-SATs have been installed at selected seismological observatories, Cyclone Radar stations, Cyclone Warning Centres and Meteorological Centers for reception of observational data utilizing communication transponder of INSAT. The installation of VSAT at Port Blair & Minicoy is still to be completed by the supplier.

1.1.2.2.4.5 Internet Services

At present we have wide range of Internet services 45 Mbps from VSNL and 45 Mbps from Airtel. IMD is also connected to NKN (National Knowledge Network) over 1 Gbps link for internet, close user group & Telepresence services.

1.1.2.2.4.6 GMDSS

India has been designated as an issuing authority under the GMDSS programme for Meteorological Area VIII(N). This covers the area of the Indian Ocean enclosed by the lines from Indo-Pakistan frontier in 23°45'N 68°E; 12°N 63°E, thence to Cape Gardafui; the east African coast south to equator, thence to 95°E to 6°N, thence to the Myanmar/Thailand frontier in 10° N 98° 30' E.

India Meteorological Department is transmitting daily two GMDSS bulletins for Met. Area VIII(N), one at 0900 UTC and other at 1800 UTC. During Cyclone Season additional bulletins (4) are also being issued for GMDSS broadcast depending on the requirement. GMDSS bulletins are transferred to VSNL Earth Station at Pune through email and put up on IMD Website at URL *http://www.imd.gov.*in Pune Earth Station uplinks this information to INMARSAT satellite for broadcast to all ships in Met Area VIII(N).

1.1.2.2.4.7 Regional Telecommunication Hub (RTH)

Regional Telecommunication Hub became operational in the year 1971. RTH New Delhi was automated and first DS- 714 Philips Computer System became operational in the year 1976. This RTH Computer has been replaced by VAX- 11/ 750 Computer in 1988. In July, 2000

RTH New Delhi has installed a SUN E- 250 Computer. Latest system has been installed in the year 2010 by Meteo France International (MFI). This is connected to WMO Centres on the GTS. The existing RTH computer system is driven primarily by dual HP server working on the state-of-the-art distributed networking technology. The whole system has been designed to handle high speed data circuits, message exchange through web interface,through SMS & Email. It has also fax interface and audio alarm. NMTC New Delhi is connected to HPCS of NCMRWF through NKN and the HPCS computer at Regional Specialised Meteorological Centre (RSMC) New Delhi for instantaneous transmission of global observational data and processed information received via GTS. As regards the Meteorological Telecommunication Networks within the GTS, New Delhi telecommunication center is designated as Regional Telecommunication Hub (RTH) located on the Main Trunk Network (MTN). The MTN is the core network of GTS. It links WMO together three World Meteorological Centers (WMCs) and 14 other RTHs on the MTN. The Centre is also a National Meteorological Centre (NMC) for telecommunication purposes within the framework of GTS. RTH New Delhi is directly connected with World Meteorological Centre (WMC) Moscow, RTH Tokyo and RTH Cairo on the MTN. RTH New Delhi is also directly connected with RTH Beijing, RTH Jeddah and WMC Melbourne located on the MTN; RTHs Bangkok and Tehran and National Meteorological Centres (NMCs) Colombo, Dhaka, Karachi, Kathmandu, Male, Muscat and Yangon in the Regional Meteorological Telecommunication Networks (RMTNs).

Automatic Message Switching Systems (AMSS) are also operational at the major International airports viz. Mumbai, Delhi, Kolkata, Chennai and Guwahati. The circuits linking New Delhi (Palam), Mumbai, Kolkata, Chennai and Guwahati Airport computers with the NMTC New Delhi are working at high speed.

Under the Modernization programme of India Meteorological Department, following systems have been installed at RTH New Delhi:-

a) ***Central Information Processing System (CIPS).*** High end database management system having task centre to develop, test and operationalize meteorological tasks for real time generation of meteorological products.
b) ***Transmet: Automatic Message Switching System (AMSS)***: to receive, check and route the meteorological data and products according to WMO standards/requirements.
c) ***Public Weather System (PWS):*** To deliver High quality weather products and alerts to end users like print media and Television.
d) **Clisys** Climatological data storage system with scalable management tool for effective utilization of these data.
e) **Synergie:** Decision support system for forecasters to gather, visuslize, interact and value add meteorological forecasts and products.

New AMSS System at Nagpur and Guwahati has been installed and accepted and is under the stage of completion. The process of procurement and installation of Mirror RTH at Pune which will act as Disaster Recovery Centre (DRC) which should be able to take over all the responsibilities of RTH New Delhi in case of any catastrophe at RTH New Delhi. Stores have been received for the Mirror RTH at Pune and equipments are likely to be commissioned by 31st March, 2013 at site. This will also act as WMO WIS GISC for South East Asia and cater to all data needs for Indian users and all other WMO GISC centres in real time with 24 hours cache for all data.

1.1.2.2.4.8 Website of IMD

Website of IMD is operational since 1st June, 2000. It contains static & dynamically updated information on all India Weather and forecasts, special monsoon report, local weather forecasts for 200 cities, satellite cloud pictures (updated every half an hour), animated satellite cloud pictures, Dynamical Model (LAM) generated products and prognostic charts, special weather warnings, tropical cyclone information and warnings, daily, weekly and monthly rainfall distribution maps, earthquake reports, etc. This also contains a lot of static information including temperature and rainfall normals over the country and a brief overview of the activities and services rendered by India Meteorological Department. This site can be accessed round the clock with the URL: http://www.imd.gov.in. The Regional Meteorological Centres have also their own websites. IMD is also providing 100 Indian city forecast on the WMO Website daily at http://worldweather.wmo.int/066/m066.htm

India Meteorological Department developed its own intranet website with the address http://metnet.imd.gov.in exclusively for the use of IMD staff. All employees can access this site using their login ID. This is a very useful site and all IMD officials are accessing this site all over the country for numerous applications on office matters. The list of email addresses are available at IMD website.

1.1.2.2.4.9 Information Technology Cell

Considering the ever growing influence of Information Technology in day - today affairs of the department, a new division was formed, initially, to coordinate the various IT related activities of the department. However, considering the administrative aspects as well as the inter-operability of communication and IT, this was brought, later, under the umbrella of Information System and Services Division (ISSD). The objectives of IT Unit are:

a) Coordination of IT initiatives of the department.

b) Supervise various IT projects to be implemented.

c) Asserting the IT literacy and imparting suitable mechanisms for its improvement.

d) Development of various in-house softwares for routine activities.

Conforming to these objectives, IT Division has developed an intra - IMD Portal, which is considered as the first step towards e-governance implementation in the department.

1.1.2.2.4.10 Annual Global Monitoring

Annual Global Monitoring during the period 1-15th October, 2013 and the result sent to WMO via Internet. The % of SYNOP was 97.72% and TEMP 40.60%.

1.1.2.2.4.11 Ongoing projects:

1.1.2.2.4.11.1 Provision of adequate communication system for data and product transmission:

Under modernization programme, India Meteorological Department procured Automatic Message Switching System (AMSS), Central information processing System(CIPS) which will store almost all observational data , Clysis (to store Climatologcal data),High Performance Computer System (HPCS) to run the numerous numerical weather prediction model etc. Mirror RTH, Pune is a part of the WMO Information System (WIS) implementation, which includes design, development, integration with existing systems like CIPS, Clisys, AMSS, HPCs, supply and installation of WMO Information System which will act as Global Information System Centre (GISC) and Data Collection and Processing Centre(DCPC) with disaster recovery centre at Pune

- As per guideline of WMO, RTH New Delhi applied for GISC as well as DCPC for South Asia.

- Conducted training cum workshop on WMO information system and WMO expert delivered the lecture.
- After installation Mirror RTH Pune, WMO member will be invited to declare as GISC & DCPC.
- WIS for New Delhi is also under process.
- GISC/DIPC Will be functional at Mirror RTH, Pune by June, 2013.

a. Up Gradation of AMSS (Automatic Message Switching Systems) at Guwahati, Nagpur and Mirrror RTH at Pune.
b. On line Briefing System at Chennai & Delhi (Palam).
c. Development of Centralized GIS Based content managed Website of IMD.
d. Development of Met GIS – Web based GIS Portal.

1.1.2.2.4.11.2 Maintenance of operational forecast system, delivery system for forecast and other services

a) Maintenance and Expansion of Improved Operational Numerical Weather Prediction for Short to Medium range Weather Forecasting.
b) Expansion and Improvement of Operational Nowcast and very short range forecast system.
c) GIS based rainfall analysis for development of flood prone map zonation and Urban Flood forecasting model.
d) Android based applications for dissemination of weather forecast and warning products.
e) Establishment of IMD Pune Archives.

1.1.3 Maldives

1.1.3.1 Surface Observation

Maldives has 5 meteorological stations all are manned 24 hours, both synoptic and aviation reports are made on all five stations. Only one of them is categorized additionally as upper-air station.

- Hanimaadhoo (43533) Synoptic and Aviation Reports
- Male' (43555) Synoptic and Aviation Reports
- Kadhdhoo (43577) Synoptic and Aviation Reports
- Kaadehdhoo (43588) Synoptic and Aviation Reports
- Gan (43599) Synoptic and Aviation Reports + Radio Sonde

1.1.3.1.1 AWS

Total of 24 Automatic Weather Stations (AWS) has been installed and are in operation. However sustaining of these AWS have become difficult due to financial limitations year after year. As a result, only 9 stations are sending out data to the National Meteorological Centre at present.

1.1.3.1.2 Rainfall Stations

Across the country, Maldives has 7 rainfall stations which measure only accumulated rainfall for 24 hours and reading are collected at 0300UTC for national use only.

- HA. Kela
- Sh. Funadhoo
- B. Dharavandhoo
- M. Muli
- Dh. Kudahuvadhoo
- Th. Veymandoo
- Gn. Fuvanmulah

1.1.3.2 Upper Air Observation

A few Radio-Sonde observations were done at the Meteorological Office, Gan (WMO # 43599) in 2012 and the old Vaisala upper air observation system in Gan was replaced by a new Inter MET System (iMet-2-AA) during April 2013 through WMO and GCOS. There were continuous interruptions to observations between 19 May and 11 July 2013 due to a technical problem in the Hydrogen Generator.

No observations were done at Male' (WMO # 43555) during 2013 due to unavailability of upper air equipment.

As the location of Maldives in the Indian Ocean happens to be a data sparse area in which shifting of ITCZ and phases of MJO take place. Therefore, upper air observations from both Male' and Gan are very important to entire meteorological community in the region and globe. Maldives urge assistance from donors and Panel Members to consider rebuilding our upper air observation network.

1.1.3.3 Meteorological Satellites.

Digital Meteorological Data Dissemination (DMDD) system donated by India Meteorological Department (IMD) receives WMO coded GTS data, half hourly cloud imagery from KALPANA and Fax charts in LRIT/HRIT format transmitted by IMD and display on a high resolution color monitor. Images can be further enhanced using different image processing functions and can be focused more on the area of interest. This system has the capability to plot the received met data by values or contours on a specific image. With all these features it helps forecasters to do more precise predictions. However, this system is facing signal loss therefore nothing has been received during 2012 and 2013. The High Resolution Satellite Image Receiving System GEOSAT 500 has stopped functioning since 2010. It is required to pay a considerably high amount to the manufacturer to renew its service agreement.

An integrated satellite receiving system generously donated by China Meteorological Agency was installed on 25 October 2012. This **CMACast** system receives Satellite imageries from FY2E and FY2D series of Chinese geostationary satellites at an interval of 30 minutes. Surface synoptic data, Upper air sounding data, NWPs of ECMWF, T213: NWPs of CMA global model, NWP accumulation preci from Germany model and Japan model. Another component of this system is the application software MICAPS (meteorological data analyzing system) which enables to display satellite pictures, surface & upper air data and NWP products and overlay different products and analysis of various weather phenomena. This SYSTEM is satisfactorily operational during 2013.

1.1.3.4 Doppler Weather Radar

Doppler Weather Radar received as part of Multi-hazard Early Warning System has been out of service since 2011. An engineer was hired from the manufacturer during July 2013 and he reported that the main supply modulator needs to be replaced. However, further consultation with the manufacturer, reveals that some more hardware and software needs to be upgraded to bring the system back to operation.

1.1.3.5 Numerical Weather Prediction

WRF basic run is made twice a day with the 00 and 12UTC data set with a horizontal resolution 9 km and 23 vertical pressure levels run on a single domain.
Model run on a desk top PC having an i5 processor with 1TB hard drive that takes about 2 and half hours to complete single run of 48H for Maldives domain.
If present computing power is elevated many improvements such as model run with nested domain to increase resolution to 3 km or even 1 km and the preciseness of forecast lead time can also be improved accordingly.
MMS need more of its staff time to be dedicated on research of WRF model to fine-tune on physical parameterization so that the model skills can be enhanced.
MMS need to train its staff on data assimilation so that satellite radiance data and AWS data can be assimilated on the WRF system for a better performance.
However, due to financial crisis, upgrading of NWP service is limited internally. Hence we welcome all sources of opportunities coming on our way.
Maldives Meteorological Service continues to use NWP outputs provided by RIMES, ECMWF, IMD and others on the web.

1.1.3.6 Telecommunications

The 10 mbps internet service and the computer based telecommunication system between the local Meteorological Offices and the National Meteorological Centre (NMC), functioned very well.

1.1.3.7 NMC's Global Telecommunications System (GTS) and Message Switching System (MSS)

MESSIR-COMM message switching system developed by COROBOR is a TCP/IP based multi-channel communication link that is capable of handling vast amount of data. Although this GTS is in operation throughout 2013, Maldives received many complains from other countries and GCOS of not receiving our SYNOPs, RS observation (TEMP) messages through GTS. Likewise, the monthly CLIMAT report sent via GTS is also reported not received by users. Efforts have been made in late 2011 – 2013 in consultation with RTH New Delhi in this regard and still this matter needed to be taken care of and work closely to arrive at a sustainable solution.

1.1.3.4 Meteorological information through internet

MMS launched an upgraded version of the official website www.meteorology.gov.mv during 2013 and served its users with current weather updates, forecasts, warnings, met reports and aviation weather charts.

1.1.4 Oman

1.1.4.1 Surface Observations

There are a total of 44 meteorological stations out of which 23 are listed in the WMO's Regional Basic Synoptic Network (RBSN) including 2 radiosonde stations, 12 Regional Basic Climatological Network (RBCN) stations out of which 3 listed in Global Climate Observing System Surface Network. Additional 36 Automatic Weather Stations will be installed during this year.

1.1.4.2 Upper Air Observation

The Sultanate of Oman operates two upper air-observing stations located at Muscat (41256) and Salalah (41316). Both these are equipped with Vaisala's Digicora GPS wind finding system. The radiosonde used is Vaisala RS92 equipment. One flight is launched from each of these stations in a day.

1.1.4.3 Ship Weather Reports

Weather Reports from Ships are received through GTS as well as from Muscat Coastal Radio Station. In addition Ship reports are also received from the Royal Oman Navy.

1.1.4.4 Wave Measurements

One wave radar measurement station was installed offshore of Qalhat (Sur)- Oman liquid Gas Company- and other two wave measurement stations located offshore of Sohar Station and Mina Salalah Station. Seven tide gauges were installed at Diba, Sohar, Wudam, Quriyat, Sur, Alashkhara and Duqm as part of Tsunami Network

1.1.4.5 Doppler Weather Radars

Five Dual Polarization S-Band Doppler Weather Radar is expected to be commissioned during May of this year. The Radars are supplied by Selex Gematroniks.

1.1.4.5 Telecommunication

All the meteorological stations operated by the Directorate General of Meteorology and Air Navigation (DGMAN) are connected to the MSS computer located at the Central Forecasting Office at Muscat International Airport by a reliable telephone links (dial-up Telephone lines and GSM Network).

The MSS is connected to the RTH Jeddah by a dedicated link at 64 kbps based on TCP/IP protocol. In addition a 4 Mbps Internet leased line has been established as well as for transmitting and receiving meteorological data with different meteorological centers such as New Delhi and Abu Dhabi.

1.1.4.6 Satellite reception

The Department installed Satellite ground receiving station for intercepting High Resolution images from Polar Orbiting satellites operated by NOAA, EUMETSAT and China as well as from geostationary satellites operated by EUMETSAT and China. It is expected that reception from MODIS (Aqua and Terra) will be available before the end of the year.

1.1.4.7 Oman Center of Excellence (COE)

The 10th EUMETSAT Satellite Application Course was successfully organized and conducted at Oman Centre of Excellence (COE) for training satellite meteorology during February 2014.

1.1.4.8 Data Visualization

The Directorate General of Meteorology and Air Navigation (DGMAN) is using a visual weather application for visualizing all meteorological data in most standard formats including data in GRIB1, GRIB2 and BUFR format coded data. It has proved to be a useful and powerful tool for visualization, analyzing and forecasting the weather.

1.1.4.9 Data Processing System

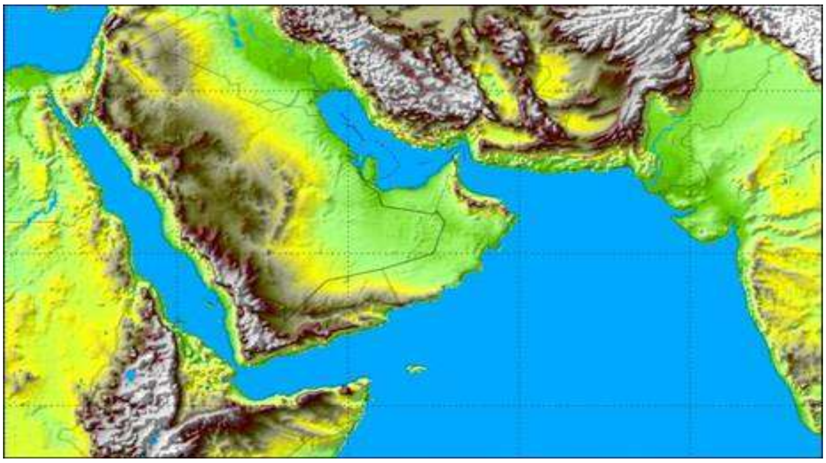
Global Numerical Weather Prediction NWP products are received via Internet, GTS, DWD Sat. We receive products from meteorological centers including ECMWF, UK met office and German Weather Service (DWD).

Current processing capabilities consist of a PC Cluster of 72 nodes with total of 144 processors. Quad-coreAMD Opteron 3.2 is used for each node. This make a total of 576 processing core. All nodes are connected via very fast Interconnection network using 144-port Infiniband switch with guarantees 3Gbps full duplex.

Local Oman Regional Model ORM was established with the kind cooperation of National Weather Service of Germany DWD since 1999. The details of the model versions as follow.

A] High Resolution Model HRM is Hydrostatic limited-area numerical weather prediction model. DGMAN runs HRM with two model resolutions:

ORM_14: 14x14 km resolution. It covers the area between 30.0 E, 7.0 N (lower left corner) to 78.0E, 35.25 N (Upper right corner) with mesh size of 0.125 degree. There are 385x227 grid points and 40 vertical layers. The model is running on 10 nodes from the PC Cluster. It produces up to 120-h forecast at 00 and 12 UTC. The figure below shows the domain area.



B] DGMAN runs an operational version of COSMO model (Consortium for Small-scale Modeling) COSMO is a non-Hydrostatic limited-area numerical weather prediction. It runs on 7x7 km covers the same domain of ORM_14 and 2.8km resolution covering Oman and adjacent areas. COSMO was introduced to enhance the accuracy of predicting local rainfall over Hajar Mountains and adjoining area during summer and to compare the forecast with the forecast of ORM_07.

C] A WAM based wave model was established with the kind cooperation of GKSS of Germany, which covers the Arabian Sea, gulf of Oman and Arabian gulf. WAM model run of 14km resolution and nested into 3.5km resolution and it runs on 8 processors on the PC cluster.

D] With the kind cooperation and assistance from NOAA a Hurricane Weather Research Forecast (HWRF) Model was installed during June 2013 at the Oman National Meteorological Service. This Model will be used to forecast Track, Intensity and Direction of Movement for Storms and Cyclones over the Arabian Sea and Bay of Bengal. It is currently under Test Trials.

1.1.4.10 Module Output Statistics (MOS)

The Directorate General of Meteorology and Air Navigation (DGMAN) successfully established a MOS based on HRM model at 7km resolution. MOS output is generated with each Model run. MOS is an approach to incorporate NWP forecasts information into statistical weather forecast. After installing MOS we noted improvement in Temperature and wind forecast. In addition we were able to get a probability forecast for thunderstorms and fog.

1.1.4.11 Verification Package

The Directorate General of Meteorology and Air Navigation (DGMAN) managed successfully to develop in-house its own verification package. The developed system verifies the continuous weather parameters such as T_2m, TD_2m and for the categorical weather parameters such as Total precipitation. The system generates different statistical scores such as Hit rate with a margin of error, Bias, Root Mean Squared Error (RMSE). The package provides a friendly UGI to allow the user to select different choices (Model type, stations list, observation time, weather element and statistical score) to be verified. This system will help find the systematic errors in the Model output, which can be tuned. The package is being used by about twenty five countries worldwide such as UAE, Brazil, Jordan, Malaysia, Hungary, Vietnam, Iran, University of Berlin, Kenya, Madagascar, etc.

1.1.4.12 Aeronautical Services

In order to meet ICAO recommended practices and to fulfill the requirements for Aviation the Directorate General of Meteorology and Air Navigation (DGMAN) installed a SADIS workstation as early as 1996. In addition all the SADIS data and products are also received thru a secured FTP Server from UK as a back-up. A new service was established for the provision of en-route flight folders for all Airlines operating in the Sultanate to be accessed on our web portal.

1.1.5 Thailand

1.1.5.1 Upper-Air Observation

Routine upper-air observation at 11 stations across Thailand is released four times a day at 00, 06, 12, 18 UTC for Met-data, for examples, pressure, temperature, humidity, and wind speed and direction at vertical levels up to altitude about 16-25 km. Each station has different types of observatory as shown in Table 3 below:

Table 3

No.	Region	Station	Types of Observatory		
			Pilot	*Rawinsonde (403 MHz)*	*Radiosonde (1680 MHz)*
1	N	Chiang Mai (Center)	•	NA	•
2		Phitsanulok	•	NA	NA
3	NE	Ubon Ratchathani (Center)	•	NA	•
4		Udon Thani	•	NA	NA
5		Nakhon Ratchasima	•	NA	NA
6	C	Bangkok (Headquarters)	•	NA	•
7	E	Chanthaburi	•	•	NA
8	S, east-coast	Songkhla (Center)	•	NA	•
9		Prachuap Khiri Khan	•	NA	NA
10		Surat Thani	•	•	NA
11	S, west-coast	Phuket (Center)	•	NA	•

1.1.5.2 Surface observation

A total of 124 surface weather stations (74 synoptic stations, 16 hydro-Met stations and 34 Agro-Met Stations) are employed throughout Thailand, mostly surface weather. Some stations are assigned for WMO-RBSN, RBCN, GSN and GUAN stations. Almost all surface stations are operated 8 synoptic times daily (00UTC, O3UTC, 06UTC, 09UTC, 12UTC, 15UTC, 18UTC, 21UTC). Mixed standard manual and modern automatic weather instruments are used. Coded messages are sent from the observing stations manually. Data quality assurance/control is performed both real-time (on message programing) and non-real-time. Data are recorded manually at the station in a log-book and on PC to be sent as WMO-coded messages to the head quarter in Bangkok to further distributed via GTS and kept as archive at the climatological data section. Real time automatic weather reports are available to the forecasters and public (via web) and separately archived. If we divided by region, northern part has 31 stations, north eastern part has 28 stations, central part has 21 stations, south western part has 8 stations and south eastern part has 21 stations.

1.1.5.3 Satellite Reception

The satellite ground receiving station had been enhanced with application program for meteorological data in different platforms through satellites, for example, MTSAT, FY-2, TIROS (NOAA), and Terra/Aqua Direct Broadcast (MODIS). About severe weather monitoring, these products would support more accurate analysis. The success of the project was admirable due to completion and effectiveness.

The proceeding project plan is to change the data links between the satellite receiving center and regional center. Data link from leased line connection to VPN (Virtual Private Network) has been using in TMD. This will increase network performance and reduce cost.

1.1.5.4 Improvement of weather Radar

To strengthen severe weather observations and monitoring networks and now casting of the country, the installations of following two Dual Polarization Doppler weather Radars were started in 2011 and now are in the operation.

1. Dual Polarization Doppler weather Radar in Chainat,
2. Dual Polarization Doppler weather Radar in Phitsanulok.

Additionally, two Dual Polarization Doppler weather Radar are being installed as follows, and all are expected to be completed in 2015:

1. Dual Polarization Doppler weather Radar in Sakon-nakhon,
2. Dual Polarization Doppler weather Radar in Narathiwat.

1.1.5.5 Telecommunication

For improve the receiving-disseminating of local meteorological data before exchanging meteorological data with the network Global Telecommunication System, (GTS) telecommunication division has improved data storage and recording systems or METNET system. The project is now under implementation. Its installation was started in 2010, and is expected to be completed in 2014. The completion of this project will improve the exchange potential of local meteorological data and also increase the overall performance of the communication system.

1.1.5.6 Aeronautical Services

Nowadays, air travel is increasing rapidly. The safety of air navigation is the first priority, especially around the airport. Thai Meteorological Department set up plans to improve, repair and install meteorology instrument in many airports as follows:

- Establish Automated Weather Observing System (AWAS) at the Lampang airport and was completed in 2013.
- Establish Automated Weather Observing System (AWAS) at the Narathiwat airport, and is expected to be completed in 2014.
- Establish Automated Weather Observing System (AWAS) at the Hua-Hin airport and is expected to be completed in 2014.
- Upgrade Automated Weather Observing System (AWAS) to Low Level Wind Shear Alert System (LLWAS) at the Udonthani airport and is expected to be completed in 2014.
- Establish Low Level Wind Shear Alert System (LLWAS) at the Hatyai airport and is expected to be completed in 2014.
- Maintenance and repairing Low Level Wind Shear Alert System (LLWAS) from 2011 flood at the Donmuang airport, was completed in 2013.
- Establish Low Level Wind Shear Alert System (LLWAS) and Wind Profiler system at the Suvarnabhumi airport, is expected to be completed in 2014.

- Establish Lighting Detection system at the Suvarnabhumi airport, was completed in 2013.

1.1.5.7 Information Access

The official website of Thai Meteorological Department www.tmd.go.th serves people very well. They can surf and access to weather forecasts, warnings, tracks, meteorological reports, aviation weather charts and earthquake reports.

To avoid heavy traffic access to major websites during disasters that web server could not provide service and crash; TMD has split the information into subsets such as:

www.seismology.tmd.go.th : Services for earthquake and tsunami information.
www.marine.tmd.go.th : Services for marine meteorological information.
www.aeromet.tmd.go.th : Services for aviation meteorological information.

And also local meteorological centers provide service on weather forecasts, weather warnings detail in each area.

www.cmmet.tmd.go.th	:	Northern Meteorological Center
www.khonkaen.tmd.go.th	:	Northeastern Meteorological Center (Upper Part)
www.ubonmet.tmd.go.th	:	Northeastern Meteorological Center (Lower Part)
www.songkhla.tmd.go.th	:	Southern Meteorological Center (East Coast)
www.phuketmet.tmd.go.th	:	Southern Meteorological Center (West Coast)

Activities of WMO

Regional Basic Synoptic Network (RBSN)

The representative of WMO reported that the Integrated WWW Monitoring (IWM) and the Annual Global Monitoring (AGM) continued to provide information on the performance level of the observing and telecommunication systems. As per the results of the AGM exercise carried out in October 2013, the availability of expected SYNOP and TEMP reports on the Main Telecommunication Network (MTN) from a total of 297 surface and 53 upper-air stations (remained unchanged during the intersessional period) in the RBSN operated by Members of the WMO/ESCAP Panel on Tropical Cyclones. The availability of SYNOP reports continued to be more than 75% for all countries while the average availability ranged from 78% to 100% during the intersessional period. Overall, the total availability of SYNOP reports increased to 95% from 94% in the previous year.

Average availability of TEMP reports ranged from zero to 52% with increased availability in most countries. As during the previous year, the availability of TEMP reports from Sri Lanka remained at zero percent along with Myanmar during the current period. Overall, with the positive increase in the number of reports received from a majority of Panel Members the total availability of TEMP reports increased from 33% to 40% during this period.

Investigations into dissemination of especially upper-air data indicate that some countries continue to perform observations at non standard times of observations1 resulting in the possible non inclusion of availability in the Annual Global Monitoring (AGM) results. The four main standard times of observations for surface synoptic stations are 00, 06, 12 and 18 UTC and for upper-air synoptic stations carrying out radiosonde and radiowind observations it is 00 and 12 UTC

Marine and Ocean Meteorological Observations

The Panel noted that the Observations Programme Area (OPA) work plan of the Joint WMO-IC Technical Commission for Oceanography and Marine Meteorology (JCOMM) is aligned with the ocean chapter of the GCOS Implementation Plan for the Global Observing System for Climate in support of the UNFCCC (GCOS-138 in its 2010 update). The implementation goals provide specific implementation targets for building and sustaining an initial global ocean observing system representing the climate component of the Global Ocean Observing System (GOOS) and the ocean component of the Global Climate Observing System (GCOS). Although the baseline system proposed under the implementation goals was designed to meet climate requirements, non-climate applications, such as NWP, tropical cyclone prediction, global and coastal ocean prediction, and marine services in general, will be improved by implementation of the systematic global observations of Essential Climate Variables (ECVs) called for by the GCOS-138 plan.

The Panel noted that the Fourth Session of the joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM, Yeosu, Republic of Korea, May 2012) has updated the implementation goals for its Observations Programme Area (OPA) according to the latest developments with regard to (i) the outcome and recommendations from the OceanObs'09 Conference; (ii) the outcome of the Third World Climate Conference (WCC-3); and (iii) non-climate requirements arising from the CBS Rolling Review of Requirements, including Statements of Guidance and gap analysis.

Implementation of marine observing network in the region is realized thanks to role of WMO Members, including with support from Members in the region. Globally, the ocean in situ observing system is now 62% implemented although no substantial progress according to the completion targets has been noticed in the last few years. All data are being made freely available to all Members in real-time. Completion will require substantial additional yearly investment by the Members/Member States, including in WMO Regional Association II (RA-II).

The global surface buoy network coordinated through the Data Buoy Cooperation Panel (DBCP) is now essentially complete and being sustained (1250 global units in December 2013, including 608 reporting sea level pressure). The technical problems with regard to the drifter life-times and their drogues that have been noted since 2011 have been addressed, and the robustness of the drifters increased. Regions such as the North West Indian Ocean, the Mozambique Channel, the SouthWest Pacific Ocean, the SouthEast Pacific Ocean, and the Southern Ocean appear relatively data sparse. Barometer drifters are currently not being deployed in the tropical regions. Cost-effective technology exists for surface drifters equipped with thermistor strings and designed to be deployed in tropical cyclone conditions. However, no such drifters are being deployed operationally in area of interest from the Regional Association.

The Panel was infromed that the Argo profiling float programme reached completion in

November 2007 and is now providing essential Upper Ocean thermal and salinity data for Tropical Cyclones research, monitoring and forecast activities. 3613 floats were operating worldwide in December 2013 but the core mission targets are just recently reached (3000 floats operating 60N/60S, no marginal seas), as some floats are operating a pilots in non-core regions. Argo is in active discussions with the community to evolve its original core design and sampling to meet increasing needs and exploit technological advances. Pilots continue in the sea ice zone, near surface sampling, chemical and optical sensors and in special areas with enhanced array density. A possible future 'Global Argo' might involve over 4000 active floats. Argo is still short of requirements in the far Southern Ocean. Regions such as the East Equatorial Pacific Ocean, the Mozambique Channel, the Eastern sector of the Bay of Bengal, and around Indonesia appear poorly covered. Regions such as the South China Sea, and the East China Sea now appear much better sampled than one year ago. Efforts are necessary to ensure adequate geographical coverage and ensure sustainability of the array (requiring around 800 new floats each year). While over 20 nations deploy Argo floats, the program is still overly dependent on a small number of national programs and thus Argo must strive to increase contributions from a larger number of nations. 90% of Argo profiles reach the GTS within 24 hours of collection and efforts to reduce delays in the GDACs data distribution are increasing their timeliness. Most Argo data centres are meeting the requirements for throughput of delayed-mode quality control. Argo is regularly auditing the data stream for consistent formatting, pressure bias removal, consistency with altimetric data, and for outliers in the realtime data stream. The profiling float technology is evolving and new generations of instruments are emerging. Their long term performance will not be known for several years and diligence in monitoring the array performance is required. The use of high bandwidth two-ways telecommunication systems is projected to rapidly increase. Around 23% (>900 floats) of the array is now delivering highly vertically resolved (2db) profiles thanks to the use of high bandwidth satellite data telecommunication systems. Pilot deployments of bio-optical-geochemical sensors and ice-avoidance capabilities continue. Several groups are developing and field testing "deep floats" (4000m and below). The evolution of Argo to pursue new and additional missions is being discussed at various workshops and by the Argo Steering Team.

The Panel was further informed that the Tropical Pacific Ocean moored buoy array (TAO/TRITON) is now complete, and salinity is available nearly on every mooring site. The Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) is still developing in the Indian Ocean to complete coverage of the tropical oceans - the heat engine of global climate and weather patterns. RAMA provide essential data to complement other existing satellite and in situ observations in the region. However, data availability for both the moored buoy arrays in the Tropical Pacific (TAO, now complete with 67 units) and Indian oceans (RAMA, with 26 deployed units of the planned 32 units) it not at its optimum (reduced to 50% only) due to vandalism on the data buoys, and difficulties to assure maintenance due to the cost of ship time, and piracy. The primary data telemetered in real time from surface moorings in the arrays are daily or hourly mean surface measurements (wind speed and direction, air temperature, relative humidity and sea surface temperature and salinity) and subsurface temperatures. Moorings provide optional enhanced measurements, which include precipitation, short and long wave radiation, barometric pressure, salinity, and ocean currents. These enhancements provide heat, moisture and momentum flux measurements at 4 Tropical Indian ocean moorings. High temporal resolution (10-min or hourly) measurements are available in delayed mode.

Voluntary Observing Ships (VOS) provide for valuable marine meteorological observations in the region. However the tropical regions remain relatively data sparse. Efforts are being made to increase the number of Automatic Weather Stations installed on ships to improve real-time reporting for weather forecasting and climate. VOSClim class vessels are delivering high quality observational data for climate related applications. The target is to have at least 25% of the operational VOS fleet comprised of VOSClim class vessels. On average, in excess of 100,000 VOS reports from more than 2,000 ships are distributed on the GTS per month worldwide, predominantly in the Northern Hemisphere.

The Ship of Opportunity Programme (SOOP) addresses both scientific and operational goals for building a sustained ocean observing system with oceanographic observations mainly from cargo ships. It provides for valuable upper ocean thermal data through 41 global high resolution and frequently repeated Expendable Bathythermograph (XBT) lines now fully occupied (target is 51 lines). Globally, approximately 22,000 XBTs are deployed every year (target is 37,000 units) under the SOOP, of which over 15,000 are distributed in real-time on GTS to end users. There are approximately 40 ships participating in the XBT network. A large number of XBTs deployed by non-US agencies are the result of donations from the US (NOAA), thereby making the operation highly dependent on the continuing support of one single institution. International collaboration is key to the success to the implementation of the XBT network, where the operations are related to ship recruiting, deployment of probes, data transmission, data quality control, and archiving. There are approximately 30 ships transmitting Thermosalinograph (TSG) data, most of which are operated by French institutions and by the US/NOAA research and SOOP fleet.

The Global Sea Level Observing System (GLOSS) has expanded beyond the original aim of providing tide gauge data for understanding the recent history of global sea level rise and for studies of interannual to multi-decadal variability. Tide gauges are now playing a greater role in regional tsunami warning systems and for operational storm surge monitoring. The GLOSS tide gauge network is also important for the ongoing calibration and validation of satellite altimeter time series, and as such is an essential observing component for assessing global sea level change. The number of sea level stations reporting to the GLOSS Data Centres has increased markedly over past last ten years, particularly for stations that report in near real-time. Just over 75% of the GLOSS Core Network (GCN) of about 290 stations can be considered operational, and there are focused efforts to address the remaining 25% of stations not currently on-line.

The WMO Secretariat invited Panel members to explore enhanced contributions of WMO Members in the region in support of the implementation of the buoy networks in the tropical Indian and Pacific Oceans in particular (RAMA and TAO Arrays). Of particular interest is the provision of ship time to assist in the deployment and servicing of tropical moored buoys, and for the deployment of drifters and XBTs. Members interested to contribute are invited to contact the Technical Coordinator of the Data Buoy Cooperation Panel (DBCP), Ms Kelly Stroker (support@jcommops.org).

Aircraft Based Observations

The representative of the WMO informed the Panel that aircraft-based observing system, comprising the AMDAR observing system supplemented by aircraft-based observations derived from ICAO systems, now produces well over 400,000 upper air observations per day on the WMO GTS, with the AMDAR system contributing the vast majority from 39 participating airlines and a global fleet of over 3000 aircraft. This important sub-system of the WMO Integrated Global Observing System produces both en-route and vertical profile (from AMDAR aircraft at airport locations) high quality, upper air data, that continues to demonstrate a significant positive impact on global, regional and high resolution NWP and other forecasting and meteorological applications.

The meeting noted that the CBS Implementation Plan for the Evolution of Global Observing Systems identifies several actions related to the development and expansion of the Global AMDAR Programme in order to support greater and wider utilization of aircraft-based observations and AMDAR as a contribution to derivation of high quality upper air data and vertical profiles. In line with this, CBS, through its Expert Team on Aircraft-Based Observing Systems, is currently working with WMO RAs to develop strategy and implementation plans for each WMO region. This activity will be based in part on the results of a study on airline capabilities for future AMDAR participation, which will identify the key target airlines that might contribute to AMDAR data coverage improvement over this region. Such growth and enhancement of this observing system would be expected to have a significant additional positive impact on tropical cyclone forecasting and monitoring skills and applications.

Surface-Based Remotely-Sensed Observations

Regarding the surface-based observation system, the Panel was informed that owing to critical importance of weather radar system and the data derived from them in severe weather and tropical cyclone monitoring and prediction, the WMO and the Commission for Basic Systems (CBS) have overseen a development, led by the Turkish State Meteorological Service (TSMS), resulting in the operational implementation of the WMO Weather Radar Database (WRD) (http://wrd.mgm.gov.tr/default.aspx?l=en). This database is already making an important contribution to the WIGOS Information Resource and the WMO Information System as a source of radar metadata. WMO is encouraging its Members to continue to nominate WMO radar metadata focal points to ensure that all weather radars are included and routinely maintained and updated in the WRD.

In April 2013, the CBS Expert Team on Surface-Based Observations (ET-SBO) held a Workshop on Regional and Global Exchange of Weather Radar Data in Exeter, UK, where 20 recommendations were made on the topic, the most significant of which was the recommendation to form a CBS Task Team to undertake to work on the development and finalization of WMO standards for the international exchange of weather radar data. This development is in line with Action G48 of the CBS Implementation Plan for Evolution of the GOS, which calls for greater exchange of weather radar data in support of NWP applications. Since the Workshop, ET-SBO has formed the Task Team on Weather Radar Data Exchange that recently held a first virtual meeting on the development of a work plan for the team. A further outcome of the workshop, was the identification of several regional pilot projects on weather radar data exchange, one of which was a joint pilot proposed for Region II and Region V and which has been further developed and presented to the ASEAN Sub-Committee on Meteorology and Geophysics (SCMG) held in Indonesia, 2-4 July 2013. In addition to supporting greater access to weather radar data for NWP, thereby likely improving NWP skill in severe weather applications, it is also expected that, subject to suitable international agreements, such data exchange can and will facilitate the development of international and regional data products.

Surface Based Observational Infrastructure

The Panel was infromed that the Fifteenth Session of the WMO Commission for Instruments and Methods of Observations (CIMO XV, 2-8 September 2010, Helsinki, Finland) noted that maintenance of high quality observational records (historical and real time) is critical for DRR applications, including: (i) risk identification; (ii) risk reduction through the provision of early warnings to support emergency preparedness and response as well as climate services for medium- and long-term sectoral planning; and (iii) risk transfer through insurance and other financial tools. Thus, interruptions in monitoring caused by damages to instruments and observing networks as a result of natural hazards, hamper NMHSs capacities in delivering effective services during and following a disaster. In this regard, the Commission agreed to: (i) develop standards for instruments and their installation so that they could withstand extreme hydrometeorological events; and (ii) to assist CBS and CHy in developing guidelines for the design of observing networks capable of reliably and accurately measuring extreme hydrometeorological events especially in regions at risk. Accordingly, the Commission included in the Terms of Reference of its Expert Team on New In-Situ Technologies (ET-NIST) the need for the Expert Team to review and make proposals on the:

- Need for development of more robust instruments with greater resilience to extreme weather conditions and combinations of weather conditions;
- Need for development of instruments with increased measuring range;
- Investigation of performance of instruments in extreme climate.

ET-NIST has now investigated this matter by identifying and reviewing existing guidance material on these topics, but has found the availability of existing information to be difficult to locate. To better address the topic in future, CIMO invites the ESCAP Panel on Tropical Cyclones to nominate a Point of Contact, to assist in encouraging Members to share information with CIMO ET NIST on common practices employed to design and deploy instrumentation with increase resilience to natural hazards, such as tropical cyclones.

<u>ICAO</u>

ICAO presented information about the implementation of the tropical cyclone advisories, including graphics, issued by tropical cyclone advisory centres (TCACs) for international air navigation, the continued desire for day-to-day operational coordination between the world area forecast centres (WAFCs) and the TCACs using a web-based chat room facility hosted by WAFC Washington, quality assurance of aeronautical meteorological information, and trends in the provision of meteorological service for international air navigation.

Action proposed

a) To fully implement the provisions related to the content, format and dissemination of tropical cyclone advisories, in particular tropical cyclone advisories in graphical format,as contained in ICAO Annex 3/WMO Technical Regulations [C.3.1];
b) To participate, as resources allow and particularly during respective TC season(s), in routine coordination sessionswith the WAFCs, hosted by WAFC Washington four times per day using a web-based chat room facility; and
c) To note recent developments concerning the migration to the use of XML/GML for the digital exchange of operational meteorological (OPMET) information to support

international air navigation, and medium term intentions to include other meteorological information (such as tropical cyclone advisories) in such developments.

Implementation of Tropical Cyclone Advisories for International Air Navigation

He stated that the Tropical cyclone (TC) advisories issued by tropical cyclone advisory centres (TCAC) continue to play an important role in the safety and efficiency of international air navigation worldwide. Therefore, their full implementation in accordance with the provisions contained in ICAO Annex 3/WMO Technical Regulations [C.3.1] is of utmost importance to ICAO. This includes the *issuance*, correct *formatting* and *dissemination* of these advisories. It is important that TC advisories issued by the TCACs reach the uplink station of the ICAO satellite broadcast (called SADIS) in the United Kingdom, as well as the ICAO Internet-based services provided by the United Kingdom and the United States (called the Secure SADIS FTP service and the WAFS Internet-File Service (WIFS) respectively), so that civil aviation users worldwide have access to the advisory information.

In addition, TC advisories should reach the following:

a) the two World Area Forecast Centres (WAFCs) – WAFC London in the United Kingdom and WAFC Washington in the United States – in view of ensuring that information on the name and location of tropical cyclones is included in the significant weather (SIGWX) forecasts issued by the WAFCs;
b) meteorological watch offices (MWOs) in the TCAC area of responsibility, in view of supporting the preparation of tropical cyclone SIGMET by the MWOs;
c) other TCACs whose areas of responsibility may be affected, in view of supporting the preparation of consistent advisories at a regional TCAC interface; and
d) International OPMET databanks, in view of ensuring appropriate national and international availability.

Implementation of TC Advisories in Graphical Format

An amendment related to the provisions governing the TC advisories was developed in 2009 based on long-standing requirements by airline users (through IATA). The amendment (Am. 75 to Annex 3), which became applicable on 18 November 2010, included the addition of a specification for tropical cyclone advisory information in graphical format at Appendix 1 to Annex 3/Technical Regulations [C.3.1]

The TC advisories in graphical format must include all the information included in the equivalent alphanumeric tropical cyclone advisory, together with areas affected by gale-force surface winds and frequent cumulonimbus clouds. TC advisory information, when prepared in graphical format in accordance with Appendix 1 of Annex 3/Technical Regulations [C.3.1] should be issued using:

a) the portable network graphics (PNG) format; or

b) the BUFR code form, when exchanged in binary format.

ICAO suggested that the TCACs should consider using the portable network graphic (PNG) chart form for TC advisories in graphical format – which is based on commercial-off-the-shelf software, rendering it cost effective both for TCAC and users of the TC advisories in States.

It may be noted that whilst the ICAO aeronautical fixed telecommunication network (AFTN) cannot be used to transmit any PNG-coded products, the introduction of enabling clauses in Annex 3/Technical Regulations [C.3.1] allowing the use of the public Internet in 2010 resolved this problem.

As of March 2012, two of the seven TCACs had reportedly implemented the tropical cyclone advisory in graphical format (in PNG chart or BUFR code form), although only one of these centres (La Reunion) was reportedly in a position to make the information available (under a bilateral arrangement) to the SADIS Provider State. Of the remaining (five) TCACs, two had indicated plans to implement the tropical cyclone advisory in graphical format in 2012.

In view of the importance of tropical cyclone advisory information to the safety and efficiency of international air navigation and civil aviation users worldwide, the meeting may wish to consider what additional efforts are required to ensure that all TCACs are in a position to fulfil the ICAO provisions/WMO technical regulations in respect of the TC advisories in graphical format.

Coordination between the WAFCs and the TCACs

In 2008/2009, as a means of harmonizing the information on tropical cyclones contained in the significant weather (SIGWX) forecasts prepared and issued by the two WAFCs to users worldwide within the framework of ICAO's world area forecast system (WAFS), the TCACs were invited to participate in an web-based chat room facility (routine coordination sessions) hosted by WAFC Washington and operated four times per day.

A WAFC-TCAC coordination trial was conducted in 2008/2009 where overall feedback provided by participant TCACs had indicated that the web-based chat room facility was easy to access and understand and of satisfactory duration. Involvement of the TCACs in these coordination sessions was (and remains) on a voluntary basis and the duration of TCAC involvement in the web-based chat room facility is a matter of only a few minutes per session.

The coordination sessions enable the WAFC duty forecasters to confirm, directly with the TCAC concerned, the name(s) and position(s) of TCs that are active or are expected to develop during the next 24 hours – which is the time horizon of the WAFS SIGWX forecasts. Such coordination is operationally relevant, since it ensures that the information included in the WAFS SIGWX forecasts is consistent with the output of the TCACs. Users consequently have greater confidence in the TC information contained in the WAFS significant weather forecasts, allowing better operational decisions to be made.

Information provided by the WAFC Provider States (the United Kingdom and United States) indicated that the engagement of some of TCACs in the coordination sessions with the WAFCs has been rather less than expected and it seems that it is now rare for TCACs to join the routine coordination sessions with the WAFCs.

Notwithstanding the value that can be gained for the WAFC forecasters from using the TC advisories to determine the location and forecast movement of a TC, the routine WAFC-TCAC coordination sessions offer a unique opportunity to amplify or fine-tune the information amongst like-minded experts, particular in those instances where a system has not yet reached TC intensity but is expected to do so within the next 24 hours, or where a system is degenerating below TC limits.

Recognizing the value that can be gained from discussing and harmonizing the actual and expected position of TCs, the TCACs are encouraged to participate, as resources allow, in the routine coordination sessions with the WAFCs, particularly during respective TC season(s), at the following times (daily):0030, 0600, 1230 and 1800 UTC.

Information concerning the web-based chat room hosted by WAFC Washington, including login credentials and login address, can be obtained by contacting:matt.strahan@noaa.gov

Quality Management Systems (QMS) for Aeronautical Meteorological Information

The provisions for QMS contained in ICAO Annex 3/WMO Technical Regulations [C.3.1] became a Standard Practice from 15 Nov 2012: each State shall ensure that the designated meteorological authority establishes and implements a properly organized quality system comprising procedures, processes and resources necessary to provide for the quality management of the meteorological information to be supplied to the users.

Furthermore, it is a recommended practice that the quality system should:

a) Conform with the International Organization for Standardization (ISO) 9000 series of quality assurance standards and should be certified by an approved organization;
b) Provide the users with assurance that the meteorological information supplied complies with the stated requirements;
c) Include verification and validation procedures; and
d) Demonstrate compliance by audit

Trends in the Provision of Meteorological Service for International Air Navigation

Amendment 76 to Annex 3/Technical Regulations [C.3.1], applicable 14 November 2013, introduced provisions to enable to exchange of aeronautical operational meteorological (OPMET) messages, specifically METAR/SPECI, TAF and SIGMET, in a digital form (XML/GML) amongst States in a position to do so.

This development can be seen as the first step towards transitioning all meteorological information to a digital information exchange environment, which will be a fundamental development over the coming years as civil aviation transitions from today's predominantly air traffic controlled environment to tomorrow's air traffic management environment, where system-wide information exchange will be a necessary prerequisite.
Subsequent amendments to Annex 3 / Technical Regulations [C.3.1] in 2016 and 2019 (Amendments 77 and 78 respectively) are expected to upgrade the enabling clause for METAR/SPECI, TAF and SIGMET in XML/GML to the status of a Recommended Practice and a Standard respectively.

The ICAO invited Panel members to note that the future availability of all other types of meteorological information - including tropical cyclone advisories and volcanic ash advisories - in a digital form is envisaged. It is anticipated that the ICAO Meteorology Divisional Meeting, to be held in July 2014 conjoint with the 15th Session of WMO Commission for Aeronautical Meteorology (CAeM), will establish timeframes for digital exchange of TCA information which could be as early as November 2016 as part of Amendment 77 to ICAO Annex 3/Technical Regulations [C.3.1].

1.2 HYDROLOGICAL ACTIVITIES

1.2.1 Bangladesh

Bangladesh Meteorological Department provides all sorts of data, information and weather forecast to the Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB). A Metropolitan Area Network (MAN) between SWC, Dhaka and FFWC was established through which FFWC receives meteorological and hydrological data (including rainfall and water discharge data of upstream) along with Radar and Satellite images. Through the completion of the establishment of Meteorological and Hydrological Doppler Radar at the northeastern part of Bangladesh under JICA Grant Assistance, FFWC is being connected by VSAT link to get all the radar information for flood and flash flood monitoring and forecasting. Also during execution of JICA's Technical Cooperation on the Human Capacity Development training will be imparted to FFWC for radar data calibration and its utilization.

1.2.2 India

IMD provides the necessary technical and operational support to various Central/State Govt. Organisations and other agencies in the field of Hydromet design flood forecasting, water management and agricultural planning purposes. In the performance of these activities, this discipline carried out compilation of rainfall statistics, hydro meteorological analysis of different river catchments for project authorities and provided meteorological support for flood warning and flood control operations to field units of Central Water Commission. Research Programmes in (a) Design Storm Analysis, (b) Rainfall Frequency Analysis and (c) Quantitative Precipitation Forecast are the ongoing hydro meteorological activities. The main activities of the Division are;

Rainfall Monitoring

Real time monitoring of district wise daily rainfall is one of the important functions of IMD. A network comprising a large number of raingauge stations is utilized under District wise Rainfall Monitoring Scheme (DRMS). Based on real time daily rainfall data, weekly,monthly, seasonal and annual district wise, subdivisionwise and statewise/ rainfall distribution summaries are prepared in the form of rainfall tables and maps. District wise and sub-divisionwise rainfall statistics provides important information useful to the agricultural scientists, planners and decision makers. The software used for preparation of districtwise rainfall summary has been modified to get outputs in Excel Format. Preparation of weekly sub-divisionwise/ districtwise/statewise rainfall reports including the statistics for the country as a whole as well as for the four regions viz., North-West India, South Peninsula, Central India and North East India. During the Monsoon Season 2013 daily sub-division rainfall report were prepared and supplied to the Cabinet Secretary and other users. Distrctwise reports for last 5 years were uploaded on IMD Website.

A book entitled, “Updated Rainfall Statistics-2013” was prepared by Hydromet division and the publication was released by the minister of Science & Technology, Govt. of India on IMD foundation day.

The seasonal statistics for the year 2013 is as follows:

- Winter Season (Jan-Feb) 2013:- During Winter season the updated rainfall statistics is, the country as a whole received 26% more rainfall of LPA. Out of 36 sub-divisions 25 subdivisions recorded excess rainfall, 04 recorded normal rainfall, 02 recorded deficient rainfall and 05 recorded scanty rainfall.
- Pre- Monsoon (March-May) 2013:- During Pre- monsoon the updated rainfall statistics is, the country as a whole received 21% less rainfall of LPA. Out of 36 sub-divisions 6 recorded excess rainfall, 11 recorded normal rainfall, 12 recorded deficient rainfall and remaining 07 sub-divisions recorded scanty rainfall.
- SW Monsoon (June-Spt.) 2013:- During the monsoon season the updated rainfall statistics for the country as a whole received was 6% more than the LPA. East & NE India, Southern peninsula, NW India and, Central India received rainfall of 73%,115%,109% and 123% of LPA respectively. Out of 36 sub-divisions 14 recorded excess rainfall, 16 recorded normal rainfall and remaining 06 sub-divisions recorded deficient rainfall.
- Post Monsoon Season (Oct- Dec) 2013 :- During the Post Monsoon season as per the real time rainfall data country as a whole received 18% more rainfall of LPA. Out of 36 subdivisions 16 recorded excess, 06 recorded normal, 13 recorded deficient and one recorded scanty rainfall.

Flood Meteorological Service

Flood Meteorological Service of IMD provides the hydrometeorological inputs to Central Water Commission (CWC) through their 10 FMOs established in different flood prone parts of India for operational flood forecasting by CWC.

Model based Quantitative Precipitation Forecast

Sub-basin wise Quantitative Precipitation Forecast (QPF) for day-1, day-2, day-3 using IMD’s operational NWP models, WRF ARW (9 km x 9km) and Multi-model Ensemble (0.25° X 0.25°), are computed and uploaded on the IMD’s website www.imd.gov.in operationally during flood season 2013 for 127 flood prone river sub-basins. An example is shown in Fig.1.

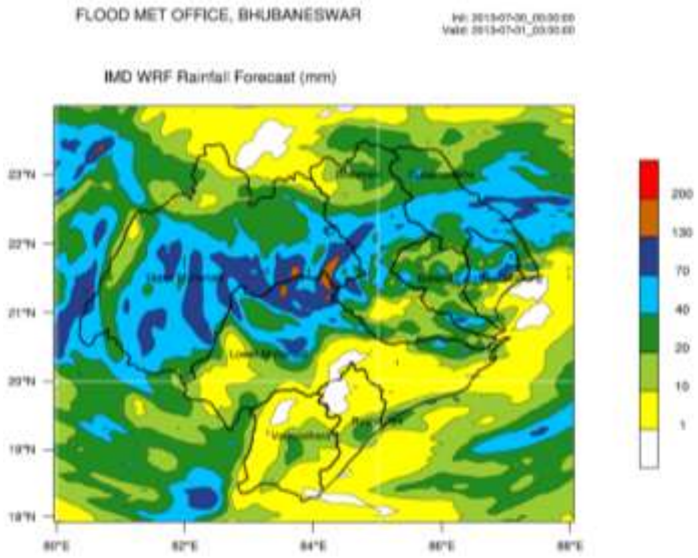


Fig.1 Design Storm Studies

Design Storm Studies are being conducted to evaluate design storm estimates (rainfall magnitude and time distribution) for various river catchments/projects in the country, for use as main input for design engineers in estimating design flood for hydraulic structures, irrigation projects, dams etc. on various rivers. This estimation of design values is required for safe and optimum design of storage and spillway capacity. On the request of Central Govt. / State Govt. and Private Agencies, design storm values (Standard Project Storm, Probable Maximum Precipitation along with Time Distribution) are being provided for users as main input. For Govt. agencies, these studies are being carried out free of cost and for private/profit earning agencies on payment basis.

The design storm studies for 38 projects have been completed in the year 2013 and results communicated to the concerned project authorities. The PMP Atlases for all river basins of India are being prepared which is a joint project of India Meteorological Department and Central Water Commission. The study is likely to be completed by June, 2014.

Major Activities of Central Water Commission (CWC)

CWC is charged with the general responsibility of initiating, coordinating and furthering in consultation with the State Governments concerned, schemes for the control, conservation and utilization of water resources in the respective State for the purpose of flood management, irrigation, drinking water supply and water power generation. The Commission, if so required, can undertake the construction and execution of any such scheme.

In exercise of the above responsibilities, following are the main functions of CWC:

1. To carry out Techno-economic appraisal of Irrigation, flood control & multipurpose projects proposed by the State Governments.
2. To collect, compile, publish and analyze the hydrological and hydrological data relating to major rivers in the country, consisting of rainfall, runoff and temperature, etc. and to act as the central bureau of information in respect of these matters;
3. To collect, maintain and publish statistical data relating to water resources and its utilization including quality of water throughout India and to act as the central bureau of information relating to water resources;
4. To provide flood forecasting services to all major flood prone inter-state river basins of India through a network of 175 flood forecasting stations.

5. Monitoring of selected major and medium irrigation projects, to ensure the achievement of physical and financial targets. Monitoring of projects under Accelerated Irrigation Benefit Programme (AIBP), and Command Development (CAD) programme has also been included in its field of activities.
6. To advise the Government of India and the concerned State Governments basin-wise development of water resources;
7. To undertake necessary surveys and investigations as and when so required prepare designs and schemes for the development of river valleys in respect of power generation, irrigation by gravity flow or lift, flood management and erosion control, anti-water logging measures, drainage and drinking water supply;
8. To undertake construction work of any river valley development scheme on behalf of the Government of India or State Government concerned;
9. To advise and assist, when so required, the State Governments (Commissions, Corporations or Boards that are set up) in the investigation, surve1 preparation of river valley and power development schemes for particular and regions;
10. To advise the Government of India in respect of Water Resources Development regarding rights and disputes between different States for the conservation and utilization and any matter that may be referred Commission in connection with river valley development;
11. To impart training to in-service engineers from Central and State Organizations in various aspects of water resource development;
12. To initiate studies on socio-agro-economic and ecological aspects of irrigation projects for the sustained development of irrigation;
13. To conduct and coordinate research on the various aspects of river development schemes such as flood management, irrigation, navigation, power development, etc., and the connected structural and design features;
14. To promote modern data collection techniques such as remote sensing technology for water resources development, flood forecasting and development of related computer software;
15. To conduct studies on dam safety aspects for the existing dams and stand related instrumentation for dam safety measures;
16. To carry out morphological studies to assess river behaviour, bank erosion/coastal erosion problems and advise the Central and State Governments on all such matters;
17. To promote and create mass awareness regarding the progress and achievements made by the country in the water resources development, use and conservation.

1.2.3 Maldives

There are no much hydrological issues in the Maldives; only a few lakes or swamps exist here.

1.2.4 Thailand

1.2.4.1 Overview

The river system in Thailand provide into 25 main river basins. Which hydrology and water management comes under the care of two government agencies: Royal Irrigation Department (RID) and Department of Water Resource (DWR).

The RID has strategies for flood prevention and mitigation, as well as impacts in urban and cultivated areas, with aims to reduce the loss of lives and properties of population at risk. Management plans are set in terms of monitoring, predicting and warning by establishment of Water Watch and Monitoring System for Warning Center (WMSC) to examine flood situations 24 hours. In addition, the collaborations with national related agencies for implementation plan cope with local flood protections in economic zones where severe flood may occur.

The state-of-art technologies were established, such as telemetry and flood forecasting systems. Similar to 571 manual river gauges and 2,294 manual rain gauges, 23 of 25 main river basins have 711 telemetric stations installed for water resources management and flood prevention and mitigation.

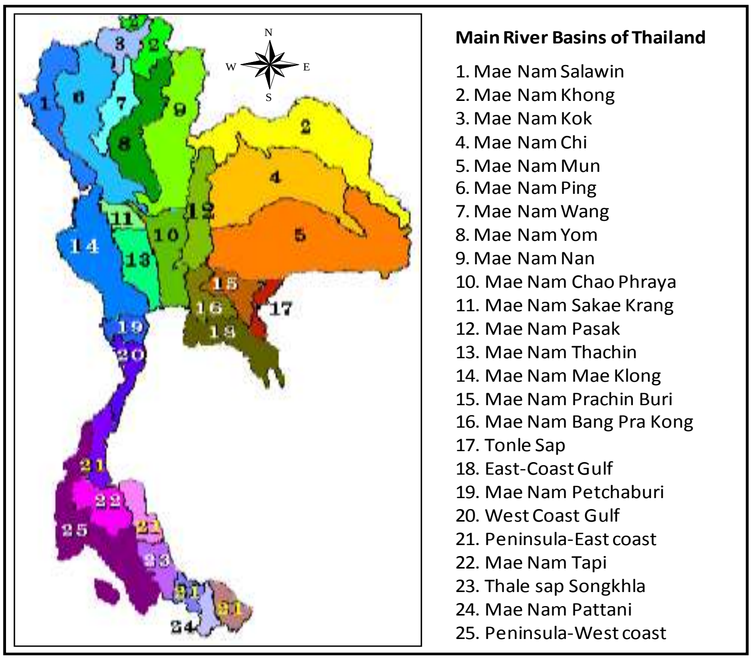


Fig. 4: Main river basin in Thailand

1.2.4.2 Particular Impact in Year 2013

During the period 1 January to 31 December 2013, there is no impact from tropical cyclone in Thailand. However the impact of tropical depression and tropical storm of year 2013 caused the flood occurred in some regions of Thailand, for example, Mun River in the northeastern region and Prachinburi River in the eastern region. It is related to RID responsibility to monitoring, forecasting and mitigation in flood situation.

The tropical depression during September 2013, and Typhoon “NARI” caused the water level in Prachinburi river at Sakaew and Prachin Buri Province, as same as in Mun river at Burirum, Surin and Ubon Ratchathani Province were risen up and overbank flow.

Prachinburi River:

- At A.Krabin Buri, water level started flow overbank on 21 Sep. and reached to peak on 9 Oct. and back to normal on 20 Oct. Totally 1 months flood situation.
- At A.Srimahaphod, water level reached to peak on 10 Oct. and back to normal on 15 Oct. About 2 weeks flood situation.
- At A.Muang Prachinburi, water level started flow overbank on 28 Sep. and reached to peak on 11 Oct. and back to normal on 23 Oct. About 1 months flood situation.

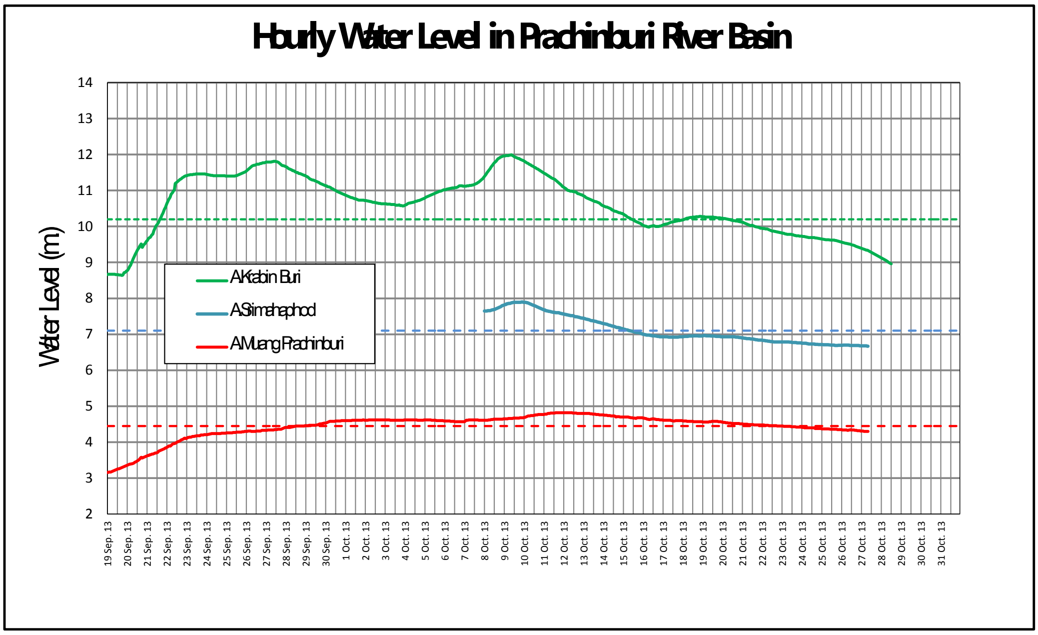
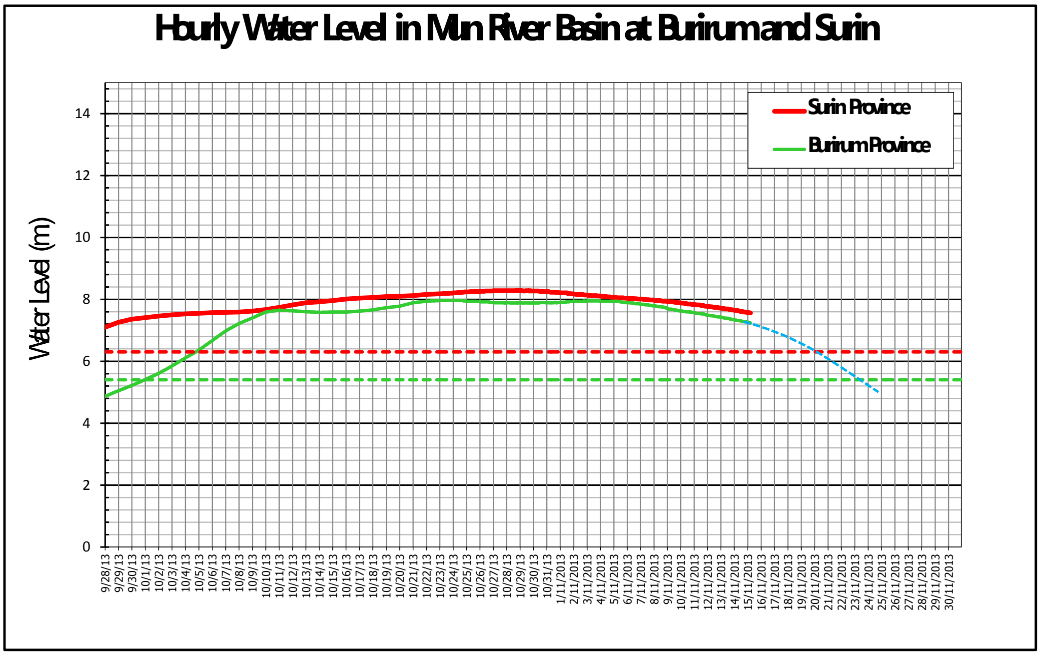


Fig.5: Flood situation in Prachinburi River Basin in East region.

Mun River:

- At Surin province, water level started flow overbank on 23 Sep. and reached to peak on 29 Sep. and back to normal on the beginning of November.
- At Burirum province, water level started flow overbank on 23 Sep. and reached to peak on 29 Sep. and back to normal on the beginning of November.
- At Ubon Ratchathani Province, water level started flow overbank on 22 Sep. and reached to peak on 3 Oct. and back to normal on the beginning of November.
- Actually more than 1 months flood situation.



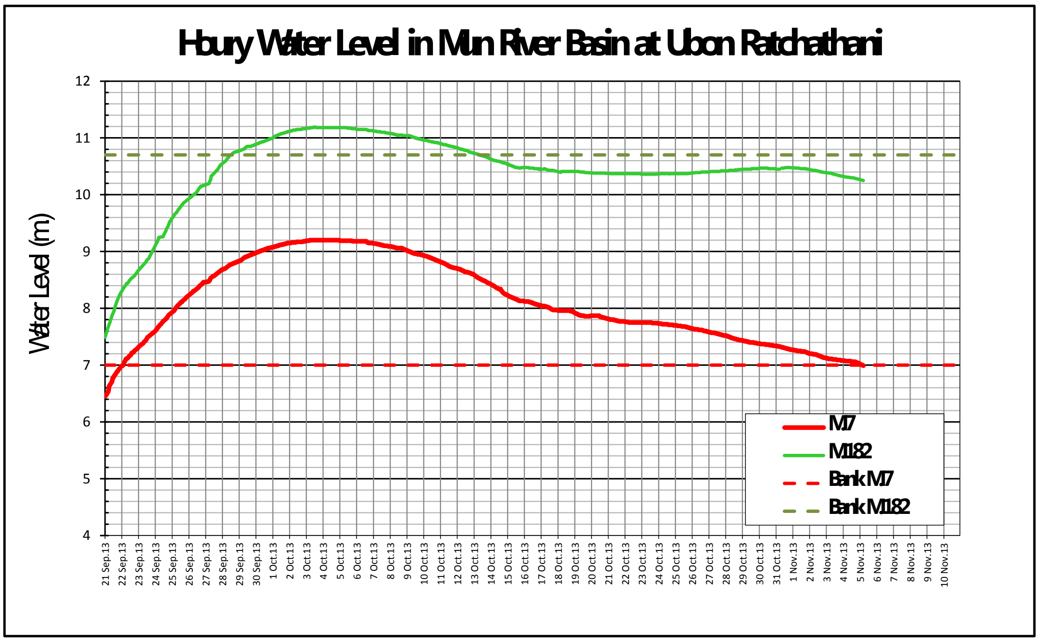


Fig. 6-7: Flood situation in Mun River Basin in Northeast region.

1.2.4.3 Forecasting and Communication

Collaboration with other agencies related to discussion and making decision during flood situation under the government.

Coordinate and exchange information of climate, rainfall and runoff and water operation to analyze and forecast the future situation for water management before announcement to public.

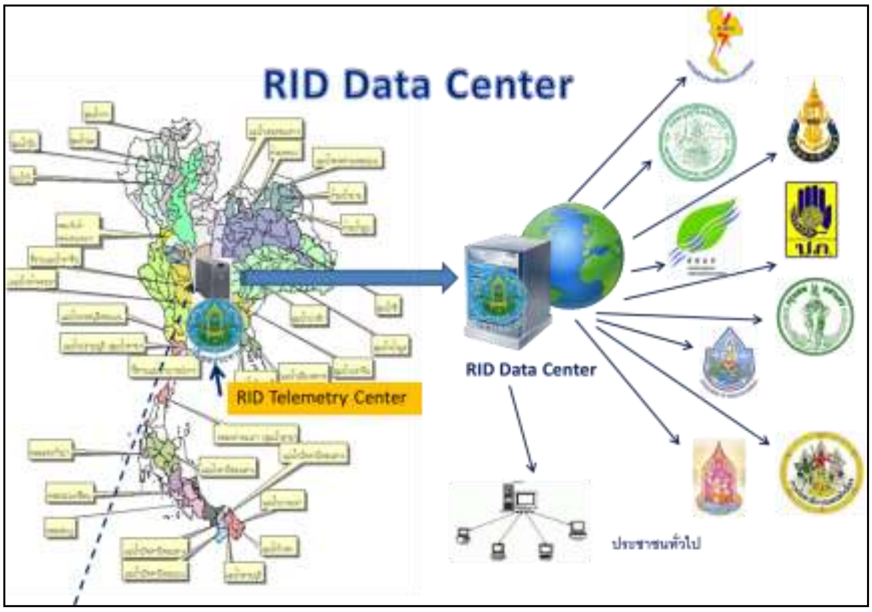


Fig.8: RID Data Centre and Communication.

1.2.4.4 Activities

- Produce the inundation map after flood situation for report.
- Produce the impact area before release the storage by dam operation.
- Establish the announcement board at the communities area related in flood risk area or impact area.
- Addition the latest data to improve the early warning system.
- Training in flood forecasting and flood inundation model.

1.2.4.5 State of Mitigation

- Telemetry system is used as a method for flood forecasting in different river basins covering nearly the whole country. Only Royal Irrigation Department has already got the system for monitoring 23 river basins in the criteria of real-time hydrological data.
- The forecasting situation is then announced to public with different ways like website or radio broadcasting or networks. For network mentioned above means regional offices which take part in communicating in the local areas with other methods or media.
- Support machines, equipments and tools by the regional offices. After flooding situation, pumping for water drainage has to be prepared in order to reduce the height of water level or inundated areas.

<u>Activities of WMO</u>

Flood Forecasting Initiative

With regard to the implementation of WMO Flood Forecasting Initative (FFI), notable progress has been made including:

- To establish an overarching Advisory Group for the Flood Forecasting Initiative (FFI-AG), as decided by Congress (Resolution 15 (Cg-XVI)). The first meeting of the FFI-AG took place in Geneva from 7 to 9 October 2013, aiming to ensure adequate monitoring, evaluation and guidance with respect to the implementation of the Strategy and Action Plan on the Flood Forecasting Initiative. As a result of this meeting a list of projects, both completed and ongoing, was prepared. A list of WMO and non-WMO programmes related to the FFI was also prepared. Both lists are available in the Hydrology and Water resources Programme web site. Regional Association II had encouraged Members to further develop national and regional projects that would contribute to the achievement of the objectives of the initiative. The Association felt in particular that principal tiers in implementation would be: strengthened institutional capacities; use of state-of-the art observation platforms; upgraded monitoring networks; use of modeling approaches; and joint development of requirements-driven forecasting products including urban floods.

- Considerable progress continued to be made in the development and implementation of Flash Flood Guidance Systems (FFGS) particular in the Mekong River Basin (system is operational) and the South Asia region including Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. A planning meeting was held successfully. Myanmar will be shortly included in benefitting from the system operation.
- Efforts are under way to establish closer links between the Severe Weather Forecasting Demonstration Project (SWFDP) and the FFGS with the intent to establish a predictive capability for flash floods;
- Further, a draft report on the Intercomparison of Flood Forecasting Models was developed by a Task Team, established as a result a workshop on this topic held in Koblenz, Germany in September 2011 and a draft report has been prepared for the development of a methodology to improve the effectiveness of flood forecasting services. This draft report is being reviewed under the guidance of the Vice-President of CHy, Mr Zhang Liu (China).
- Progress has been made in the implementation of WHYCOS projects and in particular the Mekong-HYCOS that ended by November 2012 and the Hindu Kush Himalayan (HKH) HYCOS project that is currently being implemented. The objective of both HYCOS projects is the establishment of regional flood information systems.

The Associated Programme on Flood Management (APFM) that promotes the concept of Integrated Flood Management practices has progressed largely and in particular the development of Tools on a wide variety of flood management issues and the HelpDesk established under the programme. National workshops on the development of flood management strategies were held in Thailand and Laos PDR. A considerable number of tools have been developed under the APFM that can be downloaded from www.apfm.info. Substantial support has far been provided by the Governments of Japan, Switzerland, Italy and Germany to the success of the Programme. USAID pledged additional funds in support of the APFM.

Quality Management Framework (QMF)for Hydrology

The QMF – Hydrology aims at improving all aspects of operations and activities of NMSs/NMHSs of the WMO Member States. In this regard efforts are underway in the followin areas:

- Enhanced cooperation between WMO and the international Organization for Standardization (ISO) in the development of international standards related to meteorological and hydrological data, products and services.

- To highlight the role and benefits of applying the Quality Management System and provision of necessary guidance to the Members on technical standards from data collection through to service delivery.
- *Publications*

A draft publication: "*A Practical Guide for the Implementation of a Quality Management System for National Meteorological and Hydrological Services"*, is available under: (http://www.wmo.int/pages/prog/amp/aemp/documents/QM_Guide_NMHSs_V10.pdf).It represents the most authoritative blueprint for WMO Members to follow in pursuing a quality management approach to the delivery of their services.

The following publications are seen as of particular interest for the PTC namely: the *"Manual on Estimation of Probable Maximum Precipitation"* (PMP) (WMO N° 0145), the *"Manual on Stream Gauging"* (WMO N° 1044), the *"Manual on Flood Forecasting and Warning"* (WMO N°1072), the *"Guidelines for the Assessment of Uncertainty of Hydrometric Measurements"*, the *"Technical Report on Climate and Meteorological Information Requirements for Water Management"* (WMO N° 1094), the *"Technical Report on Water Quality Monitoring, and the Technical Report on Technical Material for Water Resources Assessment"* (WMO N° 1095). These publications are available at: http://www.wmo.int/pages/prog/hwrp/index_en.php.

1.3 DISASTER PREVENTION AND PREPAREDNESS

1.3.1 Bangladesh

Bangladesh is most vulnerable to recurring natural disasters including cyclone and the associated storm surge. These particular disasters are known to disrupt people's lives, livelihood, and development momentum in some part of the country. Over the past few years, climate change has added significant perturbation in the hydrological cycle and increased the frequency and intensity of the hydro-meteorological disasters such as the cyclones. This reaches to the extent where the international community has placed Bangladesh as the worst victim of climate induced disaster.

In view of the cyclone season, the government intends to implement the provisions of the National plan for disaster Management, 2010 (Section 10: Disaster Management Regulatory Framework, section 11: Disaster Management plans, and standing order Disaster, 2010) in the form of Response Plan for Cyclone Season. This response plan aims at eliminating or mitigating the cyclone risk by undertaking coordinated activities for the prevention of, preparation for, response to and recoveries from the impact of cyclone. Bangladesh Government has enacted Disaster Management Act 2012.

1.3.2 India

1.3.2.1 Cyclone Warning Services

The extensive coastal belts of India are exposed to cyclonic storms, which originate in the Bay of Bengal and the Arabian Sea every year. These cyclones, which are accompanied with very heavy to extremely heavy rain, gales and storm surges cause heavy loss of human lives and cattle. They also cause extensive damage to standing crops and properties.

It is the endeavour of India Meteorological Department (IMD) to minimise the loss of human lives and damage to properties due to tropical cyclones by providing early warnings against the tropical cyclones. Cyclone warning is one of the most important function of the IMD and it was the first service undertaken by the department in1865. The cyclone warnings are provided by the IMD from the Area Cyclone Warning Centres (ACWCs) at Kolkata, Chennai & Mumbai and Cyclone Warning Centres (CWCs) at Vishakhapatnam, Bhubaneswar and Ahmedabad.

The complete Cyclone Warning Programme in the country is supervised by the Cyclone Warning Division (CWD) at Head Quarter Office of the Director General of Meteorology at New Delhi. The CWD monitors the cyclonic disturbance both in the Bay of Bengal and Arabian Sea and advises the Government of India at the Apex level. Information on cyclone warnings is furnished on a real time basis to the Control Room in the Ministry of Home Affairs, Government of India, besides other Ministries & Departments of the Central Government. This Division provides cyclone warning bulletins to Doordarshan and All India Radio (AIR) station at New Delhi for inclusion in the National broadcast/telecast. Bulletins are also provided to other electronic and print media and concerned state govts. The Deputy Director General of Meteorology (Cyclone Warning) and Deputy Director General of Meteorology (Weather Forecasting) Pune monitor technical aspects and review the standard practices in the area of cyclone forecasting.

1.3.2.2 Cyclone warning bulletins

The following is the list of bulletins and warnings issued by ACWCs/CWCs for their respective areas of responsibility:

1. Sea area bulletins for ships plying in High Seas.
2. Coastal weather bulletins for ships plying in coastal waters.
3. Bulletins for Global Maritime Distress and Safety System (GMDSS). Broadcast through Indian Coastal Earth Stations.
4. Bulletins for Indian Navy.
5. Port Warnings.
6. Fisheries Warnings.
7. Four stage warnings for Central and State Govt. Officials.
8. Bulletins for broadcast through AIRs for general public.
9. Warning for registered users.
10. Bulletins for press.
11. Warnings for Aviation (issued by concerned Aviation Meteorological Offices).
12. Bulletins for ships in the high seas through Navtex Coastal Radio Stations.

The cyclone warnings are issued to state government officials in four stages. The **First Stage** warning known as **"PRE CYCLONE WATCH"** issued 72 hours in advance contains early warning about the development of a cyclonic disturbance in the north Indian Ocean, its likely intensification into a tropical cyclone and the coastal belt likely to experience adverse weather. This early warning bulletin is issued by the Director General of Meteorology himself and is addressed to the Cabinet Secretary and other senior officers of the Government of India including the Chief Secretaries of concerned maritime states.

The **Second Stage** warning known as **"CYCLONE ALERT"** is issued at least 48 hrs in advance of the expected commencement of adverse weather over the coastal areas. It contains information on the location and intensity of the storm likely direction of its movement, intensification, coastal districts likely to experience adverse weather and advice to fishermen, general public, media and disaster managers. This is issued by the concerned ACWCs/CWCs and CWD at HQ.

The **Third Stage** warning known as **"CYCLONE WARNING"** issued at least 24 hours in advance of the expected commencement of adverse weather over the coastal areas. Landfall point is forecast at this stage. These warnings are issued by ACWCs/CWCs/and CWD at HQ at 3 hourly interval giving the latest position of cyclone and its intensity, likely point and time of landfall, associated heavy rainfall, strong wind and storm surge alongwith their impact and advice to general public, media, fishermen and disaster managers.

The **Fourth Stage** of warning known as **"POST LANDFALL OUTLOOK"** is issued by the concerned ACWCs/CWCs/and CWD at HQ at least 12 hours in advance of expected time of landfall. It gives likely direction of movement of the cyclone after its landfall and adverse weather likely to be experienced in the interior areas.

Different colour codes as mentioned below are being used in since post monsoon season of 2006 the different stages of the cyclone warning bulletins as desired by the National Disaster Management.

Stage of warning	**Colour code**
Cyclone Alert	**Yellow**
Cyclone Warning	**Orange**
Post landfall out look	**Red**

During disturbed weather over the Bay of Bengal and Arabian Sea, the ports likely to be affected are warned by concerned ACWCs/CWCs by advising the port authorities through port warnings to hoist appropriate Storm Warning Signals. The Department also issues **"Fleet Forecast"** for Indian Navy, Coastal Bulletins for Indian coastal areas covering up to 75 km from the coast line and sea area bulletins for the sea areas beyond 75 km. The special warnings are issued for fishermen four times a day in normal weather and every three hourly in accordance with the four stage warning in case of disturbed weather.

The general public, the coastal residents and fishermen are warned through State Government officials and broadcast of warnings through All India Radio and Doordarshan telecast programmes in national and regional hook-up. A system of warning dissemination for fishermen through World Space Digital Based radio receivers is being planned.

1.3.2.2.1 Specific objectives

It is proposed to modify the format of Cyclone Warning bulletins to make it more comprehensive for the use of Disaster Managers in view of the recent introduction of graphical warning products. The possibility of automation in generating and disseminating the bulletins through a suitable software whereby several different bulletins which are focused towards the needs of specific groups such as fishermen, shipping, AIR, press, port etc. is being pursued by Cyclone Warning Division at New Delhi. We are also planning to modify the SOP for issuing warnings to these users in view of recent upgradation in monitoring, prediction and dissemination infrastructure in the country. A dedicated website has been developed for RSMC and same will be operational soon. Also steps are being taken to introduce common alert protocol (CAP).

1.3.2.2.2 Common Alert Protocol (CAP)

Guidelines of implementation of Common Alert Protocol (CAP) have been received from WMO and India Meteorological Department (IMD) already has taken action for implementation of CAP with respect to cyclone, thunderstorm & earthquake.

1.3.2.3 Cyclone Warning Dissemination

Cyclone warnings are disseminated through a variety of communication media, such as, radio, television, print media, telephones, fax, telex, telegrams, police, wireless network. A specially designed Cyclone Warning Dissemination System (CWDS) which works via the INSAT Satellite provides area-specific service even when there is a failure of conventional communication channels. A set of 250 analog and 100 digital CWDS receivers have been employed in vulnerable coastal areas in the east and west coast. Steps are being taken for introduction of shortly for 500 new CWDS (Cyclone Warning Dissemination Systems), which are based on DTH concept through cable network.

1.3.2.4 Disaster Management

1.3.2.4.1 Institutional and Policy Framework

1.3.2.4.1.1 The institutional and policy mechanisms for carrying out response, relief and rehabilitation have been well-established since Independence. These mechanisms have proved to be robust and effective in so far as response, relief and rehabilitation are concerned.

1.3.2.4.1.2 At the national level, the Ministry of Home Affairs is the nodal Ministry for all matters concerning disaster management. The Central Relief Commissioner (CRC) in the Ministry of Home Affairs is the nodal officer to coordinate relief operations for natural disasters. The CRC receives information relating to forecasting/warning of a natural calamity from India Meteorological Department (IMD) or from Central Water Commission of Ministry of Water Resources on a continuing basis. The Ministries/ Departments/Organizations concerned with the primary and secondary functions relating to the management of disasters include:

India Meteorological Department, Central Water Commission, Ministry of Home Affairs, Ministry of Defence, Ministry of Finance, Ministry of Rural Development, Ministry of Urban Development, Department of Communications, Ministry of Health, Ministry of Water Resources, Ministry of Petroleum, Department of Agriculture & Cooperation. Ministry of Power, Department of Civil Supplies, Ministry of Railways, Ministry of Information and Broadcasting, Planning Commission, Cabinet Secretariat, Department of Surface Transport, Ministry of Social Justice, Department of Women and Child Development, Ministry of Environment and Forest, Department of Food. Each Ministry/Department/Organization nominate their nodal officer to the Crisis Management Group chaired by Central Relief Commissioner. The nodal officer is responsible for preparing sectoral Action Plan/Emergency Support Function Plan for managing disasters.

1.3.2.4.1.3 National Crisis Management Committee (NCMC)

Cabinet Secretary, who is the highest executive officer, heads the NCMC. Secretaries of all the concerned Ministries /Departments as well as organizations are the members of the Committee The NCMC gives direction to the Crisis Management Group as deemed necessary. The Secretary, Ministry of Home Affairs is responsible for ensuring that all developments are brought to the notice of the NCMC promptly. The NCMC can give directions to any Ministry/Department/Organization for specific action needed for meeting the crisis situation.

1.3.2.4.1.4. Crisis Management Group

The Central Relief Commissioner in the Ministry of Home Affairs is the Chairman of the CMG, consisting of senior officers (called nodal officers) from various concerned Ministries. The CMG's functions are to review every year contingency plans formulated by various Ministries/Departments/Organizations in their respective sectors, measures required to deal with a natural disasters, coordinate the activities of the Central Ministries and the State Governments in relation to disaster preparedness and relief and to obtain information from the nodal officers on measures relating to above. The CMG, in the event of a natural disaster, meets frequently to review the relief operations and extend all possible assistance required by the affected States to overcome the situation effectively. The Resident Commissioner of the affected State is also associated with such meetings.

1.3.2.4.1.5 Control Room (Emergency Operation Room)

An Emergency Operations Centre (Control Room) exists in the nodal Ministry of Home Affairs, which functions round the clock, to assist the Central Relief Commissioner in the discharge of his duties. The activities of the Control Room include collection and transmission of information concerning natural calamity and relief, keeping close contact with governments of the affected States, interaction with other Central Ministries/Departments/Organizations in connection with relief, maintaining records containing all relevant information relating to action points and contact points in Central Ministries etc., keeping up-to-date details of all concerned officers at the Central and State levels.

1.3.2.4.2 National Disaster Management Authority (NDMA)

About 8% of the area in the country is prone to cyclone-related disasters. Recurring cyclones account for large number of deaths, loss of livelihood opportunities, loss of public and private property and severe damage to infrastructure, thus seriously reversing developmental gains at regular intervals.

Broad-scale assessment of the population at risk suggests that an estimated 32 crore people, which accounts for almost a third of the country's total population, are vulnerable to cyclone related hazards. Climate change and its resultant sea-level rise can significantly increase the vulnerability of the coastal population.

As mandated by Disaster Management Act, 2005, the Government of India (GoI) created a multi-tiered institutional system consisting of the National Disaster Management Authority (NDMA) headed by the Prime Minister, the State Disaster Management Authorities (SDMAs) by the respective Chief Ministers and the District Disaster Management Authorities (DDMAs) by the District Collectors and co-chaired by Chairpersons of the local bodies. These bodies have been set up to facilitate a paradigm shift from the hitherto relief centric approach to a more proactive, holistic and integrated approach of strengthening disaster preparedness, mitigation and emergency response.

1.3.2.4.2.1 Guidelines for the Management of Cyclones

The NDMA has prepared Guidelines for the Management of Cyclones to assist ministries and departments of GoI and state governments to prepare their DM plans. The guidelines are presented in nine chapters as detailed below:

I. Chapter 1 provides an introductory overview that reflects the risk and vulnerability of the country to cyclones, including the dimensions and magnitude of the problem.
II. Chapter 2 discusses the Early Warning Systems (EWS) for cyclones. In this chapter, the present status of EWSs has been discussed and the gaps have been identified. Requirement to bring them up to international standards and making them state-of-the-art systems has been recommended.
III. Chapter 3 deals with the present status of Warning Communication and Dissemination, its gaps and future improvements required towards making it fail-proof and modern.
IV. Chapter 4 covers structural measures for preparedness and mitigation, covering cyclone shelters, buildings, road links, culverts and bridges, canals, drains, saline embankments surface water tanks, cattle mounds and communication/power transmission networks.
V. In Chapter 5, important aspects of the management of coastal zones and its relevance to CDM, including some other non-structural mitigation options have been presented. This chapter discusses issues related to coastal zone management, sustainability of coastal resources, bioshields, coastal flood plain management, coastal erosion, natural resources management, etc.
VI. Chapter 6 deals with various aspects of awareness generation related to CDM as an important preparedness measure.
VII. Chapter 7 covers Disaster Risk Management (DRM) issues, risk assessment and vulnerability analysis, hazard zoning and mapping, data generation, including the use of GIS tools, and capacity development.
VIII. Chapter 8 deals with CDM-related response and relief strategies. A detailed account of several issues related to effective response such as response platforms, linking risk knowledge with response planning, evolving disaster response capabilities, etc., is brought out in this chapter.
IX. In Chapter 9, guidelines and implementation strategies have been discussed.
X. Salient initiatives recommended for implementation as part of the National Guidelines for Management of Cyclones are listed for undertaking action by various relevant Departments.
XI. The detail Guideline is hoisted in the NDMA website.

1.3.2.4.3 National Disaster Response Force (NDRF)

Two national calamities in quick succession in the form of Orissa Super Cyclone (1999) and Gujarat Earthquake (2001) brought about the realization of the need of having a specialist response mechanism at National Level to effectively respond to disasters. This realization led to the enactment of the DM Act on 26 Dec 2005. The NDMA was constituted to lay down the policies, plans and guidelines for disaster management.

The DM Act has made the statutory provisions for constitution of National Disaster Response Force (NDRF) for the purpose of specialized response to natural and man-made disasters. Accordingly, in 2006 NDRF was constituted with 08 Bns (02 Bn each from BSF, CRPF, ITBP and CISF). As on date NDRF is having strength of 10 Bns. Each NDRF Bn consists of 1149 personnel. Union cabinet has also approved the conversion/up-gradation of 02 Bns from SSB.

The force is gradually emerging as the most visible and vibrant multi–disciplinary, multi-skilled, high-tech, stand alone force capable of dealing with all types of natural and man-made disasters.

The DM Act, 2005 envisages a paradigm shift from the erstwhile response centric syndrome to a proactive, holistic and integrated management of disasters with emphasis on prevention, mitigation and preparedness. This national vision inter alia, aims at inculcating a culture of preparedness among all stakeholders.

NDRF has proved its importance in achieving this vision by highly skilled rescue and relief operations, regular and intensive training and re-training, capacity building & familiarization exercises within the area of responsibility of respective NDRF Bns, carrying out mock drills and joint exercises with the various stakeholders.

Vision of NDRF is to emerge as the most visible and vibrant multi-disciplinary, multi-skilled, high-tech force capable to deal with all types of natural as well as manmade disasters and to mitigate the effects of disasters.

1.3.2.4.3.1 Role and Mandate of NDRF

- Specialized response during disasters
- Proactive deployment during impending disaster situations
- Acquire and continually upgrade its own training and skills
- Liaison, Reconnaissance, Rehearsals and Mock Drills
- Impart basic and operational level training to State Response Forces (Police, Civil Defence and Home Guards)
- Vis-à-vis Community- All NDRF Bns are actively engaged in various:
- Community Capacity Building Programme
- Public Awareness Campaign
- Exhibitions : Posters, Pamphlets, literatures

1.3.2.4.3.2 Unique Force

- The only dedicated disaster response force of the world.
- The only agency with comprehensive response capabilities having multi-disciplinary and multi-skilled, high-tech, stand alone nature.
- Experienced paramilitary personnel specially trained and equipped for disaster response.
- Capabilities for undertaking disaster response, prevention, mitigation and capacity building

1.3.2.4.4 National Institute of Disaster Management (NIDM)

- The National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its redesignation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

- Both as a national Centre and then as the national Institute, NIDM has performed a crucial role in bringing disaster risk reduction to the forefront of the national agenda. It is our belief that disaster risk reduction is possible only through promotion of a "Culture of Prevention" involving all stakeholders. We work through strategic partnerships with various ministries and departments of the central, state and local governments, academic, research and technical organizations in India and abroad and other bi-lateral and multi-lateral international agencies.

- NIDM is proud to have a multi-disciplinary core team of professionals working in various aspects of disaster management. In its endeavour to facilitate training and capacity development, the Institute has state-of-the-art facilities like class rooms, seminar hall, a GIS laboratory and video-conferencing facilities etc. The Institute has a well-stocked library exclusively on the theme of disaster management and mitigation. The Institute provides training in face-to-face, on-line and self-learning mode as well as satellites based training. In-house and off-campus face-to-face training to the officials of the state governments is provided free of charge including modest boarding and lodging facilities.

- NIDM provides technical support to the state governments through the Disaster Management Centres (DMCs) in the Administrative Training Institutes (ATIs) of the States and Union Territories. Presently NIDM is supporting thirty such centres. Six of these centres are being developed as Centres of Excellence in the specialised areas of flood risk management, earthquake risk management, cyclone risk management, drought risk management, landslides risk management and management of industrial disasters. Eleven larger states (Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Odisha) have been provided with additional centres to cater their needs in this area.

- NIDM hosts the SAARC Disaster Management Centre (SDMC) and works as its national focal point.

- The vision is to create a Disaster Resilient India by building the capacity at all levels for disaster prevention and preparedness.

1.3.3 Maldives

Maldives Meteorological Service is the authoritative organization in the country for issuing advisories and warnings related to meteorological, hydrological, tectonic and oceanographic disasters. To accomplish these tasks, MMS has prepared the Standard Operating Procedures (SOP) to act upon any likely event of meteorological, hydrological, tectonic and oceanographic disasters. MMS acquired a High Resolution Satellite Image Receiving System, Doppler Weather Radar, number of Automatic Weather Stations, broadband and short-period seismometers within the framework of establishing a National Multi-Hazard Early Warning System. Maldives’ sea level network comprises of three tide gauges in *Hanimaadhoo*, *Male’* and *Gan* to monitor low frequency changes in sea level associated with global sea level rise or decadal climate variations like other gauges in GLOSS network. They have been upgraded with more sensors such as radar/ pressure/ float based water level sensors, and the reference level float switch sensors and with these improvements, it shall even detect any slight variations in sea level due to a tsunami wave.

Warnings and Advisories

Alert Level	Description	Action	
1	**WHITE**	Mean wind speed is expected or prevailed between 23 –30 mph. Rainfall of more than 50 mm is expected to occur within 24 hours. High tidal waves are expected.	Significant weather changes expected or occurred. Look-out for update information.
2	**YELLOW**	Mean wind speed is expected or prevailed between 30 –40 mph. Torrential rain is expected and or heavy rain occurred for more than 2 hours. A severe thunderstorm is occurring or expected. Tropical Cyclone is formed or passing through effective area of Maldives. Significant tidal or swell waves occurring or approaching.	Concerned authorities and people are advised to be on watch or alert. Be ready to take preventive measures.
3	**RED**	-Flash flood is expected. -Tropical Cyclone is tracked towards or to cross Maldives. -Destructive tidal, swell waves or storm surge is expected.	People at risk to be evacuated from danger zones.
4	**GREEN**	Condition improved (Cancelation Message)	Cancel Watch or Warning.

During 2013 Cyclone Season, the severe weather was monitored locally through the 5 Met. Stations, 9 Automatic Weather Stations and CMACast image receiving system. Products of in-house WRF model output and various numerical weather prediction models and dynamical-statistical models received through internet were utilized to predict the variations in local atmosphere. Experimental forecast from RIMES and Bulletins from RSMC – New Delhi were used to predict the intensity and track of the Bay of Bengal System.

Maldives Meteorological Service followed the Standard Operating Procedure (SOP) and issued 110 WHITE Alerts, 10 YELLOW Alerts 2013 Cyclone Season. Apart from these, interviews/ personal briefing to sea travelers, fisherman, national defense, police, disaster management and various media were conducted.

Apart from severe weather or tropical cyclone warnings, earthquake or tsunami warning bulletin dispatched by Regional Tsunami Service Providers – Australia, India and Indonesia, were received at MMS. Similar Bulletins plus severe weather advisories were also received from RIMES. All the advisories and warnings were disseminated to public satisfactorily in time.
MMS in collaboration with RIMES convened during 2013 a Monsoon Forum and a workshop “Training on Forecast Interpretation, Translation, Communication and Application. This forum and workshop served as a national platform for its dialogue process between forecast providers and users, with the following objectives:

- The national training of forecast translation intended to build the capacity of key sectoral decision-makers in translating forecasts/warning into potential impacts outlook and response options, for enhanced management of risks.
- Ensure that forecasts/ warning information products, including their uncertainties and limitations, are communicated to and understood by users.
- Encourage the use of forecasts to mitigate risks in climate-sensitive sectors, including, but not limited to agriculture, water resources, disaster management, and health.
- Receive user feedback for improving usability of forecast products.
- Provide a platform for inter-agency coordination of policies, and sectoral plans and programs for dealing with potential impacts of hydro-meteorological hazards.
- Provide a platform for long-term process of understanding risks posed/opportunities brought about by past, current, and future climate.

The deliberation and feedback from these were brought forward in developing a training manual for future use.

1.3.4 Thailand

1.3.4.1 Overview of DDPM

As one of the international agency in Thailand Disaster Management, Department of Disaster Prevention and Mitigation (DDPM) is primary responsible for imposing and implementing program policy, formulating operational guidelines and establishing criteria on disaster management. In addition, DDPM still organizes and conducts training activities which are related to all disaster management by collaboration with local and international organizations. Besides that, disaster management in Thailand has been focused on preparedness activities to reduce the vulnerability impacts and increase the resilience in disaster prone areas as well as general public using Community-Based Disaster Risk Management (CBDRM) approaches. DDPM in cooperation with all national involved agencies has initiated various projects, such as CBDRM, One Tambon One Search and Rescue Team (OTOS), Mr. Disaster Warning and Civil Defence Volunteers etc.

1.3.4.2 Structure of Disaster Management System

In Thailand, the structure of disaster prevention and mitigation system are divided into 3 levels as policy level and operational level while national prevention and mitigation plan has significantly changed to the Disaster Prevention and Mitigation Act 2007. Under the present Act 2007, the Disaster Prevention and Mitigation Committee are responsible for formulation of national disaster prevention and mitigation plan. The substantial of national plan shall comprises as follows: 1) Guideline, measures budget allocation systemically and continuously 2) Guideline the method to assist the victims in short and long terms for evacuation of affected people with providing of public health and solving problems for communications and utilities 3) Concerned government and local agencies have to follow the procedures and instructions advised by 1 and 2 4) Guideline for assessment of resources preparedness and operation system including capacity building of staffs and people at risks 5) Guideline to effected people on reconstruction, recovery and rehabilitation.

1.3.4.3 Overview of Tropical Cyclones which have affected/impacted Member's area in 2013

During 1 January to 18 October 2013 there were 3 tropical cyclones over the West Pacific and South China Sea that posed severe effects to Thailand namely TD2, Wutip (1323) and Nari (1325).

Tropical Depression (TD2)

At 1300 UTC on 16 September, TD2 originated from low pressure area in South China Sea with maximum wind speed of 55 km/hr. The storm moved generally westward, making landfall on the central provinces of Viet Nam on early morning of 19 September, passing over Laos PDR and then moving into Thailand at Ubon Ratchathani at 0300 UTC. After that it move westward passing Amnat Charoen and Yasothon provinces and the central part of country. It produced abundant rainfall in upper Thailand with heavy rainfall in many areas and very heavy rainfall in some areas mainly in lower northern, central and eastern parts. The highest daily rainfall of 279.5 mm. was recorded at Muang district of Surin province on 19 September. Flash floods were reported at Kamphang Phet, Tak, Nan, Phetchabun, Phitsanulok, Khon Kaen, Ubon Ratchathani, Surin, Sri Sa Ket, Nakhon Ratchasima, Amnat Charoen, Buri Ram, Nakhon Sawan, Lop Buri, Kanchanaburi, Sa Kaeo, Prachin Buri and Nakhon Nayok provinces during late period. The river overflowed its banks at Uthai Thani province on 11 September, at Phra Nakhon Si Ayutthaya and Ang Thong provinces on 17 September and at Kamphang Phet province on 19 September.

Typhoon Wutip (1321)

Typhoon Wutip was the second tropical cyclones which crossed over the country. The storm originated from disturbance over central South China sea on west of Luzon, the Philippines on 25 September at night time. After making landfall on 29 September on the central provinces of Viet Nam, it rapidly weakened to the tropical depression and centred over Laos PDR on the same day and then moved to Thailand, where it downgraded from a typhoon to a tropical depression.

Typhoon Nari (1325)

The storm originated from disturbance over West Pacific approximately 1,300 km west of Manila city, the Philippines on 8 October at afternoon, intensified to tropical depression and moved slowly and continued intensifying to tropical storm at 1200UTC on 9 October and become Typhoon center 15.3 north degree and 125.4 east degree at 0100UTC on 11 October. The maximum wind speed near the center was about 140 km/hrs. The storm crossed over central Luzon Island, the Philippines to South China Sea and continued moving westward and making landfall at Danang, Viet Nam at 0600UTC of 15 October then downgraded to tropical storm at 1000UTC and to tropical depression at 2200UTC on the same day. The storm later became active low pressure cell before covering the lower northeastern, lower northern and central parts of Thailand on 16 and 17 October respectively.

After Viet Nam, Nari moved over central Laos PDR and eastern Thailand. The highest daily rainfall of 138.0 mm was recorded at Wang Chin in Phrae province on 17 October. Floods were reported at Nakhon Ratchasima, Kanchana Buri, Chachoengsao, Chonburi, Pathum Thani, Nonthaburi and Samut Prakarn province especially in Pracheen Buri province.

The tropical depression and tropical storm of year 2013 have caused floods in some regions of Thailand. The Royal Irrigation Department was responsible for monitoring forecasting and mitigation of flood situation. During September 2013, the tropical depresstion caused the water levels in Pracheen Buri river at Sakaeo and Pracheen Buri provinces as well as in Mun River at Burirum, Surin and Ubon Ratchathani Provinces to rise up and overflow their banks.

In case of Socio-economic Assessment, between July and November 2013, tropical cyclones brought torrential rains to northern, northeastern and central parts of the country. In overall, 38 provinces across Thailand have been affected by floods, killing 36 people. Over 3 million people have become flood victims and 3.1 million rais of farmland has been damaged.

1.3.4.4 Disaster Risk Reduction Achievements/Results

Title of Item: Enhanced beneficial typhoon-related effects for the betterment of quality of life
Strategic Goal 3a: To identify and explore the beneficial use of rainfall brought by typhoon-related impact.

The key agency working on disaster preparedness and protection of vulnerable communities against typhoon-related disaster is, according to the National Disaster Prevention and Mitigation Act B.E. 2007, is Department of Disaster Prevention and Mitigation (DDPM). DDPM has been working in close collaboration with other agencies such Thai Meteorological Department, Royal Irrigation Department, and National Disaster Warning Center.

The National Plan for Disaster Prevention and Mitigation 2009-2014 is the core document used as the strategic guideline for disaster risk management. The plan has the provision that addresses how to protect the people living in the vulnerable communities.

Title of Item: Improve typhoon-related Disaster Risk Management in various sectors **Strategic Goal 4b:** To strengthen capacity of the members in typhoon-related disaster risk management in various sectors

In 2013, Department of Disaster Prevention and Mitigation has signed MOU with UNDP to implement the 3-years projects on Disaster Risk Reduction. Four priorities of this projects are: 1) building capacity of DRR 2) formulation of Disaster Response Operating Procedures 3) implementation of Post Disaster Need Assessment and 4) Standardization of Disaster Criteria.

Title of Item: Strengthen Resilience of Communities to Typhoon-related

Strategic Goal 5b: To promote education, training and public awareness of typhoon-related disaster among the members

In 2013, DDPM in collaboration with Ministry of Education and other relevant agencies continued the implementation of the project on strengthening the capacity of teachers and school personnel on disaster risk reduction. The project also includes training to students especially in schools located in disaster-prone areas.

Title of Item: Improve capacity to generate and provide accurate, timely and understandable information on typhoon-related threats

Strategic Goal 6c: To enhance capacity of Members' typhoon-related observation and monitoring
Since 2006, DDPM has implemented a project called "Mr. Disaster Warning" to be a mechanism to save lives of the people from hazard such as landslide. This project provides training to volunteers in landslide disaster warning.

This project aims at creating disaster warning network in flashflood and mudslide prone village. "Mr. Disaster Warning" is the village volunteer who has been selected and trained to function as a vigilant, a forewarner and a coordinator. As the vigilant, he will keep the close watch on the development of the potential flood and mudslide and check the level of rainwater in the simple rain gauge installed in his village and then report to the village headman if there is any indication that these will be an emergency. Since the inception of the programme, approximately 23,858 villagers were trained and tasked as the "village – based disaster warning in their respective villages" DDPM made "Mr. Disaster Warning" manual and distribute to villages and agencies concerned.

1.3.4.5 Civil Defence Volunteers (CDVs):

CDVs play an important role in disaster management in Thailand on a voluntary basis. Authorized by the Civil Defense Act 1979 and MOI's Civil Defense Regulations 2005, Local governments can recruit local residents with age over 18 years to have 5-days trainings and then grant them the CDV status. Roles of CDVs can be found in disaster response, relief, recovery, prevention, mitigation and preparedness. In other words, all activities in disaster management have been involved by the volunteers. CDVs have been also engaged in general activities organized by government agencies at national, provincial and local level. At present, there are around 1,229,274 CDVs in the country (update data on 31 January 2014).

1.3.4.6 One Tambon One Search and Rescue Project (OTOS):

DDPM has recognized the immediate need to establish a range of search and rescue capacities at national, provincial and most importantly, local levels. Thus, DDPM has launched the "One tambon One Search and Rescue Team (OTOS) Programme" which will resulted in the establishment, training and logn-term maintenance of specially trained search and rescue team in every tambon community.

DDPM has incorporated various government agencies and NGO such as Department of Local Administration, Health Insurance Office, Office of Health Promotion and Support Fund, and Thai Red Cross, to achieve the following OTOS objectives;

- To ensure the safety of life, and the rapid and efficient search and rescue operation,
- To established efficient search and rescue team at every provinces, district and tambon,
- To enhance capacity and efficient search and rescue team through technical training and drilling,
- To provide fist-aid treatment and rapid transfer to the appropriate medical establishment.

At present, the data information on 31 January, 2014, OTOS programme has been implemented of training in 61 Provincial Administration Agency, 1,943 municipalities, 5,074 Sub-district Administration Agency and approximately 74,411 trainees are trained. It is also expected that here will be a SAR team (10 members) based in each tambon (7,078 tambons) throughout the country.

1.3.5 Activities of UNESCO/IOC

Mr Tony Elliott representative from Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) provided an update on the status of the Indian Ocean Tsunami Warning and Mitigation System (IOTWS). He reminded the Panel about the governance structure of the Intergovernmental Coordination Group (ICG) for the IOTWS and informed the Panel of the main policies relating to the dissemination of products from the Regional Tsunami Service Providers (RTSPs). He provided an update of the performance of the RTSPs of Australia, India and Indonesia in the period 1 November 2012 to 30 September 2013 against Performance Indicators approved by the ICG, noting that there had been only threeearthquakes greater than the M6.5 in the Indian Ocean, the threshold for issuing earthquake bulletins (Service Level 1).

Mr Elliott provided details about other main activities of the IOTWS in 2013, including a regional workshop on Standard Operating Procedures (SOPs) for tsunami warning and emergency response held in Jakarta in September. He provided a summary of the progress of two projects funded by the UN-ESCAP Trust Fund for Tsunami, Disaster and Climate Preparedness, in particular a project to help the development of national policy and technical guidelines to support tsunami exercises in Bangladesh, Myanmar and Timor Leste.

Mr Elliott gave details of the activities planned for 2014. He noted that another workshop on SOPs would be held in Hyderabad, India in June and that an ocean-wide IOWave14 exercise would be held in September or October. He stressed the value of ocean-wide exercises to test the readiness of the IOTWS from regional to national and local level and encouraged thePanel members to participate to the extent possible. He also noted that the 10th anniversary of the Indian Ocean Tsunami would occur on 26th December 2014 and informed the Panel that the ICG/IOTWS would be organizing events to commemorate the event.

He highlighted the role played by IOC-UNESCO in the global coordination of tsunami warning and mitigation systems and reported that the 7th meeting of the TOWS Working Group had been held in Paris in February. He also commented on the role of IOC UNESCO and JCOMM in sea level monitoring through the Global Sea Level Observing System (GLOSS) and provided an update on the global sea level station network, which can be accessed through www.ioc-sealevelmonitoring.org. He encouraged the Panel members to help densify the network and to share sea level data over the GTS to the extent possible,He welcomed the proposed installation of two new sea level stations in Bangladesh under the CIFDB project, and requested that data from these stations be made available to the international community via the GTS.

1.4 TRAINING

1.4.1 Bangladesh

Mr. Shamsuddin Ahmed, Deputy Director, participated in the “Operational Tropical Cyclone Forecasting at RSMC Tropical Cyclone” at India

Ms. Mahnaz Khan, Deputy Director, participated in the “WMO Regional Training Seminar for National Trainers of RA II and RA V”

Mossammat Ayesha Khatun, Deputy Director, participated in the “4th Project Meeting between BMD and Met no.”

Mr. Md. Azizur Rahman, Assistant Director, participated in the “Customization of Seasonal and Medium Range of Agricultural Weather Forecasts by RIMES”

Mr. Md. Asdur Rahman, Assistant Director, participated in the “Aeronautical Meteorology Services International Training Course”

Mr. Mohammad Sazzad Hossain, Senior Communication Engineer, participated in the “Ninth Post Graduate Course in Satellite Communications” India

Mr. Syed Abul Hasanat, Meteorologist, participated in the “Information and Communication Technologies for Meteorological Services”

Ms. Taslima Imam, Meteorologist, participated in the “Synergized standard Operating Procedures (SSOP) for Coastal Multi-Hazards Early Warning System”

1.4.2 India

WMO sponsored Tropical Cyclones Forecasters’ training was organinsed by RSMC, New Delhi during 1-12 April, 2013. Prartipants from Myanmar, Oman and Bangladesh participated in this training.

The training activities at RMTC Pune are as follows:

Human resource development has always been one of the prime thrust areas of the India Meteorological Department for capacity building and to keep pace with latest trends in various activities of the Department. The Meteorological Training Institute (MTI) of the India Meteorological Department (IMD) is always fulfilling this need by conducting following regular courses.

I- Regular Courses in general meteorology

S.No.	Departmental/Non Departmental courses	Duration	Training centres	Eligibility Criteria
1.	Advanced Met. Training Course (Non-Departmental)	1 Year	Pune	B.Sc*. (with Physics or Maths as main subject) /M.Sc./B.E./ B.Tech.
2.	Forecasters Training course	6 months	Pune	B.Sc. (with Physics or Math as main subject) and after successful completion of

				Intermediate Met. Training course
3.	Intermediate Training course including one month on the Job training.	3 months	Pune & Delhi centres.	B.Sc. (with Physics or Maths as main subject) after successful completion of Basic Met. Training course.
4.	Integrated Meteorological Training course.	4 months	Pune , Delhi, Chennai and Kolkata	Fresh recruited Scientific Asst.with B.Sc.(Phy., Math/ BE/B. Tech. qualification
5	LA's Modular Course	2 Months	Delhi, & Kolkota.	Departmental Met. Attendant who have passed SSC and working in same cadre for 5 years

II Familiarization training on tropical cyclones monitoring at RSMC New Delhi

One official each from Bangladesh, Oman and Myanmar had received familiarization training on tropical cyclones monitoring at RSMC New Delhi during 1-12 April, 2013.

III- Additional courses conducted on demand from users end:

1. BHUTAN MET. PERSONNEL TRAINING COURSE: A special training course was conducted at Pune for seven personnel from Bhutan Aviation Met. Services of the Civil Aviation Department of Bhutan, during the period from 15th October 2013 to 11th January, 2013.
2. A short term training course on maintenance of Surface Meteorological Instruments was conducted during August 2013 for two week.
3. A short term tailor-made training course was conducted during 2nd to 20th September, 2013 at IMD, New Delhi for the scientists from NCMRWF, Noida.
4. A training Workshop/Course on Doppler Weather Radar and its Utilisation in Weather Prediction was conducted at IMD Kolkata during 23rd to 27th September, 2013 for the officers from Indian Air Force; Indian Navy and IMD. Total 17 officers (7 from Indian Navy, 7 form IAF and 3 from IMD) participated in the course.
5. A short term training course in General Meteorology was conducted at Meteorological Training Institute (MTI), Pashan, Pune during 18th November to 7th December, 2013, for the officers from DRDO/IDST, Proof & Experimental Establishment, Chandipur; NCMRWF, Noida; INCOIS, Hyderabad; IITM, Pune & IMD. Total 18 officers (DRDO/IDST-4; NCMRWF-1, INCOIS-2, IITM-2 and IMD-9) participated in the course.

Training activities of Telecom Training Centre (TTC) during 2013

a. Telecommunication Training Centre (TTC) was established in New Delhi September, 1977 for imparting training in Meteorological Telecommunications. It is one of the international training centres in the field of meteorological telecommunication recognized by the World Meteorological Organisation (WMO).
b. The centre has lecture rooms and Lab equipped with all state of art facilities like multimedia projector and work station in LAN. WI-FI connectivity is also available in the lecture room & computer lab.
c. The centre provides facilities for conference/ Workshops arranged by various divisions of IMD.

d. Syllabi of various Meteorological Telecommunication courses were revised keeping in view of the provision of self study/ E-Learning at working place of trainees nominated for the courses.
e. The centre has so far imparted training to 1235 departmental personnel and 88 foreign personnel sponsored under various technical cooperation programmes such as ITEC, SAARC, Colombo Plan, UNDP and WMO.

The centre conducts the following courses:

S.N0.	Course	Duration
1.	Elementary Training Course in Met. Information System (Level-I)	4 months
2.	Intermediate Course in met. Information System (level- II)	4 months
3.	Advanced course in Met. Information System (level- III)	6 months
4.	Short term course for Mechanics/Radio-Mechanics	1 month
5.	Familiarisation Course in IT & Met. Telecommunication Technique	1 month
6.	Short term course in Fundamental of IT & PC applications	1 month afternoon only

IV- Future Plans:

1. Training Related with ongoing project:-

Under World Bank aided Hydrology Project Phase II, the following regular courses are being conducted by MTI, on demand from user end.

a) Basic Hydromet Observer's Course for Observers
b) Hydromet Supervisor Course for Asst/Section Engineers
c) Senior Level Refresher Course for Executive Engineers

The Phase II of this project is ending in May 2014 and approval for Phase III is awaited to prepare the training calendar for 2014 - 2015.

2 Approval for the project "Training in Operational Meteorology" is awaited. Once it is received, training calendar with respect to various programme s projected in that will be prepared for the next five year period.

3 To design and organise advanced refresher training course of duration ranging from 2-4 weeks for the meteorological personnel of developing/under developed countries in the RA-II region on different important topics like NWP, Tropical Cyclone, Aviation Meteorology, Agrimet, Sat. Met, DWR etc.

4 To upgrade the infrastructure of training institute & Trainees Hostel.

5 To revise the syllabus /Course contents of the different training courses

6 As an outreach programme, the centre has already proposed to install a new web portal as the main operating link between external world and the training establishment. This will provide access to the information like training particulars, course contents, lecture notes, distant learning materials, assignments, results, etc. to those interested.

7 E learning method in training programme is already introduced by MTI. Introduction of distance learning in the IMD's training programs in the form of provision of virtual class

room facilities has already been proposed in the IMD's XII FYP scheme. Under this proposal, provision is also there to share the digital content of the lectures in a broadcast mode between centres through internet based software.

8 At least three Refresher Courses are being conducted at this Institute per year; the themes for the same will be decided as per the requirement projected by the user agencies.

1.4.3 MALDIVES

- To build the capacity of MMS further and in accordance with the mandate and action plan, we urgently need to train our personnel. Coordination is required in Meteorology, Aviation, and Satellite Met, WRF/WAM, climate, tsunami propagation and storm-surge modeling.
- Funds are not available in 2014 regular budget for training programs.

Short-term training & workshops attended in 2013

- The Pacific Island Climate Service Forum, Fiji, 22 - 24 Jan.
- JMA/WMO training workshop on calibration & maintenance of Meteorological instruments in RA-II", Japan, 19 – 22 Feb.
- MJO Data and Analysis Workshop, Hawaii / USA, 4 – 8 Mar.
- International workshop on climate data requirements & applications, China, 4 – 8 Mar.
- Training on climate change & disaster preparation", Seoul / Korea, 27 Mar -18 Apr.
- Regional Training workshop on Severe Weather Forecasting and Warning Services, Macao/ China, 8 – 19 April.
- 4th session of the south Asian climate outlook forum (SASCOF-4), Nepal, 15 – 19 April.
- Workshop on SSOP project, Thailand, 8 – 9 May.
- Training course on Radar Meteorology for Developing countries, China, 17 May – 6 June.
- Training Course on 3DVAR Data Assimilation in WRF Model, SMRC, Bangladesh, 19 – 30 May.
- Workshop on application of science & technology in earthquake and risk mitigation for urban agglomerate in south Asia, India, 24 - 25 May.
- WMO Aviation Training Seminar, UK, 30 Sep – 4 Oct.
- International training workshop on Aviation Meteorology for forecasters, Doha 3 - 7 Nov.
- Integrated Workshop -WMO/ESCAP Panel on Tropical Cyclones, Bangkok 27-29 Nov.
- Attachment of storm surge experts with Indian Institute of Technology (IIT-Delhi) India 9-21 Dec 2013.

1.4.4 Oman

The 3rd Training Course on WMO SDS-WAS' has been held at the Sultan Qaboos University in Muscat, Oman, 8-12 December 2013. Also, a 'McIDAS-V Tutorial with focus on atmospheric dust cases' was held 15-16 December 2013 at the same venue.The Center of Excellence in Oman also hosted the 10th session of satellite training for Middle East countries in cooperation with Eumetsat.

Other important Workshops, Seminars, Research and Training Courses attended by the Met personnel during the year 2013 were as follows.

Workshop/Seminar/Training/Research Course	Country	No. of Persons
PhD. In Climate change	UK	1
PhD. In wind power	Oman	1
EUMETSAT Satellite Application Course	Oman	15
Doppler Radar training	Germany/South Africa	36
Tsunami	USA	10
numerical weather forecasts	UK	3
Forecaster Training	Qatar	16
Observer Training	Qatar	48
Visual Weather training	Ireland	2

1.4.5 Thailand

In 2013, Thai Meteorological Department (TMD) sent officials to attend meeting/conference under PTC working groups as shown below:

- PTC Integrated Workshop on Developing Synergy among PTC Working Groups and the finalization of Annual Operating Plan (AOP) were organized at UNCC, Bangkok, Thailand from 27–29 November 2013. Participants were representatives from three focal points under 3 PTC Working Groups (WGs), namely;
- Working Group on Meteorology (WG-M) - Mr. Maytee Mahayosananta, Director of Central Weather Forecast Division, Weather Forecast Bureau, Thai Meteorological Department (TMD) Working Group on Hydrology (WG-H) - Mr. Suraphun Inkaew, Chieft of Water Information and Flood Forecasting, and Mrs.Supinda Wattanakarn, Senior Professional Hydrologist, Hydrology Division, Royal Irrigation Department (RID), Working Group on Disaster Risk Reduction (WG-DRR) - Mr. Chainarong Vasanasomsithi, Director of Research and International Cooperation Bureau, Department of Disaster Prevention and Mitigation (DDPM)
- Training on Operational Tropical Cyclone Forecasting was held at RSMC, New Delhi, India from 17 to 28 February 2014
- Mr. Raksapol Porchit, a Meteorologist, from Upper Northeast Meteorological Center attended the training. Furthermore, Thai Meteorological Department (TMD) as a host organized two training courses in Thailand. The training courses were:

In 2013, Thai Meteorological Department (TMD) hosted SSOP Workshop in Bangkok.

Thai Meteorological Department (TMD) in collaborated with ESCAP/WMO Typhoon Committee (TC) and WMO/ESCAP Panel on Tropical Cyclones for the Bay of Bengal & the Arabian Sea (PTC) organized the Workshop on Standard Operating Procedures under the project Synergized Standard Operating Procedures (SSOP) for Coastal Multi-hazards Early Warning System at UNESCAP, Bangkok from 8 to 9 May 2013. The workshop aimed to promote the coastal community resilience to coastal multi-hazards through setting up standard

Operating procedures for effective Multi-hazards Early Warning System (EWS) and improving the policy and institutional arrangements at national and community levels.

The workshop was conducted successfully with active participation of 45 participants from TC and PTC members including representatives from WMO, ESCAP, TCS, PTC secretariat and international organizations partners under the SSOP Project.

Thai Meteorological Department (TMD) TMD conducted two training courses for Myanmar under the Technical Cooperation between Thai - Myanmar in 2013

After tropical cyclone Nargis hit Myanmar in 2008, Government of Thailand has been continuously extending technical cooperation to Myanmar in different areas. Among those, a program aimed to enhance capacity on meteorology, warning system and recovery of Irrawaddy and Yangon from the effects of cyclone Nargis. A number of training courses on meteorology, weather forecasting and other related fields was provided to Myanmar during the past years. In 2011, Government of Thailand provided one Upper Air Observation System to Myanmar under the above program. Consequently, the Thai Meteorological Department (TMD) in collaboration with the Thailand International Development Cooperation Agency (TICA) conducted two training courses at TMD in Bangkok for Myanmar officials in 2013 as shown below:

- Training course on Use/Maintenance of Upper Air Observation System for Technicians was organized for 4 weeks from 24 June to 19 July 2013.
- Training course on the Upper-Air and Sounding Observation Analysis for meteorologists was organized for 2 weeks from 5 to 16 August 2013.

Each training course was attended by 5 participants from the Department of Meteorology and Hydrology (DMH) of Myanmar. The purposes were to provide knowledge and skill for Myanmar technicians/meteorological officers to be able to use and carry out the maintenance of the Upper Air Observation System, provide data analysis from Upper-Air and Sounding Observation, and introduce weather forecasting of TMD

1.4.6 Activities of WMO

The ESCAP Panel on Tropical Cyclones (Panel) recalled the decisions of the Sixteenth World Meteorological Congress that nominated high priority areas such as Disaster Risk Reduction, approval of strategies such as the Service Delivery Strategy and Capacity Development Strategy to assist Members to structure and deliver services and the Congress's call for the WMO Technical Commissions to develop competencies in their fields of expertise that provide a minimum common set of standards.

The Panel further recalled that during its previous session competencies for tropical cyclone forecasters in this region was discussed. Noting that the safety and welfare of many of the members was heavily influenced by weather and oceanographic phenomena associated with tropical cyclones the Panel decided to set up a working group to propose a set of tropical cyclone forecaster competencies for the next session of the Panel. The Panel requested that the working group circulate the draft competencies two months prior to the session to allow members time to consider them for adoption during the session. Noting the existing work already undertaken in this area by WMO Members such as the Australian Bureau of

Meteorology, the Panel suggested that the working group review these competencies and the output of the other Tropical Cyclone committees as a first step in drafting competencies for personnel involved in forecasting tropical cyclones in this region.

In taking this step the Panel noted that such an approach would assist members:

- Provide a more uniform approach to forecasting tropical cyclones;
- Contribute to improving the consistency of forecasts within each member and between members;
- Assist in allocating the limited regional education and training resources to the key regional priority areas;
- Allow training institutes such as the WMO Regional Training Centre in India and the WMO/CGMS Virtual Laboratory for Satellite Meteorology to coordinate their regional teaching and training activities and contribute towards a common structure that will allow the region to better meet its agreed goals and targets;
- Assist members to build a case for financial support from Governments to enable the service to meet, if not exceed, the minimum regional “standards”;
- Contribute to minimizing risks associated with tropical cyclone forecasting failures;
- Assist members show that their services had met “duty of care” requirements by having staff competent to at least the regional agreed minimum standards;
- Contribute to regional back up activities; and,
- Build upon competency activities in the general forecasting, marine forecasting and aeronautical meteorological services areas.

The Panel acknowledged that whilst there were many advantages to developing and implementing a common competency approach each member would need to deal with issues such as gaining staff support for this approach, juggling tight budgets and rosters to provide time for training and assessment, dealing with staff who were assessed “as not yet competent” and in some cases gaining further resources from governments to allow them to meet the minimum standards.

In parallel with the development of the draft competencies the Panel requested its members to provide the working group with the information outlined in the annex to this paragraph to assist the working group scope out the size and breadth of the regional education and training requirements. This information could also assist groups such as the WMO Regional Training Centre in focusing their limited education and training resources to help achieve the best regional outcome.

The Panel noted that the WMO Secretariat continued to support training activities in the member countries by advertising the training events and providing partial support to participants. WMO Regional Training Centre (RTC) in Nanjing organized an international training course on “Tropical Cyclone Forecast”, from 14 to 25 October 2013, in Nanjing, China. The course had 14 participants from 10 countries. The contents included: Tropical cyclone structure, cyclogenesis, intensity change and motion, tropical cyclone and climate change, track and structure forecasts of tropical cyclones, seasonal forecasts of tropical cyclone activity, application of satellite data and radar data in early warning of tropical cyclones, societal and economic impacts of tropical cyclones and disaster mitigation and a study tour to the 5th Shanghai International Disaster Reduction and Security Show (SIDRS 2013).

The Panel noted that through the US Voluntary Cooperation Programme funds, and with WMO ETR input, the COMET programme has developed the Tropical Synoptic Meteorology Curriculum Package. This is a university-level, online meteorology course package freely available to interested institutions. The course addresses the synoptic and mesoscale meteorology requirements for the WMO Basic Instruction Package for Meteorology (BIP-M), but with an emphasis on the tropics to provide focus for those working or planning to work in tropical regions. The course package utilizes existing and newly developed resources, including the online textbook, Introduction to Tropical Meteorology (http://www.meted.ucar.edu/tropical/textbook_2nd_edition). It includes an instructor's guide, model syllabus with learning objectives, free online instructional resources, introductory slides for faculty use, case examples, questions for review or discussion, student assignments, quizzes, learning activities, and guidance for online course delivery. At least 100 institutions have examined the package for potential utilization of its contents or as the basis for a semester-length course. A first offering was made by the University of the South Pacific in late 2013 to 8 post-graduate students. A second offering is beginning in March, 2014. The University of Bergen/Bjerknes Center in Norway also used some of the materials in a tropical meteorology course offered face to face.

1.5 RESEARCH

1.5.1 India

Current Status

Research works pertaining to statistical, climatological and dynamical aspects of Tropical Cyclones of North Indian Ocean are undertaken regularly. Some recent efforts are listed below:

- **Project TCRAIN**
- A Tropical Cyclone Rainfall Analytical tool for the North Indian Ocean – **TCRAIN** that depicts rainfall characteristics of 43 Tropical Cyclones over North Indian Ocean during the period 2000-2010 was recently developed based on TRMM data by CWRC, RMC Chennai and the application is hosted in the web at the URL: www.cwrcimdchennaitcrain.in. The necessary software for generation of percentage frequency distribution of rain rates, azimuthally averaged radial profiles of rain rates and quadrant-wise mean rain rates around a cyclone centre and with respect to the direction of movement of the cyclone using 3hrly TRMM data was developed in-house. The products are generated for different stages of intensity of the system viz., (i) Depression, (ii) Cyclonic Storm and (iii) Severe Cyclonic Storm and above during its growth as well as decay for all the 43 cyclones would serve as valuable inputs for research on rainfall associated with Tropical Cyclones of the North Indian Ocean. The web page is proposed to be enhanced and updated shortly.
- Brainstorming meet on '***Research on Tropical Cyclones over the Indian Seas-RoCoIS-2013***' was organized by CWRC, RMC Chennai on 20th September 2013 at Chennai. Based on the recommendations of the meet, CWRC proposes to initiate and co-ordinate action for a multi-institutional a **Tropical Cyclone Research Programme** in the priority areas as identified in the meet.
- A pamphlet, *Memoirs of Cyclone Warning Research Centre*, was prepared to commemorate 40 years of tropical cyclone research activity at Cyclone Warning Research Centre (1972-2013), RMC Chennai.

On-going Projects

1.5.1.1 FDP on landfalling cyclones over the Bay of Bengal

Cyclone Warning Research Centre (CWRC, Regional Meteorological Centre, Chennai is functioning as the Field Operational Centre (FOC) for the FDP(Cyclones) 2013 campaign w.e.f 15th October. FOC's report on the status of observational data received was sent to the National Operations Centre (NOC), IMD New Delhi daily. Daily observational data are archived as per the FDP implementation plan.

1.5.1.2 *Cyclone eAtlas-IMD*

Cyclone eAtlas – IMD, a software for generation of tracks and statistics of cyclones and depressions over the North Indian Ocean was brought out in CD form by IMD during 2008 and subsequently hosted in the web at the URL: www.rmcchennaieatlas.tn.nic.in. The database for the software is updated and uploaded in the web every year. It is also sent to all buyers of the CD every year. During the year 2013, 6 CDs were supplied to Indian buyers and 1 CD to a German buyer.

1.5.1.3 Statistical prediction of seasonal cyclonic activity over the North Indian Ocean

An experimental outlook on the seasonal cyclonic activity over the North Indian Ocean for the period October-December 2013 was prepared on real-time basis (during September 2013). The prediction was validated at the end of the season. However, efforts are on for improving the prediction model.

1.5.1.4 TC Rain Project

A TC rain project has been completed at Chennai. It helps to find out rainfall distribution due to cyclones over the Sea. Further work is going on to improve the project.

1.5.1.5 Coastal Inundation modeling

Coastal inundation model developed by INCOIS Hyderabad, has been utilized in 2013 to issue experimental coastal inundation forecast. However, work is in progress to make it operational and improve the model by including the hydrological component.

Future Plan

- A project on development of a Tropical Cyclone Data Portal (**TCDaP**) for the North Indian Ocean is being initiated at CWRC, RMC Chennai.
- A project on development and execution of a software tool **TCWIND** - for depicting winds associated with 43 Tropical Cyclones over North Indian Ocean during 2000-2010 (time series of maximum sustained wind speed, vertical wind shear, tangential and radial velocities) based on IMD's best track data and 6-hrly NCEP FNL data is in progress.
- Research on short-lived, suddenly intensifying cyclonic disturbances near the panel member countries' coasts will be undertaken.

1.5.1.6 Papers published in Mausam

1. Outcomes and challenges of Forecast Demonstration Project (FDP) on landfalling cyclones over the Bay of Bengal by M. MOHAPATRA, D. R. SIKKA, B. K. BANDYOPADHYAY and AJIT TYAGI
2. Large-scale characteristics of rapidly intensifying tropical cyclones over the Bay of Bengal and a Rapid Intensification (RI) index by S. D. KOTAL and S. K. ROY BHOWMIK.
3. Comparison of best track parameters of RSMC, New Delhi with satellite estimates over north Indian Ocean by SUMAN GOYAL, M. MOHAPATRA* and A. K. SHARMA.
4. Barotropic energetics analysis of tropical cyclone Khai Muk by S. BALACHANDRAN
5. A case study for cyclone 'Aila' for forecasting rainfall using satellite derived rain rate data by HABIBUR RAHAMAN BISWAS, P. K. KUNDU* and D. PRADHAN
6. Observational aspects including weather radar for tropical cyclone monitoring by S. RAGHAVAN
7. Recent advances in observational support from space-based systems for tropical cyclones by R. C. Bhatia and A. K. Sharma
8. Estimation of intensity of tropical cyclone over Bay of Bengal using microwave imagery by – T. N. Jha, M. Mohapatra and B. K. Bandyopadhyay
9. A study on high resolution mesoscale modeling systems for simulation of tropical cyclones over the Bay of Bengal by U. C. Mohanty, Krishna K. Osuri and Sujata Pattanayak
10. Impact of cyclone bogusing and regional assimilation on tropical cyclone track and intensity predictions by Manjusha Chourasia, R. G. Ashrit and John P. George.
11. Tropical cyclone Genesis Potential Parameter (GPP) and it's application over the north Indian sea by S. D. Kotal and S. K. Bhattacharya
12. A preliminary study about the prospects of extended range forecast of tropical cyclogenesis over the north Indian Ocean during 2010 post-monsoon season by D. R. Pattanaik, M. Mohapatra, B. Mukhopadhyay and Ajit Tyagi
13. Ocean atmospheric coupled model to estimate energy and path of cyclone near the coast by Ramkrishna Datta
14. Numerical simulation of storm surge associated with severe cyclonic storms in the Bay of Bengal during 2008-11 by S. K. Dube, Jismy Poulose and A. D. Rao
15. Operational weather forecasting using data from Automatic Weather Stations and other modern observing systems - Case study of tropical cyclone Jal 2010 by B. AMUDHA and Y. E. A. RAJ

1.5.1.7 Workshop/Seminar/lectures attended/organised in India

1. Brainstorming meet on '***Research on Tropical Cyclones over the Indian Seas-RoCoIS-2013***' was organized by CWRC, RMC Chennai on 20th September 2013 at Chennai. Based on the recommendations of the meet, CWRC proposes to initiate and co-ordinate action for a multi-institutional a **Tropical Cyclone Research Programme** in the priority areas as identified in the meet.
2. **SAARC Seminar on high impact weather events- Dec, 2013**
3. Dr.S.Balachandran, Scientist-E, participated in the **SAARC** seminar on **High Impact Weather Events and their prediction over SAARC region** held at New Delhi during 2-4 Dec 2013 and presented a paper titled "*Eddy Angular Momentum Fluxes in relation*

with Intensity Changes of Tropical Cyclones JAL and THANE" by S.Balachandran and B.Geetha.

4. National Workshop on storm surge and coastal Inundation : New Delhi, February 2013
5. SAARC Seminar on high impact weather events- Dec, 2013.
6. 20 Trainees of Cyclone Disaster Management Course conducted by YASHADA visited on 4th April 2013. Smt. J. C. Natu, A.M.II made a presentation, discussing the cyclone warning services rendered by IMD.
7. Dr. Medha Khole, DDGM(WF) delivered a talk on "Watching the weather to Protect life and Property" on the occasion of WMO Day at All India Radio, Pune.
8. Dr. Medha Khole, DDGM(WF) delivered a lecture on "The Monsoon and its forecasting" at training course on 'Agro meteorology towards better advisories for serving end users requirements' organized by Offices of Agricultural Meteorology, Pune on 6th Dec 2013.
9. Dr.S.Balachandran, Scientist-E participated in the international conference on **Impact of Climate Change on Food, Energy and Environment (ICCFEE-2013)** organised by Satyabhama University, Chennai and delivered an invited talk on "***Variability of Tropical Cyclone activity over North Indian Ocean in the context of Climate Change scenario***" on 04th July 2013.

1.5.1.8 Workshop/Seminar/lectures attended outside India

Dr. A. Kashyapi, Sc. 'E' attended a workshop on "Impact pathways for Climate Change, Agriculture and Food Security programme in South Asia' at Dhaka, Bangladesh from 26 to 28 February, 2013 and presented paper entitled "Climate change scenario in India-Impact on Agriculture and Food Security".

Dr. Prakash Khare, Sc. 'D' visited Bogor, Indonesia to participate in the WMO Regional Training Seminar for National Trainers of RA-II and RA-V from 26 February to 7 March, 2013.

Shri B. K. Bandyopadhyay, Sc. 'F' visited Colombo, Sri Lanka to participate in the 40th Session of WMO/ESCAP Panel on Tropical Cyclones from 25 February to 1 March, 2013.

Dr. L. S. Rathore, DGM attended a "High Level Meeting on National Drought Policy (HMNDP)" during 11 - 15, March 2013 at Geneva.

Dr. S. D. Attri, DDGM (O) visited Geneva, Switzerland from 18 to 20 March, 2013 to participate in the Symposium on Global Atmosphere Watch, GAW 2013. He presented his paper on "Environmental Monitoring Activities in India"

Dr. D. P. Dubey, Sc. 'E', participated in the Meeting of the WMO Forum: Social and Economic at WMO headquarters, Geneva Switzerland from 8-11 April, 2013.

Dr. M. Mohapatra, Sc. E delivered lectures in the Severe Weather Forecast Demonstration Project (SWFDP)- Regional Training Workshop for southeast Asia and South Asia held in Macau, China during 8-13 April, 2013.

Shri V. K. Soni, Sc. 'D' participated in 24 GAWTEC training Course conducted at Hohenpeissenberg/Zugsptize, Germany from 14-27 April, 2013.

Dr. A. K. Srivastava, Sc. 'E' and **Dr. D. S. Pai,** Sc. 'E' attended the 4th Meet of South Asian Climate Outlook Forum (SASCOF- 4) from 15-19 April, 2013 held at Kathmandu, Nepal.

Dr. N. Chattopadhyay, Head, Agrimet Division attended the meeting of Commission for Agricultural Meteorology (CAgM) Expert Team on Strengthening Operational Agrometeorological Services at National Meteorological Administrative Headquarter, Bucharest, Romania on 25-26 April, 2013.

Dr. (Mrs.) Surinder Kaur, Sc. ‘F’, IMD, New Delhi attended the 2nd meeting of Joint Working Group on cooperation in field of Water Management at Canbrra Australia from 29 April to 3 May, 2013.

Dr. S. R. Ramanan, Scientist 'E' attended a workshop on “Synergized Standard Operating Procedures for coastal Multi Hazards Early Warning System” in Bangkok, Thailand on 8-9 May, 2013.

Dr. L. S. Rathore, D.G. IMD attended the seventh session of the RA II Management Group (MG-7) was held at the WMO Headquarters in Geneva on Sunday, 12 May, 2013.

Dr. S. D. Attri, DDGM (O) attended Indo-Russian Sub group meeting on meteorology during 18 May 2013 alongwith DG, IMD at Geneva.

Shri N. K. Pangasa, Scientist ‘F’, IISD, New Delhi attended 18 meeting of SADISOPG at ICAO Western & Central African Office Dakar, Senegal from 29-31 May, 2013.

Mr. M. K. Purohit, participated in the AWCI (Asian Water Cycle Initiative) training course on Improved Bias correction and downscaling techniques for climate change assessment including the drought indices held in Tokyo University, Tokyo during 18-20 June 2013 under APN (Asian Pacific Network).

Dr. D. R. Pattanaik, Scientist 'D' participated in Workshop on Climate Services for farmers at Nairobi, Kenya during 10-14 June 2013.

Dr. Y. E. A. Raj, DDGM, RMC Chennai participated in the workshop on “Sustaining National Meteorological Services – Strengthening WMO Regional and Global Centres” held at University of Mary Land and made a presentation on “Challenges in Severe Weather Forecasting– Role of Regional Specialized Meteorological Centre & what NMS need from Regional and Global Centres during 18-20 June.

Dr. L. S. Rathore, DGM and Dr. S. th D. Attri, DDGM(O) attended the 65th Session of the Executive Council (EC-65) of the WMO held during 15-23 May 2013 in Geneva, Switzerland.

Future Plans:

- Brainstorming workshop to be conducted in March-2014 on cyclonic activity over BOB during 2013
- Interactive Workshop in INCOIS to be held in next financial year
- WMO Training for cyclone forecasters from Panel countries and CWC/ACWC : February-2014

1.5.2 Activities of WMO

The World Weather Open Science Conference (WWOSC) organized by the WMO World Weather Research Programme (WWRP) will be held in Montreal, Canada from 16 to 21 August 2014. The Conference aims to review the state of knowledge in weather and weather-prediction science, related social and applied sciences, and user communities. WWOSC will explore the applications of weather prediction to the natural environment and their relevance and use in society, and encourage the next generation of research scientists to contribute to advancing all aspects of weather science. WWOSC will also enhance the ability of scientists and practitioners to bridge and communicate across boundaries between disciplines and among research scientists, forecasters, service providers, and users. This ground-breaking Conference will bring together the entire weather science and user communities for the first time to review the state-of-the-art and map out the scientific frontiers for the next decade and more. Members of the Tropical Cyclones Panel are encouraged to actively participate in this very important Conference for weather science and its benefits to society which is increasingly becoming extremely vulnerable to weather-related impacts.

Currently underway are two organized projects on tropical cyclones namely:

a) North Western Pacific Tropical Cyclone Ensemble Forecast Project (NWP-TCEFP) for Typhoon Committee members covering the period 2010 to 2015 (Lead: Japan Meteorological Agency);
b) Typhoon Landfall Forecast Demonstration Project (TLFDP) covering the period 2010 to 2015 (Lead: Eastern China Regional Meteorological Center/CMA).

The NWP-TCEFP is a collaborative effort between WMO and the Typhoon Committee. Its aim is to explore the utility of ensemble forecast products through THORPEX interactive Grand Global Ensemble (TIGGE) and, thus, promote application of the products to the operational forecasting of tropical cyclones. TLFDP is a collaborative effort with the NWP-TCEFP which had been extended to 2015 to include studies on tropical cyclone genesis. It is envisioned for both projects to be instrumental in transferring the recent research advances to operational forecast centers in NMHSs, especially those which have been affected by the recent increase in the severity of tropical cyclone events.

WWRP in collaboration with the Tropical Cyclone Programme (TCP) is organizing a Workshop on High-Impact Weather Research, tentatively, to be held in Beijing, China in October this year. The overarching objective of the workshop is to improve our understanding of high impact weather events and its predictability. A better understanding of high impact weather events such as heavy rainfall, severe thunderstorms, typhoons, etc., leads to more accurate forecasts and better guidance for risk managers, both aspects considered critical to mitigate the adverse impacts of these weather hazards.

The 8th International Workshop on Tropical Cyclones (IWTC-VIII) and the 3rd International Workshop on Tropical Cyclone Landfall Processes will be held in Jeju, Republic of Korea from 2 to10 December 2014. The two workshops are being organized by WWRP in close collaboration with TCP. The Panel on Tropical Cyclones is represented by Dr M. Mohapatra (India) in the International Organizing Committee for IWTC-VIII. Members of the Panel are urged to actively participate in these Workshops. Operational and research meteorologists from Panel Members who would not require WMO support to participate in the IWTC-VIII should, in a timely manner, inform Dr Mohapatra of their intent to attend the said workshop.

Panel News

During 2013, two publications of PTC newsletter “Panel News” were scheduled. However, owing to non-availability of timely input/material from the Panel Members only one (01) issue of the “Panel News” No 35 was published and the same was distributed among PTC Members, WMO, ESCAP and other concerned. The electronic version of the issue has also been made available on the PTC website on the web link: http://www.ptc-wmoescap.org/newsLetters.htm, while the Panel News No. 36 is at printing stage. The Panel therefore, requested the Members to provide their contributions in the form of news material related to development activities, science news, training workshops, research reports etc. in their respective countries to PTC Secretariat through their Panel News Correspondents so that next issues of the Panel News can be published timely. The PTC Secretariat requested the Panel Member countries to carefully review the current Panel News issue, and send their views/comments to PTC Secretariat for further improving the quality of the Panel News.

1.6 Publication

1.6.1 India

- 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
- Annual Report of Cyclone Warning Division, IMD and MoES
- News Letters : IMD, MoES, SMRC
- Preliminary reports of cyclonic disturbances
- Handbook on cyclone warning has been modified

❖ Publication in reviewed Journals and Books. Special Issue of Mausam on Proceedings of BOBTEX has been published

❖ A book has been released on the proceedings of International Conference, IOTCCC-2013

❖ Publication of a book on the proceeding of SAARC Seminar on 'High Impact Weather Event over the SAARC region'

❖ Report on pre-monsson season 2013 Thunderstorms over India uner SMRC STORM Project was published.

❖ Cyclone SOP-2013 has been released.

1.7. REVIEW OF THE TROPICAL CYCLONE OPERATIONAL PLAN

The Panel designated Mr M Mohapatra as the new rapporteur of Tropical Cyclone Operational Plan (TCOP) from this year.

The Panel reviewed and updated the List of Important Addresses and Telephone Numbers Connected with Tropical Cyclone Warning in the Panel Countries (ANNEX V-A-1) which was re-established by Mr. B. K. Bandayopadhyay, rapporteur of Tropical Cyclone Operational Plan (TCOP) in 2013, with the support of the PTC Secretariat and in response to the recommendation of the Panel made at the 40th session in Sri Lanka.

The Panel requested Mr Mohapatra to update other sections of the TCOP to produce its 2014 version as early as possible. To this end, the Panel urged all the Members to make a careful review of TCOP and inform the PTC Secretariat of the updates/additions/amendments, if any, before the end of March 2014.

The Panel continued to note that non-Members of the Panel in the RSMC New Delhi's area of responsibility, affected by tropical cyclones particularly Yemen and Somalia, have confronted the threat of cyclones recently. It was informed by WMO Secretariat that some channels to contact these countries had been found on case-by-case basis. In view of better preparedness in those vulnerable countries, the Panel requested the WMO Secretariat to continue to try to establish necessary communication means for the RSMC advisories to be timely communicated to them.

1.8. PTC SECRETARIAT

Secretary of PTC offered his thanks to the Panel on the confidence that Panel imposed on him and Pakistan with regards to the hosting of the PTC Secretariat.

The Panel was briefed by Mr. Arif Mahmood on the activities of PTC Secretariat during the intersessional period. The Panel expressed its satisfaction with the work of the PTC Secretariat. The summary of the activities of PTC Secretariat is given in Chapter-IV.

The PTC Secretariat provided the Panel with a detailed breakdown of its expenses incurred during the Intersessional period (see **Appendix V**). Keeping in view some savings, PTC Secretariat requested the Panel for provision of US$ 4,000 for its expenses during the year 2014-2015.

1.9 SUPPORT FOR THE PANEL'S PROGRAMME

The Panel was informed of the technical cooperation activities of WMO in support of the programmes of the Panel carried out in 2013, including the WMO Voluntary Cooperation Programme (VCP), and expressed its appreciation to WMO, ESCAP and collaborating partners for providing assistance to Members of the Panel.

The Panel took note of the presentation made by the Secretary of Typhoon Committee, Mr Olavo Rasquinho, on the status and latest development of the project Synergized Standard Operating Procedures (SSOP) for Coastal Multi-hazards Early Warning System, funded by the ESCAP Trust Fund for Disaster and Climate Preparedness for the Indian Ocean and Southeast Asian Countries and encourged Members for participation and success of this project. The Panel Members are encourged to collaborate with SSOP Project, in particular assisting the drafting of the Manual on SSOP and in the training workshop to be held in WMO RTC Nanjing tentatively in June 2014.

Panel on Tropical Cyclones Trust Fund (PTCTF)

The Panel reaffirmed that the Panel on Tropical Cyclones Trust Fund (PTCTF) should be used for achieving self-reliance of the Panel and thus be used not only for the provision of institutional support but also as funding support to the representatives of the Panel Members attending training events and conferences.

The Panel continued to consider the increase of its membership for enhancement of its activities. The Panel was aware that such countries in this region as Iran, Saudi Arabia, UAE and Bhutan are interested in the Panel's activities. It therefore requested the WMO Secretariat to approach those countries and encourage them to become the Member of the Panel.

A detailed financial report of the Trust Fund as of 31 December 2013 was submitted by WMO to the Panel (see **Appendix V)**

The Panel endorsed the use of the Trust Fund for 2014 for the following specific purpose:

1. Support for the attachment training at RSMC New Delhi for per diem of the participants (US$ 6,000)
2. Support for the attachment training at IIT Delhi for per diem of the participants (US$ 4,000)
3. Support to PTC Secretariat for its operating expenses including those for printing Panel News and running PTC-website. (US$ 4,000)
4. Support for participation of PTC in the 10th Session of ICG/IOTWS (US$3,000)
5. Support for participation of PTC in the ESCAP Commission (US$3,000)

Considering the strict budget situation of the PTCTF, the Panel requested the Secretariats of PTC, WMO and ESCAP for mobilizing resources for a adequate funding for the

Integrated Workshop. Any other emergency expenditure that can be justified for the use of the PTCTF requires the concurrence of both the Secretary of PTC and the Chairman of the Panel on Tropical Cyclones.

1.10 SCIENTIFIC LECTURES

The Panel devoted a session for presentation of scientific lectures. The list of all the presentations is as follows:

- Monitoring, Prediction and Warning Services of Very Severe Cyclonic Storm "Phailin" Dr. M Mohapatra (India)
- Case Studies of two Significant Dust Storms that Affected Oman: Synoptic and Mesoscale Based Dust Storms
  - Mr Khalid Khamis Saif ALJAHWARI (Oman)
- Challenges to Innovative Flood Risk Management
  - Mr. Badri Bhakta Sheathe (ICHARM)
- A Brief Introduction to Activities under WMO CAS WGTMR
  - Dr Yinglong XU on behalf of Yihong Duan (China)
- ADPC Involvement in Enhancing the Capacities of NHMSs in the Region
  - Mr. (ADPC) on behalf of Dr. Senaka

The Panel expressed its deep appreciation to the above lecturers for their informative and excellent presentations. PPT files of the presentations will be available on the PTC Website.

1.11 DATE AND PLACE OF THE FORTY-SECOND SESSION

Considering the common objectives and scope for exchange of information and sharing of knowledge with respect to monitoring, prediction and early warning services, the Typhoon Committee as well as the Panel on Tropical Cyclones felt the need for a possible joint session in their previous year meeting. Consequently, the Panel noted that the Typhoon Committee in its 46th session had decided to organize a joint session with PTC in ESCAP in 2015 subject to decision by PTC. The Panel discussed possibility to hold a joint session with Typhoon Committee in 2015, and agreed in principal to have the joint session, tentatively in early March 2015. The UN-ESCAP expressed its willingness to host this joint session in UN Conference Centre, Bangkok. However, there is need to chalk out in details about the organization of the programme, agenda, objectives and expected outcomes. The Secretary PTC and Secretary of the Typhoon Committee may consult with the chairman of PTC and TC and the Members as well as WMO, UN-ESCAP and take appropriate action in this regards.

1.12 ADOPTION OF THE REPORT

The report of the forty-first session was adopted at 16:00 hours on Thursday, 6 March 2014.

1.13 CLOSURE OF THE SESSION

The Panel expressed its sincere appreciation to the Government of the People's Republic of Bangladesh for hosting the Session and for providing the excellent facilities and other arrangements and its warm hospitality. The Panel also expressed its deep appreciation to Mr Md. Shah Alam, Chairperson of the Panel, Mr Ali Shareef Vice-chairperson of the Panel as well as Chairperson of the Drafting Committee, for their successful conduct of the session. The Panel also wished to express its gratitude to the Local Organizing Committee led by Mr. Shamsuddin Ahmed for their hard work in organizing the session, assistance provided to the participants and producing a session report.

The forty-first session of the Panel was concluded at 1700 hours on Thursday, 6 March 2014.

CHAPTER-II

(A) CYCLONIC ACTIVITIES OVER NORTH INDIAN OCEAN DURING 2013.

During the year 2013, 10 cyclonic disturbances developed over north Indian Ocean including one deep depression over Arabian Sea, one land depression and 8 cyclonic disturbances over Bay of Bengal. Out of 8 disturbances in Bay of Bengal, 3 intensified into Very Severe Cyclonic Storm (VSCS), one each into a Severe Cyclonic Storm (SCS) & Cyclonic Storm (CS), and three upto depression. Considering season-wise distribution, out of 10 disturbances, 2 developed during pre-Monsoon, 2 during monsoon and 6 during post-monsoon season. The track of cyclonic disturbances formed over the north Indian ocean during the year are shown in Fig. 2.1

Salient features of cyclonic disturbances during 2013 are given below.

i. There were five cyclones over the Bay of Bengal and no cyclone over the Arabian Sea against the long period average of 5.5 per year over the entire north Indian Ocean including Bay of Bengal and Arabian Sea.
ii. Five cyclones developed over the Bay of Bengal for the first time after 1987. Considering north Indian Ocean as a whole, five cyclones occurred in 2010.
iii. Four severe cyclonic storms developed over Bay of Bengal for the first time since 1982. Considering north Indian Ocean as a whole, four such severe cyclonic storms occurred in 2010.
iv. Three very severe cyclonic storms occurred over north Indian Ocean for the first time since 1999.
v. Post-monsoon season was very active, especially over the Bay of Bengal with the formation of three very severe cyclonic storms and one severe cyclonic storm.
vi. Though there were five cyclones, only one cyclone (Phailin) crossed coast as very severe cyclonic storm and other two (Viyaru and Helen) as cyclonic storms. Other two cyclones (Lehar and Madi) crossed the coast as depressions. However, cyclone Lehar crossed Andaman and Nocobar Islands as a severe cyclonic storm. Such a severe cyclonic storm crossed Andaman and Nicobar Islands for the first time since November 1989.
vii. While track of Lehar was straight moving, tracks of all other cyclones were recurving in nature. While Phailin recurved after landfall, cyclone Viyaru recurved northeastwards over the sea, cyclone Helen recurved west-southwestwards just before landfall and cyclone Madi recurved southwestwards over the sea. Comparing the tracks, the track of Madi was most unique in nature and had a rare analogue with past records.
viii. The total period of cyclonic disturbances during 2013, was maximum as compared to previous years (1990-2012)
ix. The annual cyclone energy over the north Indian Ocean, has also been maximum in 2013 as compared to previous years (1990-2012).
x. Brief descriptions of the disturbances with intensity cyclonic storm and above are given in the following sections.

(a) Cyclonic Storm 'Viyaru' (10-13 May 2013)

A cyclonic storm, Viyaru crossed Bangladesh coast near lat.22.8^{0}N and long. 91.4^{0}E, about 30 km south of Feni around 1330 hrs IST of 16th May 2013 with a sustained maximum wind speed of about 85 -95 kmph. The salient features of this storm are as follows.

(i) The genesis of the disturbance took place in a lower latitude, near 5°N.

(ii) It was one of the longest track over north Indian Ocean in recent period after the very severe cyclonic storm, Phet over the Arabian Sea (31 May-07 June, 2010)

(iii) The cyclonic storm moved very fast (about 40-50 km per hour on the day of landfall, i.e. on 16th May 2013. Such type of fast movement of the cyclonic storm is very rare.

(iv) Due to the faster movement, the adverse weather due to the cyclonic storm was relatively less.

(b) Very Severe Cyclonic Storm (VSCS) PHAILIN over the Bay of Bengal (08-14 October 2013)

A Very Severe Cyclonic Storm (VSCS) PHAILIN originated from a remnant cyclonic circulation from the South China Sea. The cyclonic circulation lay as a low pressure are over Tenasserim coast on 6th October 2013. It lay over north Andaman Sea as a well marked low pressure area on 7th October. It concentrated into a depression over the same region on 8th October near latitude 12.0^{0}N and longitude 96.0^{0}E. Moving west-northwestwards, it intensified into a deep depression on 9th morning and further into cyclonic storm (CS), '**Phailin'** in the same day evening. Moving northwestwards, it further intensified into a severe cyclonic storm (SCS) in the morning and into a VSCS in the forenoon of 10th Oct. over east central Bay of Bengal. The VSCS, **Phailin** crossed Odisha & adjoining north Andhra Pradesh coast near Gopalpur (Odisha) around 2230 hrs IST of 12th October 2013 with a sustained maximum surface wind speed of 200-210 kmph gusting to 220 kmph.

The salient features of this storm are as follows.

i. VSCS Phailin is the most intense cyclone that crossed India coast after Odisha Super Cyclone of 29th October 1999.

ii. There was rapid intensification of the system from 10th Oct. morning to 11th October morning leading to an increase in wind speed from 45 knots to 115 knots.

iii. At the time of landfall on 12th Oct, maximum sustained surface wind speed in association with the cyclone was about 115 knots (215 kmph) and estimated central pressure was 940 hPa with pressure drop of 66 hPa at the centre compared to surroundings

iv. It caused very heavy to extremely heavy rainfall over Odisha leading to floods, and strong gale wind leading to large scale structural damage and storm surge leading to coastal inundation over Odisha.

v. Maximum rainfall occurred over northeast sector of the system centre at the time of landfall. Maximum 24 hr cumulative rainfall of 38 cm has been reported over Banki in Cuttack district of Odisha.

vi. Based on post-cyclone survey report, maximum of storm surge of 2-2.5 meters above the astronomical tide has been estimated in the low lying areas of Ganjam district of Odisha in association with the cyclone and the in-land inundation of saline water extended upto about one kilometer from the coast.

vii. The numerical weather prediction (NWP) and dynamical statistical models provided good guidance with respect to its genesis, track and intensity. Though there was divergence in model guidance with respect to landfall point in the initial stage, the consensus among the models emerged as the cyclone moved closer to the coast.
viii. viii. IMD accurately predicted the genesis, intensity, track and point & time of landfall and also the adverse weather like heavy rainfall, gale wind and storm surge 4 to 5 days in advance.

(c) Severe Cyclonic Storm 'Helen' over Bay of Bengal (19-23 Nov 2013)

Under the influence of active inter-tropical convergence zone (ITCZ), a depression formed over the west central Bay of Bengal in the early morning of 19th Nov. 2013. It moved west-northwestwards and intensified into a deep depression in the night of 19th Nov. 2013 and further into a cyclonic storm, 'HELEN' in the morning of 20th Nov. at about 330 km east-southeast of Machilipatnam. It continued to move west-northwestwards and intensified into a severe cyclonic storm in the early morning of 21st Nov. at a distance of 260 km east-southeast of Machilipatnam. On 22nd November, It moved initially westwards and then west-southwestwards and crossed Andhra Pradesh coast close to south of Machilipatnam (near lat. 16.1°N and long. 81.2°E) between 1330-1430 hrs IST of 22nd Nov. 2013 as a cyclonic storm with a wind speed of 80-90 kmph gusting to 100 kmph. It then weakened gradually while moving west-southwestwards across Andhra Pradesh and lay as a low pressure area over coastal Andhra Pradesh and neighborhood in the early morning of 23rd Nov. 2013.

The salient features of this storm are as follows.

(i) It moved west-southwestward 12 hrs before landfall
(ii) It weakened rapidly after the landfall and hence caused less rainfall over coastal Andhra Pradesh.
(iii) Under its influence rainfall at most places with isolated heavy to very heavy rainfall occurred over coastal Andhra Pradesh.

(d) Very Severe Cyclonic Storm VSCS 'Lehar' (23-28 Nov. 2013)

The very severe cyclonic storm, Lehar developed over south Andaman Sea from a remnant cyclonic circulation from South China Sea on 23rd evening when it lay as depression located about 550 km south-southeast of Port Blair. It intensified into a deep depression in the same night and into cyclonic a storm in the early morning of 24th November 2013 while moving northwestward towards Andaman & Nicobar Islands. It further intensified into a severe cyclonic storm and crossed Andaman & Nicobar Island near Port Blair in the morning (around 0630 hrs IST) of 25th Nov. 2013 with a wind speed of about 110-120 kmph. It caused extremely heavy rainfall and coastal inundation leading to uprooting of trees, damage to structures and flooding of low lying areas.

On 25th it emerged into southeast Bay of Bengal and moved west-northwestward, intensified into a very severe cyclonic storm in the early hours of 26th Nov. near southeast Bay of Bengal. It maintained its very severe cyclonic storm intensity with a maximum wind speed reaching upto 140-150 gusting to 165 kmph till noon of 27th Nov. It then came under the influence of colder Sea, high vertical wind shear and entrainment of dry & cold air into the cyclone field. As a result it rapidly weakened into a deep depression by early morning of 28th (i.e. within 18 hours). It crossed Andhra Pradesh coast close to south of Machilipatnam around 1400 hrs IST of 28th Nov. 2013.

The salient features of this system are given below.

(i) It was the first severe cyclonic storm to cross Andaman and Nicobar Islands after November, 1989.
(ii) It had second landfall near Machillipatnam as a depression.
(iii) It rapidly weakened over the sea from the stage of very severe cyclonic storm to depression in 18 hrs.
(iv) It did not cause any significantly heavy rainfall over Andhra Pradesh

(e) Very Severe Cyclonic Storm VSCS 'Madi' (06-13 December 2013)

A low pressure area formed over southeast Bay of Bengal on 1st December 2013. It moved westwards and became well marked over central part of south Bay of Bengal on 2nd Dec. 2013. The well marked low pressure area lay over southwest Bay of Bengal on 3rd to 5th Dec. 2013. It concentrated into a depression in the morning of 6th December and deep depression in the same midnight. It moved very slowly northward and intensified into a cyclonic storm, 'Madi' in the morning of 7th December. It continued to move slowly and intensified into a severe cyclonic storm in the afternoon of 7th Dec. and into a very severe cyclonic storm in the forenoon of 8th December 2013.

However due to entrainment of cold air, colder sea and increase in vertical wind shear, the very severe cyclonic storm weakened into severe cyclonic storm in the evening of 9th Dec. Due to weakening, the system moved southwestward after reaching the latitude of 15.7^{o}N under the influence of lower and middle tropospheric steering ridge. It further weakened into cyclonic storm in the early hours 11th Dec., into deep depression in the morning of 11th, depression in night of 11th. It crossed Tamil Nadu coast near Vedaranniyam around 1900 hrs IST of 12th Dec., emerged into Palk strait around 2030 hrs IST and again crossed Tamil Nadu coast near Tondi around 2230 hrs IST. It then emerged into south east Arabian Sea as a well marked low pressure area in the early morning of 13th Oct. 2013.

The salient features of this system are given below.

(i) It has a unique track with near northerly movement till 15.7^{0}N and then recurving southwestwards to Tamil Nadu coast.
(ii) It moved very slowly during its northward journey and speed peaked up gradually after the recurvature to southwest.
(iii) The genesis, track, intensification and weakening of the system was well predicted by IMD.
(iv) Most of the numerical weather prediction (NWP) models could predict genesis, track, intensification and weakening of the system. However there was large divergence about the place and time of recurvature from the northerly to southwesterly movement.

The statistics of the cyclonic disturbances formed during 2013 are given in Table 2.1. The characteristic features of these disturbances are given in Table 2.2. The intraseasonal variation in frequency of genesis, intensification and life period of the disturbances is shown in Table 2.3.

Table 2.1: Cyclonic disturbances formed over north Indian Ocean and adjoining land areas during 2013

1.	Cyclonic storm Viyaru over the Bay of Bengal 10-16 May 2013
2.	Depression over the Bay of Bengal 29-31 May 2013
3.	Depression over the Bay of Bengal 30 July-01 Aug. 2013
4.	Land Depression 20-23 Aug.2013
5.	Very Severe cyclonic storm Phailin over the Bay of Bengal 08-14 Oct. 2013
6.	Deep Depression over Arabian Sea 08-11 Nov.2013
7.	Depression over the Bay of Bengal 13-17 Nov.2013
8.	Severe cyclonic storm Helen over the Bay of Bengal 19-23 Nov.2013
9.	Very Severe cyclonic storm over the Bay of Bengal Lehar 23-28 Nov2013
10.	Very Severe cyclonic storm over the Bay of Bengal Madi 06-13 Dec.2013

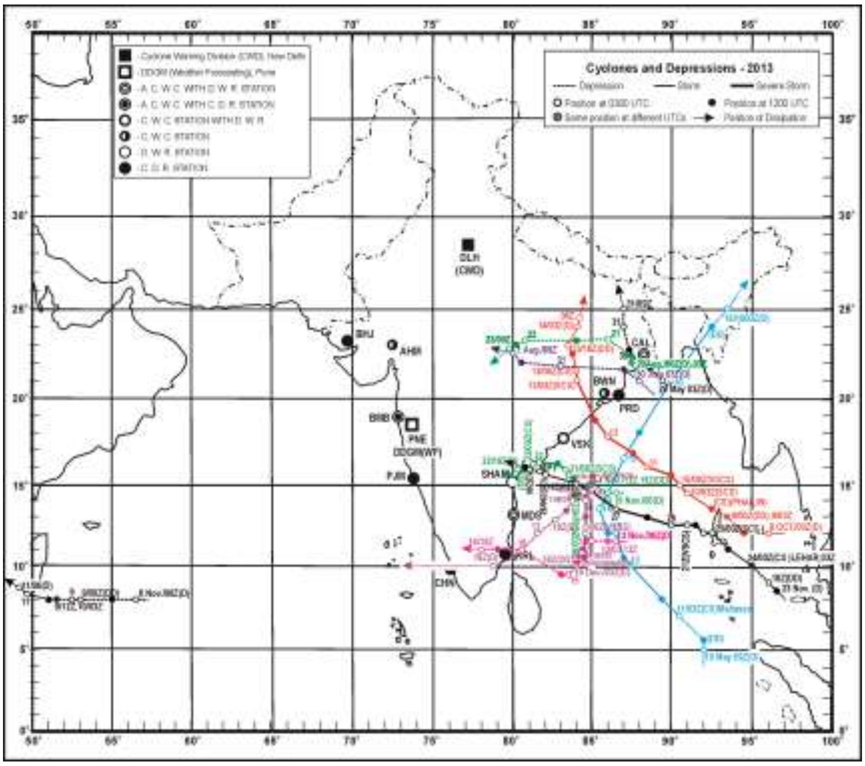


Fig. 2.1 Tracks of the cyclonic disturbances formed over the north Indian Ocean during the year, 2013

(B) Description of cyclonic storms during 2013

2.1 Cyclonic Storm, Viyaru over Bay of Bengal (10 - 16 May, 2013)

2.1.1 Introduction

A cyclonic storm, Viyaru crossed Bangladesh coast near lat.22.8^{0}N and long. 91.4^{0}E, about 30 km south of Feni around 1330 hrs IST of 16th May 2013 with a sustained maximum wind speed of about 85-95 kmph. The salient features of this storm are as follows.

(i) The genesis of the disturbance took place in a lower latitude, near 5 degree North.
(ii) It was one of the longest track over north Indian Ocean in recent period after the very severe cyclonic storm, Phet over the Arabian Sea (31 May-07 June, 2010)
(iii) The cyclonic storm moved very fast (about 40-50 km per hour on the day of landfall, i.e. on 16th May 2013. Such type of fast movement of the cyclonic storm is very rare.
(iv) Due to the faster movement, the adverse weather due to the cyclonic storm was relatively less.

2.1.2 Brief life history

A depression formed over southeast Bay of Bengal at 1430 hrs IST of 10th May 2013 near latitude 5.0^{0}N and longitude 92.0^{0}E. It moved northwestwards and intensified into a deep depression in the evening of the same day. Continuing its northwestward movement, It further intensified into a cyclonic storm, Viyaru in the morning of 11th May 2013. Under the influence of the anticyclonic circulation lying to the east, the cyclonic storm changed its direction of movement initially from northwesterly to northerly and then to north-northeasterly on 13th and 14th May respectively. On 15th May, it further came under the influence of the mid-latitude westerly trough running roughly along 77^{0}E, which further helped in enhancing the north-northeastward movement of the cyclonic storm. As this trough came closer on 16th the north-northeastward speed of the cyclonic storm significantly increased, becoming about 40-50 kmph. The cyclonic storm crossed Bangladesh coast near lat. 22.8^{0}N and long. 91.4^{0}E, about 30 km south of Feni around 1330 hrs IST of 16th May 2013 with a sustained maximum surface wind speed of about 85-95 kmph. After the landfall, it continued to move north-northeastwards and weakened gradually due to interaction with land surface. It weakened into a deep depression over Mizoram in the evening and into a depression over Manipur around mid-night of 16th. It further weakened into a well marked low pressure area over Nagaland in the early morning and moved away towards Myanmar as a low pressure area in the morning of 17th.

The track of the system is shown in Fig. 2.1. It was a recurving track with north-northeastward recurvature. Climatologically, most of the cyclones generating over the southeast Bay of Bengal recurve towards Bangladesh-Myanmar coast in the month of May. The best track parameters of cyclonic storm, Viyaru are shown in Table 2.1.1. The typical satellite and radar imageries are shown in Fig.2.1.1.

Table 2.1.1 Best track positions and other parameters of the Cyclone 'Viyaru' over the Bay of Bengal during 10-16 May, 2013

Date	Time (UTC)	Centre lat.⁰ N/ long. ⁰ E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
10-05-2013	0900	5.0/92.0	1.5	1004	25	3	D
	1200	5.5/92.0	2.0	1002	30	5	DD
	1800	6.0/91.5	2.0	1000	30	5	DD
11-05-2013	0000	6.5/91.0	2.0	998	30	6	DD
	0300	7.0/90.5	2.5	996	35	8	CS
	0600	7.0/90.5	2.5	996	35	8	CS
	0900	7.5/90.0	2.5	996	35	8	CS
	1200	8.0/89.5	2.5	994	40	8	CS
	1500	8.5/89.0	2.5	994	40	8	CS
	1800	9.0/89.0	2.5	994	40	8	CS
	2100	9.5/88.5	2.5	994	40	8	CS
12-05-2013	0000	10.0/88.0	2.5	994	40	8	CS
	0300	10.0/87.5	2.5	994	40	8	CS
	0600	10.0/87.5	2.5	994	40	8	CS
	0900	10.5/87.0	2.5	994	40	8	CS
	1200	10.5/87.0	2.5	994	40	8	CS
	1500	10.5/86.5	2.5	994	40	8	CS
	1800	11.0/86.5	2.5	994	40	8	CS
	2100	11.0/86.5	2.5	994	40	8	CS
13-05-2013	0000	11.5/86.5	2.5	994	40	8	CS
	0300	12.0/86.5	2.5	994	40	8	CS
	0600	12.0/86.5	2.5	994	40	8	CS
	0900	12.0/86.0	2.5	994	40	8	CS
	1200	12.0/86.0	2.5	994	40	8	CS
	1500	12.5/86.0	2.5	994	40	8	CS
	1800	12.5/85.5	2.5	994	40	8	CS
	2100	13.0/85.5	2.5	994	40	8	CS
14-05-2013	0000	13.5/85.5	2.5	994	40	8	CS
	0300	13.5/85.5	2.5	994	40	8	CS
	0600	14.0/85.5	2.5	994	40	8	CS
	0900	14.0/85.5	2.5	994	40	8	CS
	1200	14.5/86.0	2.5	994	40	8	CS
	1500	14.5/86.0	2.5	994	40	8	CS
	1800	15.0/86.5	2.5	994	40	8	CS
	2100	15.5/86.5	2.5	994	40	8	CS
15-05-2013	0000	16.0/87.0	2.5	994	40	8	CS
	0300	16.5/87.0	2.5	992	40	8	CS
	0600	17.0/87.5	3.0	990	45	10	CS

	0900	17.5/87.5	3.0	990	45	10	CS
	1200	18.0/88.0	3.0	990	45	10	CS
	1500	18.5/88.5	3.0	990	45	10	CS
	1800	19.0/88.5	3.0	990	45	10	CS
	2100	19.5/89.0	3.0	990	45	10	CS
16-05-2013	0000	20.0/89.5	3.0	990	45	10	CS
	0300	21.0/90.0	3.0	990	45	10	CS
	0600	22.5/91.0	3.0	990	45	10	CS
	Crossed Bangladesh coast between Chittagong and Feni, near latitude 22.8ºN and longitude 91.4ºE (about 30 km south of Feni), around 0800 UTC.						
	0900	23.5/92.0	-	994	40	8	CS
	1200	24.0/92.5	-	996	30	6	DD
	1800	25.0/93.5	-	998	25	4	D
17-05-2013	0000	Weakened into a well marked low pressure area over Nagaland					

D: Depression, DD: Deep Depression, CS: Cyclonic storm

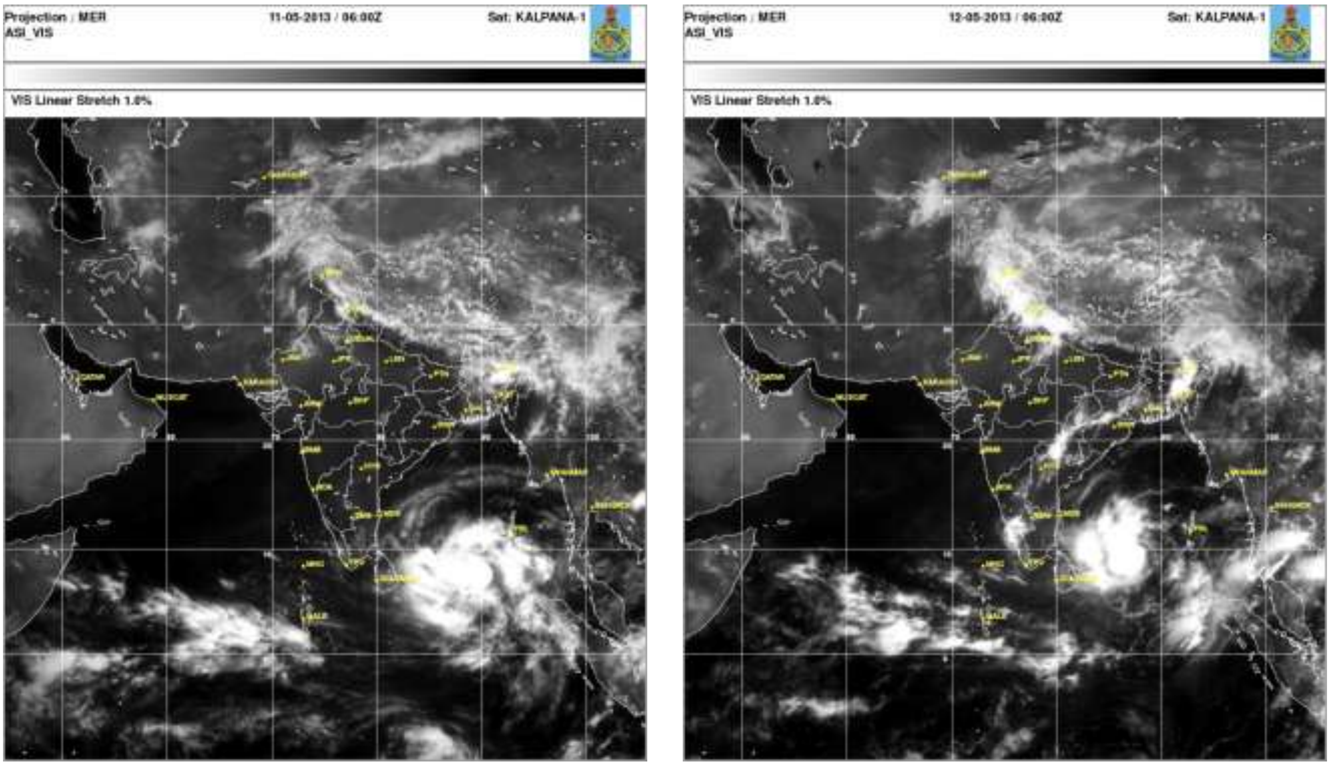


Fig. 2.1.1 Typical Kalpana-1 Satellite imageries of cyclonic storm VIYARU at 0600 UTC of 11-14 May, 2013.

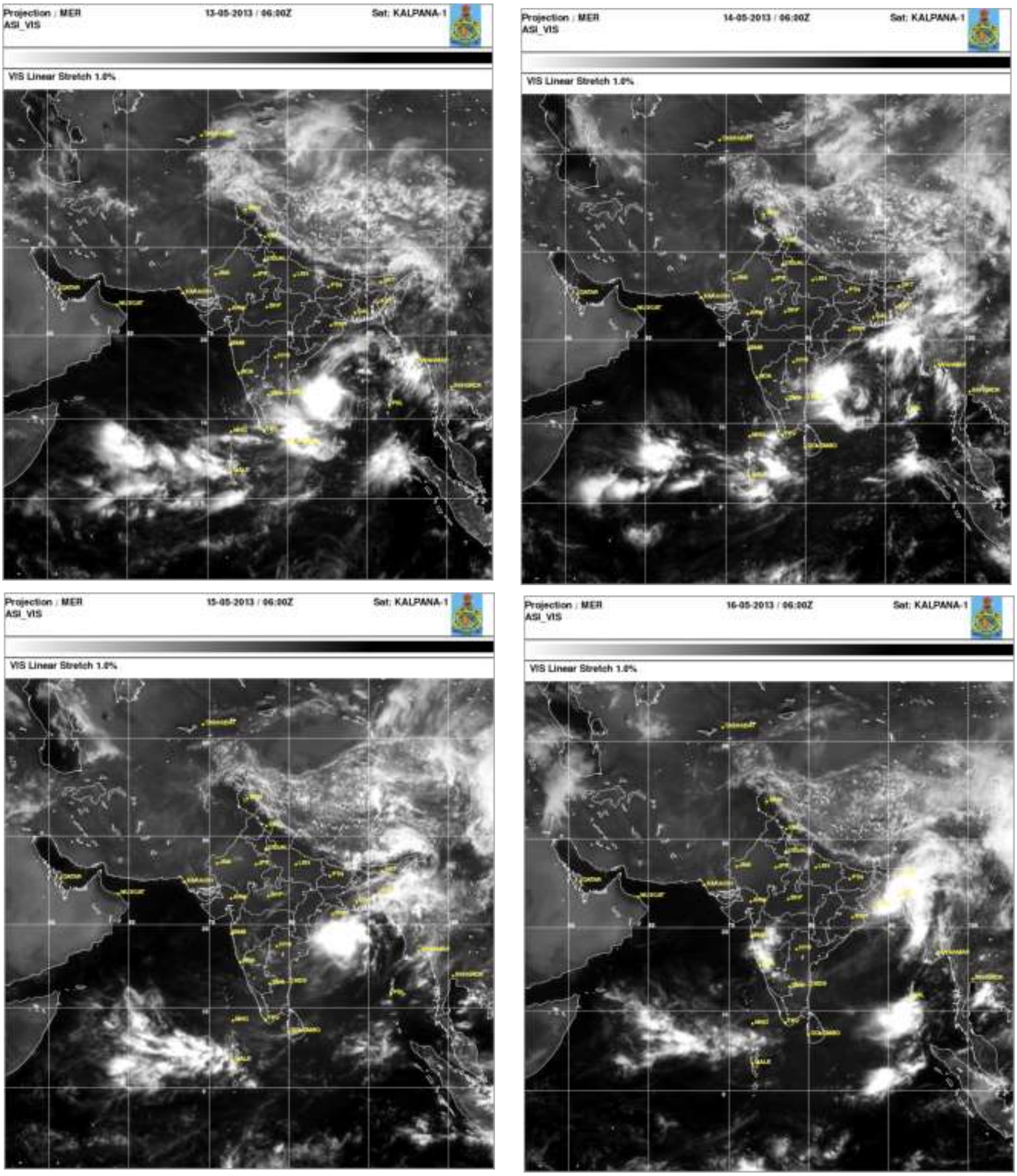


Fig.2.1.1(contd.) Typical Kalpana-1 Satellite imageries of cyclonic storm VIYARU at 0600 UTC of 15-16 May,. 2013.

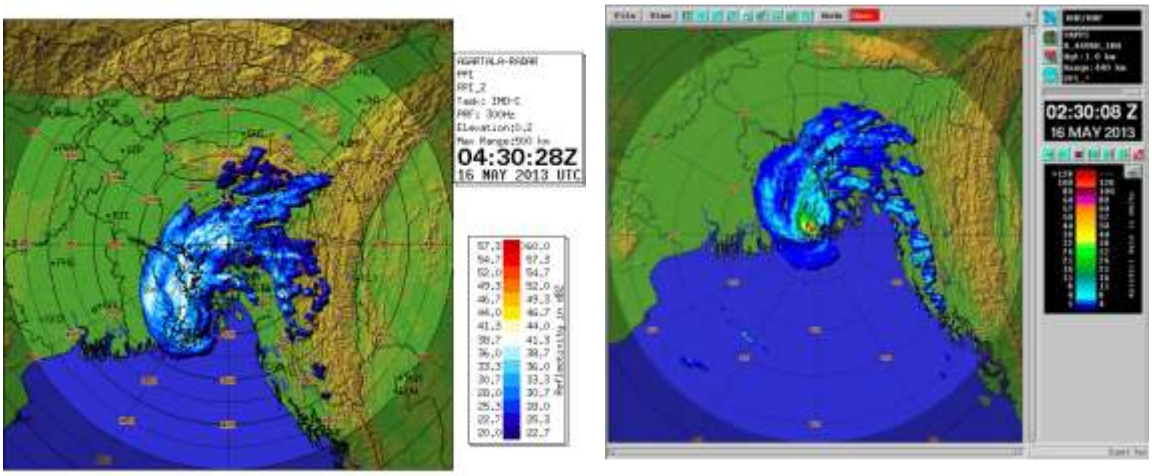


Fig. 2.1.2 Typical DWR imageries of Agartala & Khepupara (Bangladesh) in forenoon of 16 May, 2013

2.1.3 Realized Weather at the time of landfall

Surface Wind: Maximum surface wind of 92 kmph has been reported over Patuakhali, Bangladesh during the time of landfall of Cyclonic Storm, VIYARU against the forecast wind speed of 75-85 kmph gusting to 95 kmph. Surface wind of 35-45 kmph prevailed over Mizoram, Manipur and Tripura against forecast of 55-65 kmph.

Rainfall: Widespread rainfall with isolated heavy to very heavy falls occurred over Bangladesh. Fairly widespread rainfall with isolated heavy rainfall also occurred over Mizoram, Manipur and Tripura.

Storm surge: A storm surge of height of about 1 metre has been reported in section of media.

2.2 Very Severe Cyclonic Storm (VSCS) Phailin over the Bay of Bengal (08-14 October 2013)

2.2.1 Introduction

A Very Severe Cyclonic Storm (VSCS) Phailin originated from a remnant cyclonic circulation from the South China Sea. The cyclonic circulation lay as a low pressure are over Tenasserim coast on 6^{th} October 2013. It lay over north Andaman Sea as a well marked low pressure area on 7th October. It concentrated into a depression over the same region on 8^{th} October near latitude 12.0^{0}N and longitude 96.0^{0}E. Moving west-northwestwards, it intensified into a deep depression on 9^{th} morning and further into cyclonic storm (CS), 'Phailin' in the same day evening. Moving northwestwards, it further intensified into a severe cyclonic storm (SCS) in the morning and into a VSCS in the forenoon of 10^{th} Oct. over east central Bay of Bengal.

The VSCS, Phailin crossed Odisha & adjoining north Andhra Pradesh coast near Gopalpur (Odisha) around 2230 hrs IST of 12^{th} October 2013 with a sustained maximum surface wind speed of 200-210 kmph gusting to 220 kmph.

The salient features of this storm are as follows.

i. VSCS Phailin is the most intense cyclone that crossed India coast after Odisha Super Cyclone of 29th October 1999.
ii. There was rapid intensification of the system from 10th Oct. morning to 11th October morning leading to an increase in wind speed from 45 knots to 115 knots.
iii. At the time of landfall on 12th Oct, maximum sustained surface wind speed in association with the cyclone was about 115 knots (215 kmph) and estimated central pressure was 940 hPa with pressure drop of 66 hPa at the centre compared to surroundings.
iv. It caused very heavy to extremely heavy rainfall over Odisha leading to floods, and strong gale wind leading to large scale structural damage and storm surge leading to coastal inundation over Odisha.
v. Maximum rainfall occurred over northeast sector of the system centre at the time of landfall. Maximum 24 hr cumulative rainfall of 38 cm has been reported over Banki in Cuttack district of Odisha.
vi. Based on post-cyclone survey report, maximum of storm surge of 2-2.5 meters above the astronomical tide has been estimated in the low lying areas of Ganjam district of Odisha in association with the cyclone and the in-land inundation of saline water extended upto about one kilometer from the coast.
vii. The numerical weather prediction (NWP) and dynamical statistical models provided good guidance with respect to its genesis, track and intensity. Though there was divergence in model guidance with respect to landfall point in the initial stage, the consensus among the models emerged as the cyclone moved closer to the coast.
viii. IMD accurately predicted the genesis, intensity, track and point & time of landfall and also the adverse weather like heavy rainfall, gale wind and storm surge 4 to 5 days in advance.

Brief life history, characteristic features and associated weather along with performance of numerical weather prediction models and operational forecast of IMD are presented and discussed in following sections.

2.2.2 Genesis

A Very Severe Cyclonic Storm (VSCS) Phailin originated from a remnant cyclonic circulation from the South China Sea. The cyclonic circulation lay as a low pressure are over Tenasserim coast on 6th October 2013. It lay over north Andaman Sea as a well marked low pressure area on 7th October.

On 8th October, scatterometry data indicated the cyclonic circulation over the region and associated wind speed to be about 25-30 knots. The wind speed was relatively higher in southern sector in association with cross equatorial flow. According to satellite observation, intense to very intense convection was seen over Andaman Sea and adjoining area between lat 8.5^{0}N to 14.5^{0}N and east of long 88.5^{0}E to Tenasserim coast at 0530 hrs IST of 8th October. The associated convection increased gradually with respect to height and organisation during past 24 hrs. The lowest cloud top temperature (CTT) was about -70^{0}C. The convective cloud clusters came closer and merged with each other during past 24 hrs ending at 0530 hrs IST of 8th October. According to Dvorak's intensity scale, the intensity of the system was T 1.5. The system showed shear pattern with convection shifted to the west of low level circulation centre. Considering all these, the well marked low pressure area was upgraded as a depression over the north Andaman Sea at 0530 hrs IST of 8th with its centre near latitude 12.0^{0}N and longitude

96.0^{0}E. Maximum sustained surface wind speed was estimated to be about 25 knots gusting to 35 knots around the system centre.

2.2.3 Intensification and movement

The upper tropospheric ridge at 200 hPa level ran along 21^{0}N in the morning of 8th October and was providing poleward out flow in association with the anticyclonic circulation over central India and another to the northeast of the system centre. Hence upper level divergence was favourable for intensification. The low level convergence along with low level relative vorticity increased in past 24 hrs ending at 0530 hrs IST of 8th October. The sea surface temperature based on satellite and available buoys and ships observation was about 28-29^{0}C and ocean thermal energy was about 60-80 KJ/cm^2. The sea height anomaly was about 5-10 metre. The vertical wind shear of horizontal wind has decreased and was about 10-20 knots (low to moderate). The Madden Jullian oscillation (MJO) index lay over phase 6 with amplitude greater than 1. All these environmental, atmospheric and oceanic conditions suggested further intensification. Accordingly the depression moved northwestwards and intensified into a deep depression at 0530 hrs IST of 9th Oct. near 13.0^{0}N and 93.5^{0}E. Moving west-northwestwards, it crossed Andaman Islands near Mayabandar at 1430 hrs IST of 9th Oct. It moved slowly over east central Bay of Bengal and intensified into a Cyclonic Storm (CS), PHAILIN at 1730 hrs IST of 9th Oct. Most of the NWP models suggested west-northwestward to northwestward movement during next 72 hrs towards north Andhra Pradesh and Odisha coast. The NWP guidance including IMD’s dynamical statistical model also suggested intensification of the system into a severe cyclonic storm.

Tracking over an area of high sea surface temperatures and Ocean thermal energy and especially low vertical wind shear (5-10 knots), rapid intensification ensued from 10th Oct. morning. Moving westwards, the CS intensified further into an SCS at 0830 hrs IST and further into VSCS at 1130 hrs IST of 10th Oct. over east central Bay of Bengal. The system intensified further and attained its maximum intensity of 115 knots in the morning of 11th October. Thus there was a rapid intensification of the system by about 70 knots during morning of 10th to morning of 11th October. The VSCS continued to move northwestwards at a speed of about 15 kmph and crossed Andhra Pradesh & Odisha coast near Gopalpur around 2230 hrs IST of 12th Oct. 2013. However, northerly component of the movement increased gradually, about 12 hrs before landfall. It continued to move north-northwestwards after the landfall for some time and then northward and finally north-northeastwards upto southwest Bihar. The system weakened gradually into an SCS at 0830 hrs IST of 13th Oct. and into a CS over south Odisha at 1130 hrs IST of same day. It further weakened into a deep depression over north Chhattisgarh and adjoining Odisha & Jharkhand at 1730 hrs IST of 13th Oct and into a depression at 0300 UTC of 14th Oct over southwest Bihar. It weakened into a well marked low pressure area at 1430 hrs IST of 14th over southwest Bihar and neighbourhood. The observed track of the system is shown in fig.2.2. The best track parameters are shown in Table 2.2.1.

Table 2.2.1 Best track positions and other parameters of the Very Severe Cyclonic Storm 'Phailin' over the Bay of Bengal during 08-14 October, 2013

Date	Time (UTC)	Centre lat.^{0} N/ long. ^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
08-10-2013	0300	12.0/96.0	1.5	1004	25	3	D
	0600	12.0/95.5	1.5	1004	25	3	D
	1200	12.0/94.5	1.5	1003	25	4	D
	1800	12.5/94.0	1.5	1003	25	4	D
09-10-2013	0000	13.0/93.5	2.0	1002	30	5	DD
	0300	13.0/93.5	2.0	1001	30	5	DD
	0600	13.0/93.0	2.0	1000	30	6	DD
	0900	13.5/92.5	2.0	1000	30	6	DD
	1200	13.5/92.5	2.5	999	35	7	CS
	1500	13.6/92.5	2.5	999	35	7	CS
	1800	14.0/92.0	2.5	998	40	8	CS
	2100	14.0/92.0	2.5	998	40	8	CS
10-10-2013	0000	14.5/91.5	3.0	996	45	10	CS
	0300	14.5/91.0	3.5	990	55	15	SCS
	0600	15.0/90.5	4.0	984	65	22	VSCS
	0900	15.0/90.5	4.0	982	70	24	VSCS
	1200	15.5/90.0	4.5	976	75	30	VSCS
	1500	15.5/90.0	5.0	966	90	40	VSCS
	1800	15.5/89.5	5.0	960	95	46	VSCS
	2100	15.5/89.0	5.5	954	100	52	VSCS
11-10-2013	0000	16.0/88.5	5.5	946	110	60	VSCS
	0300	16.0/88.5	6.0	940	115	66	VSCS
	0600	16.2/88.3	6.0	940	115	66	VSCS
	0900	16.5/88.0	6.0	940	115	66	VSCS
	1200	16.8/87.7	6.0	940	115	66	VSCS
	1500	16.9/87.2	6.0	940	115	66	VSCS
	1800	17.0/87.0	6.0	940	115	66	VSCS
	2100	17.1/86.8	6.0	940	115	66	VSCS
12-10-2013	0000	17.5/86.5	6.0	940	115	66	VSCS
	0300	17.8/86.0	6.0	940	115	66	VSCS
	0600	18.1/85.7	6.0	940	115	66	VSCS
	0900	18.6/85.4	6.0	940	115	66	VSCS
	1200	18.7/85.2	6.0	940	115	66	VSCS
	1500	19.1/85.2	6.0	940	115	66	VSCS
	The VSCS crossed Odisha & adjoining north Andhra Pradesh coast near Gopalpur around 1700 UTC (landfall point : 19.2^{0}N and 84.9^{0}E)						
	1800	19.5/84.8	-	956	100	50	VSCS
	2100	20.0/84.5	-	966	90	40	VSCS
13-10-2013	0000	20.5/84.5	-	976	75	30	VSCS

	0300	21.0/84.0	-	990	55	15	SCS
	0600	21.5/84.0	-	996	40	10	CS
	0900	21.8/83.8	-	998	35	8	CS
	1200	22.5/83.8	-	998	35	8	CS
	1800	23.0/83.5	-	1002	30	6	DD
14-10-2013	0000	23.5/84.0	-	1002	30	6	DD
	0300	24.0.84.1	-	1004	25	3	D
	0600	24.5/84.2		1005	25	3	D
	0900	Weakened into a well marked low pressure area over southwest Bihar and neighbourhood					

2.2.4 Monitoring of VSCS, Phailin

The VSCS Phailin was monitored & predicted continuously since its inception by the India Meteorological Department. The forecast of its genesis on 8th, its track, intensity, point & time of landfall, as well as associated adverse weather like heavy rain, gale wind & storm surge were predicted exceedingly well with sufficient lead time which helped the disaster managers to maximize the management of cyclone in an exemplary manner.

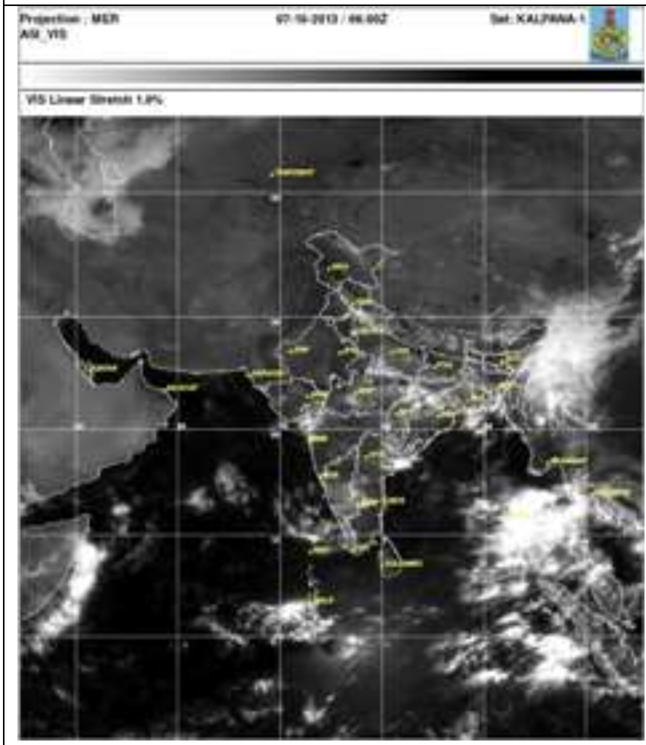
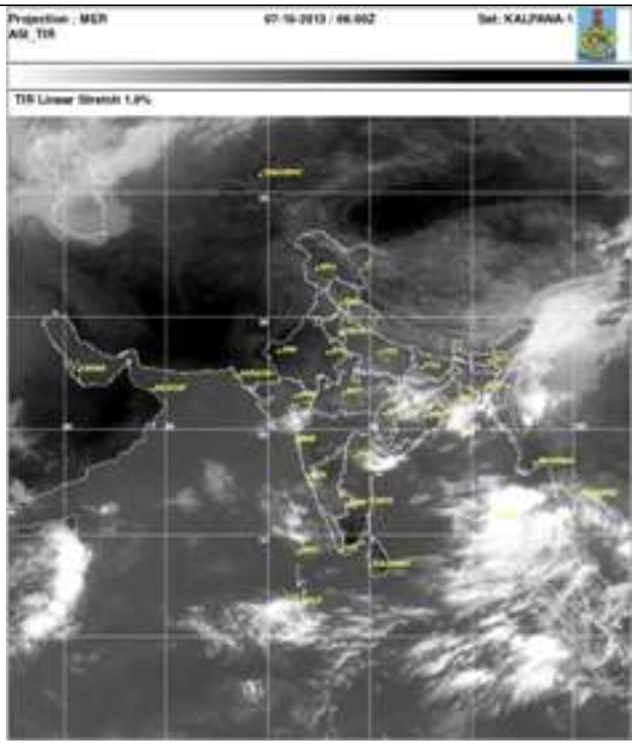
At the genesis stage, the system was monitored mainly with satellite observations, supported by meteorological buoys and coastal and island observations. As the system entered into the east central Bay of Bengal moving away from Andaman & Nicobar Islands, it was mainly monitored by satellite observations supported by buoys. On 12th October, when the system lay within radar range, the DWR at Visakhapatnam was utilized and continuous monitoring by this radar started from 0630 hrs IST of 12th when the system was at about 310 km east-southeast of Visakhapatnam coast and continued till 2330 hrs IST of that date. In addition, the observations from satellite and coastal observations conventional observatories and Automatic Weather Stations (AWS) ware used. While coastal surface observations were taken on hourly basis, the half hourly INSAT/ Kalpana imageries and every 10 minute DWR imageries, available microwave imageries and scatterometry products were used for monitoring of Phailin.

Various national and international NWP models and dynamical-statistical models including IMD's global and meso-scale models, dynamical statistical models for genesis and intensity were utilized to predict the genesis, track, intensity and rapid intensification of the storm. Tropical Cyclone Module, the digitized forecasting system of IMD was utilized for analysis and comparison of various models guidance, decision making process and warning product generation.

2.2.5 Characteristic features of PHAILIN

2.2.5.1 Features observed through satellite

A low level circulation developed over Andaman Sea on 06 October 2013 at 2100UTC. It intensified into a vortex with intensity T1.0 and centre 12.0°N/98.5°E at 0600 UTC of 7th October. The pattern was of shear type at this stage. Initially it moved in westerly direction. The system intensified again at 0300 UTC of 8th October with centre 12.0°N/96.0°E and intensity T1.5. Moving in the west-northwesterly direction it intensified with intensity of T2.0 and centre 12.5°N/94.0°E at 2100 UTC on the same day. The intensity became T 2.5 at 1000 UTC of 9th October with centre near 13.5°N/92.5°E. At this time it was of curved band pattern and the band wrapped 0.5 degree in the logarithmic spiral. It remained with intensity of T2.5 for 11 hours and intensified very rapidly then to T3.5 within just after 5 hours. The eye was visible at this time but ragged. Intensification to T4.0 occurred at 0600UTC of 10th October as the spiral bands were more organized and centre at this time was 15.1°N/90.6°E, eye temperature was -42 deg C and diameter of the eye was 12 km (Table 2). very rapid intensification occurred after this upto T6.0 at 0300 UTC of 11th October 2013, because of continuous organization of eye and spiral bands. System continued to move northwestwards till landfall near 19.26°N/84.82°E (near Gopalpur, Odisha) at 1600 UTC of 12th October 2013. Typical satellite imageries of the system are shown in fig.2.2.1(a-e)

Satellite (Kalpana-1) imageries at different stages of the VSCS (Phailin)	
Formation of well marked Low (T1.0), 0600 UTC, 07.10.2013 Centre 12.0N/98.5E	
	
Visible imagery	IR Imagery
Intensification into Depression (T1.5),0300 UTC, 08.10.2013 , Centre 12.0N/96.0E	

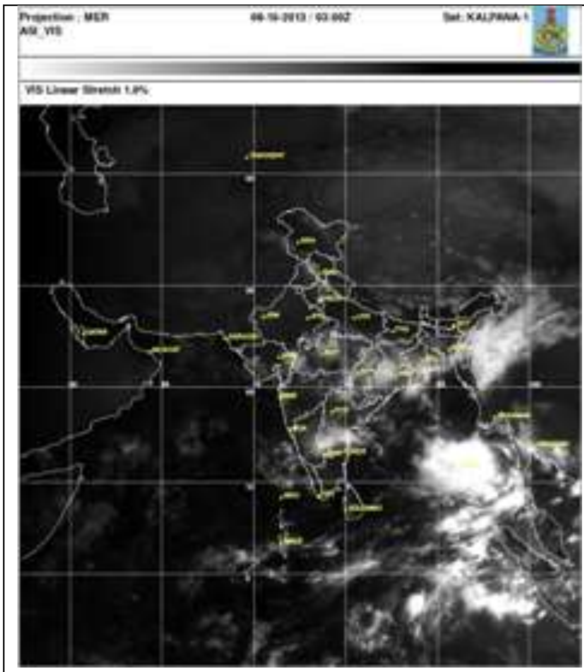
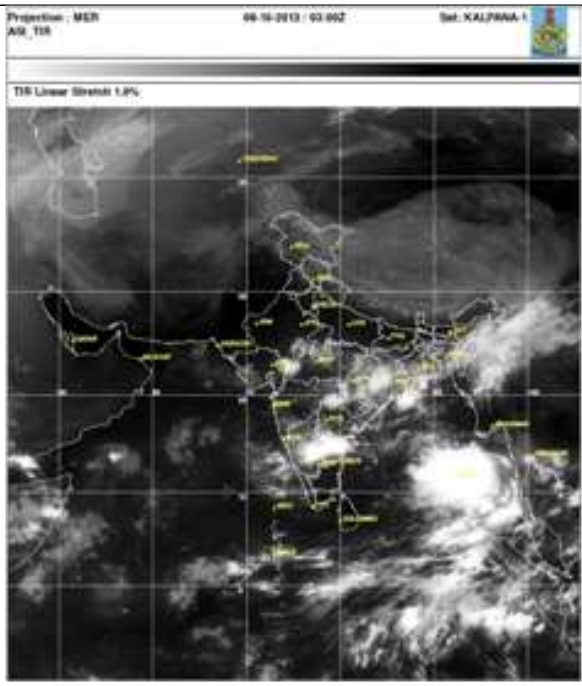
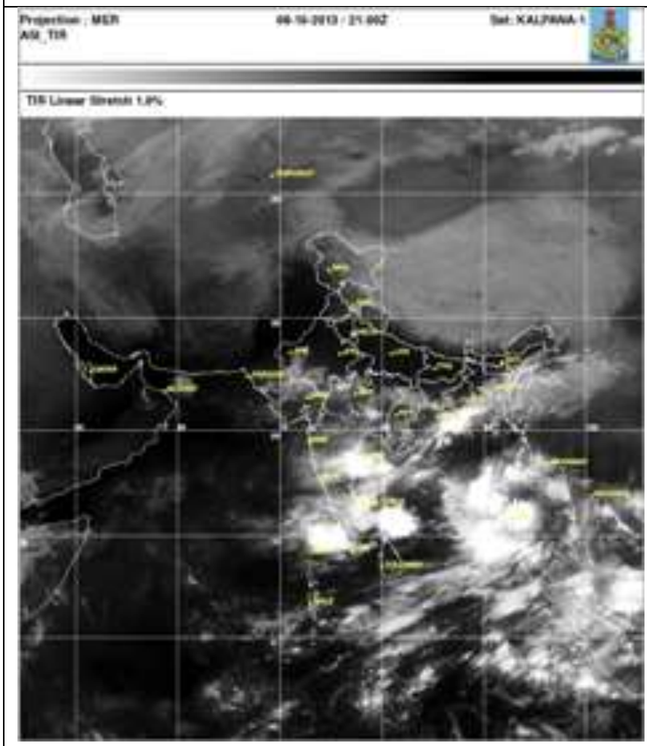
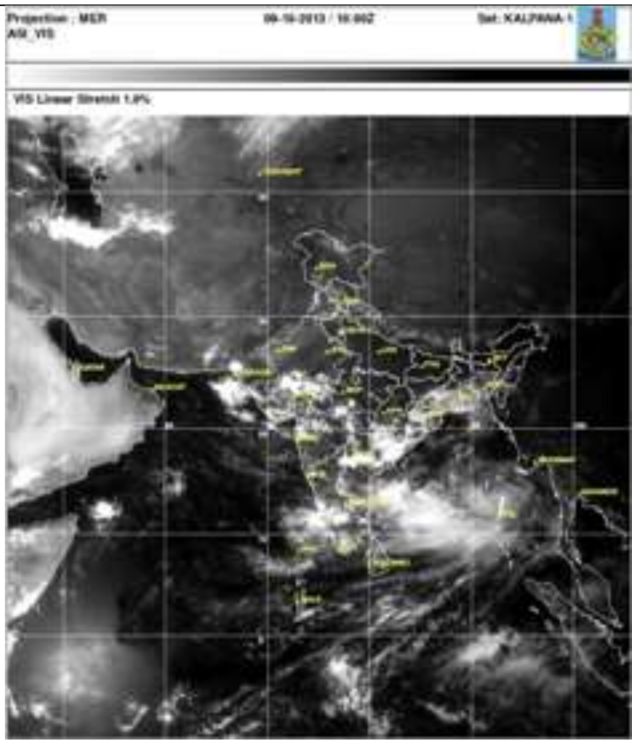
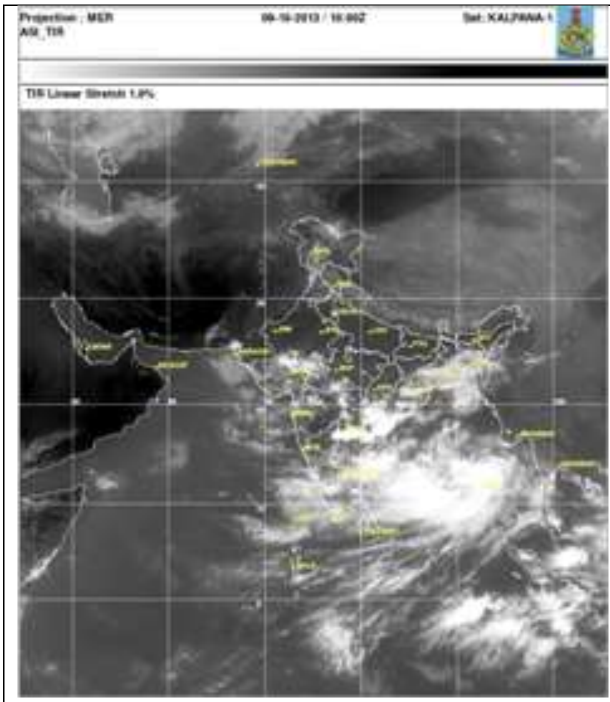
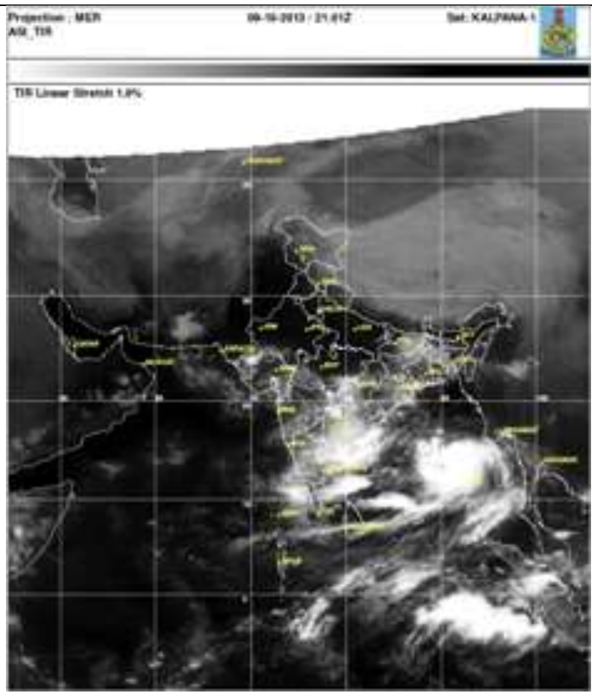
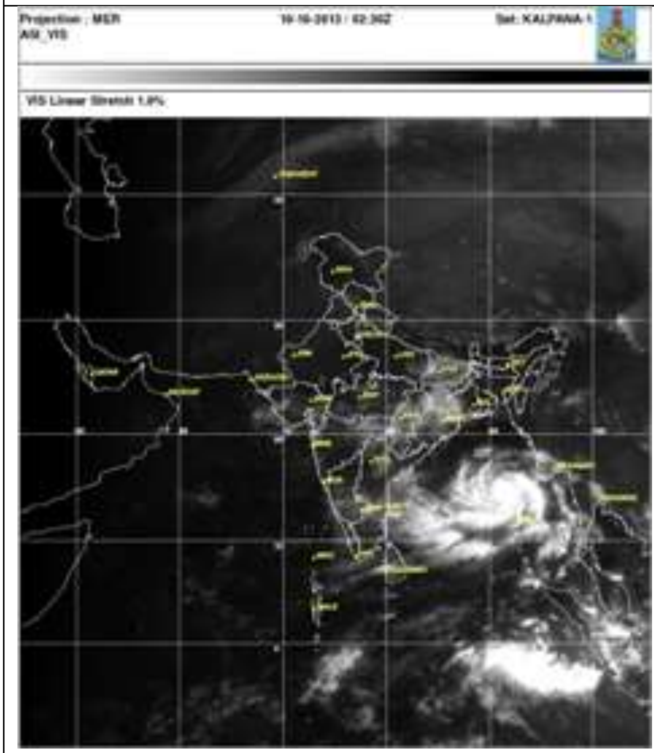
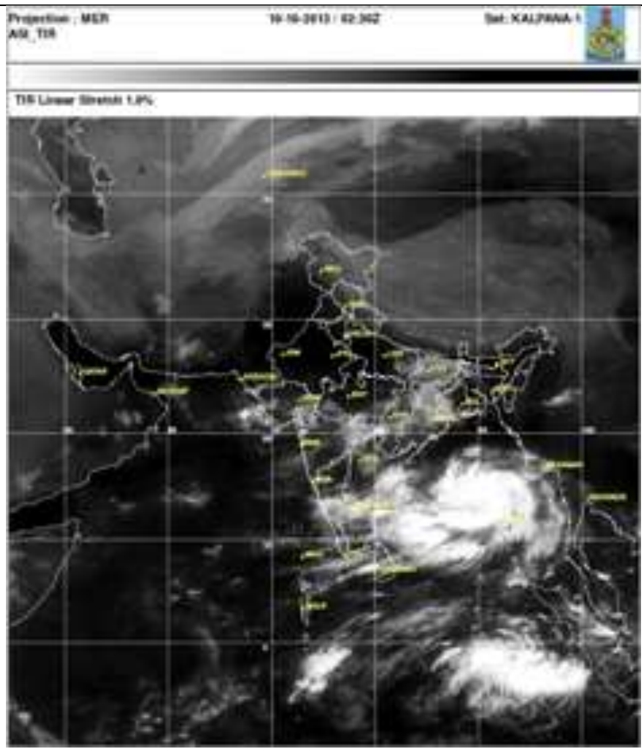
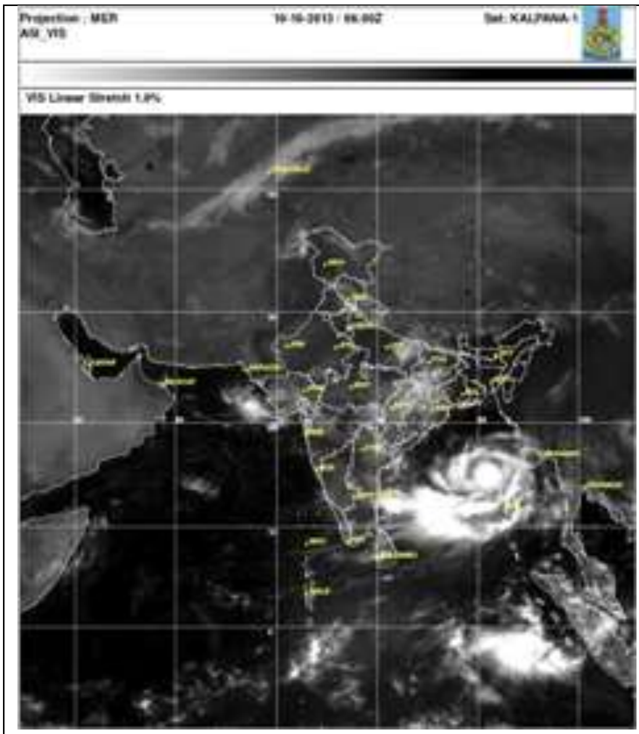
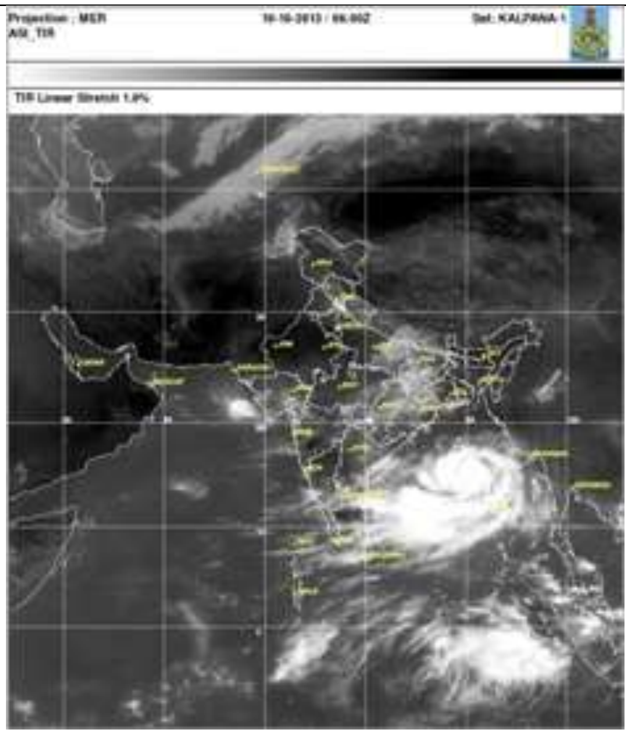
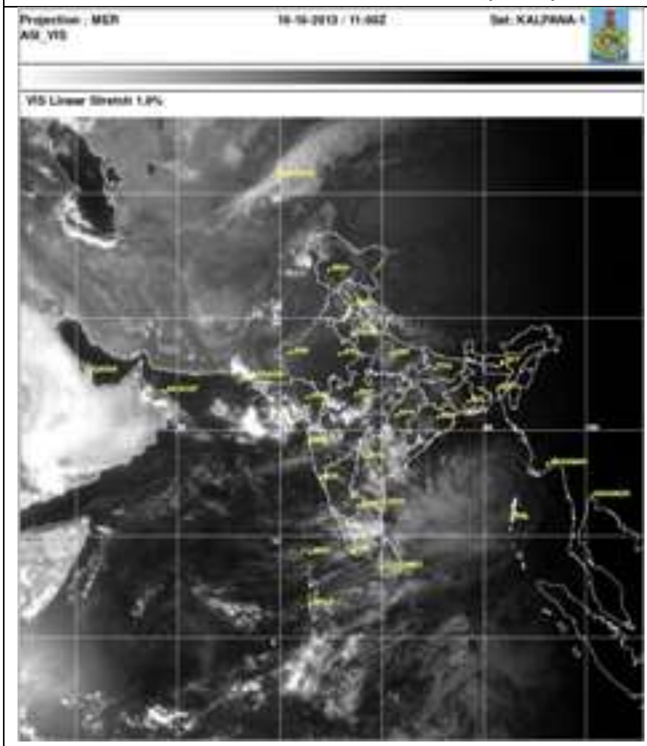
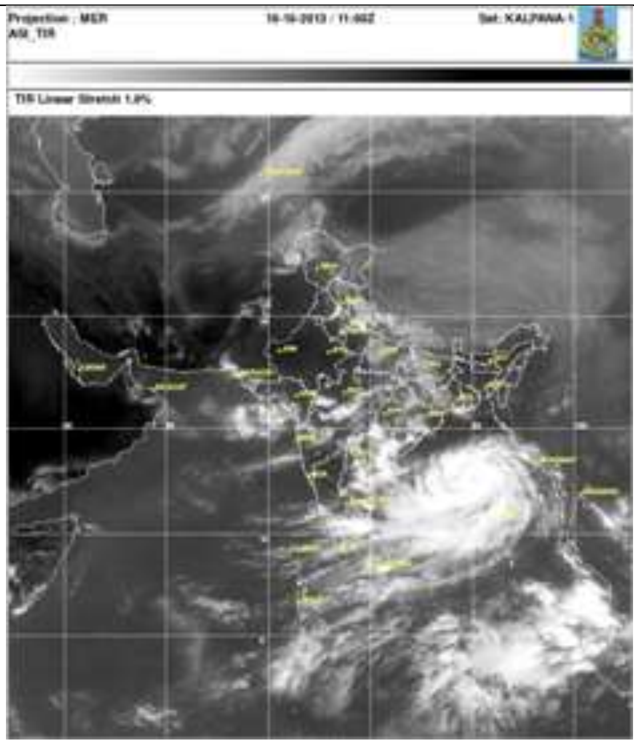
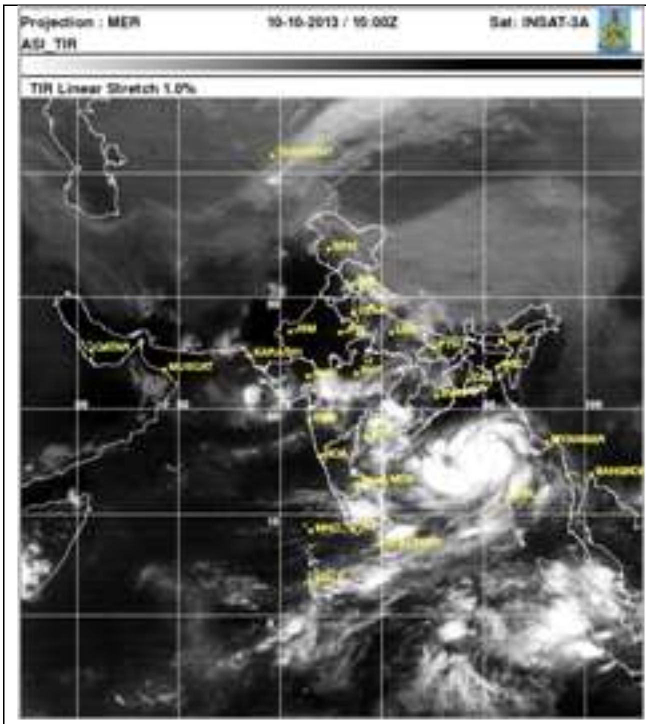
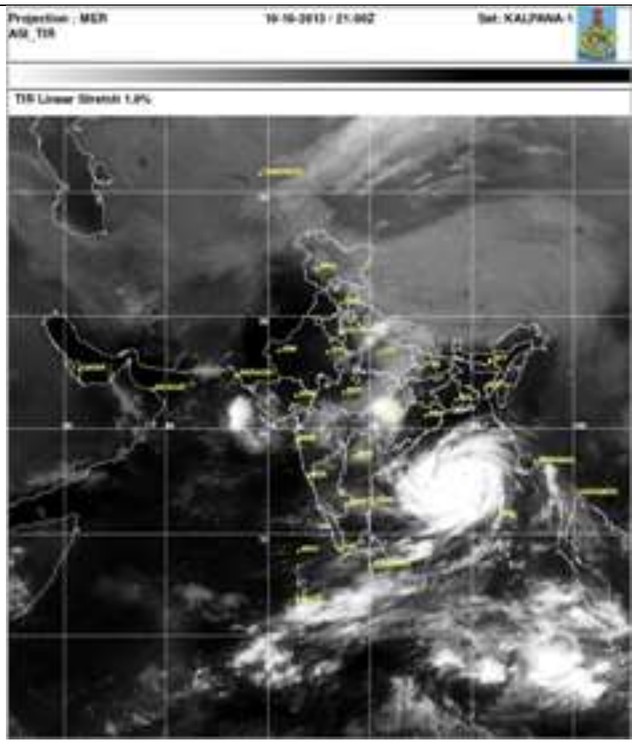
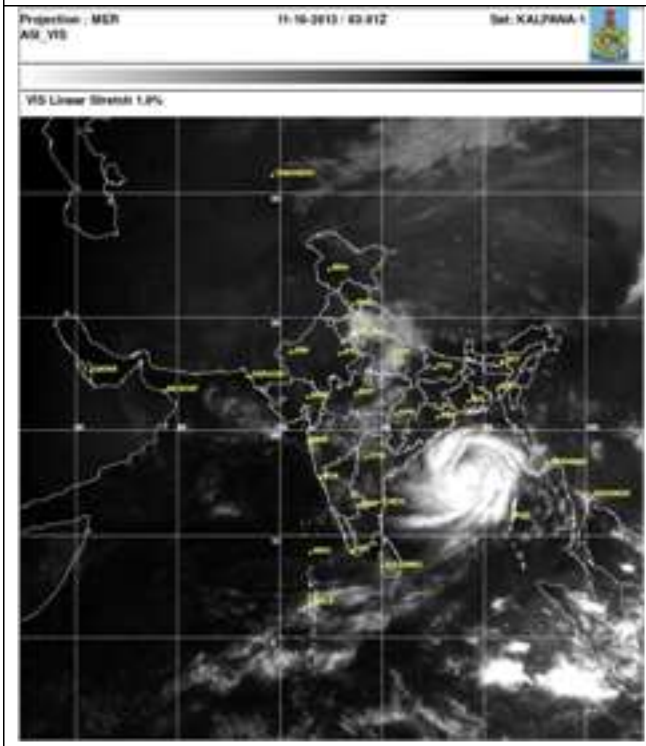
	
Visible imagery	IR Imagery

Fig. 2.2.1(a) Typical satellite imageries in different stages in cyclone, Phailin

Intensification into Deep Depression (T2.0) 2100 UTC, 08.10.2013, Centre 12.5N/94.0E	Formation of tropical cyclone (Phailin), T2.5, 1000 UTC, 09.10.2013, Centre 13.5N/92.5E
	
IR Imagery	Visible imagery
Formation of tropical cyclone (Phailin), T2.5, 1000 UTC, 09.10.2013, Centre 13.5N/92.5E	Further intensification of the tropical cyclone (T3.0), 2100 UTC, 09.10.2013, Centre 14.1N/91.8E

	
IR Imagery	IR Imagery
Intensification into Severe Cyclonic Storm (T3.5), 0230 UTC 10.10.2013, Centre 14.7N/91.1E	
	
Visible imagery	IR Imagery
Intensification in Very Severe Cyclonic Storm (T4.0). 0600 UTC, 10.10.2013, Centre 15.1N/90.6E	

	
Visible imagery	IR Imagery
Fig.2.2.1(c) Typical satellite imageries in different stages in cyclone, Phailin	
Further Intensification (T4.5), 1100 UTC, 10.10.2013, Centre 15.3N/90.2E	
	
Visible imagery	IR Imagery
Further Intensification (T5.0), 1500 UTC, 10.10.2013, Centre 15.5N/89.7E	Further Intensification (T5.5), 2100 UTC, 10.10.2013, Centre 15.6N/89.2E

	
IR Imagery (INSAT-3A)	IR Imagery
Fig.2.2.1(d) Typical satellite imageries in different stages in cyclone, Phailin	
Further Intensification (T6.0), 0300 UTC, 11.10.2013, Centre 16.0N/88.5E	
	
Visible imagery	IR Imagery
Landfall of the cyclone 1600UTC, 12.10.2013 near 19.26N/84.82E	Cyclogenesis predicted formation of Tropical cyclone

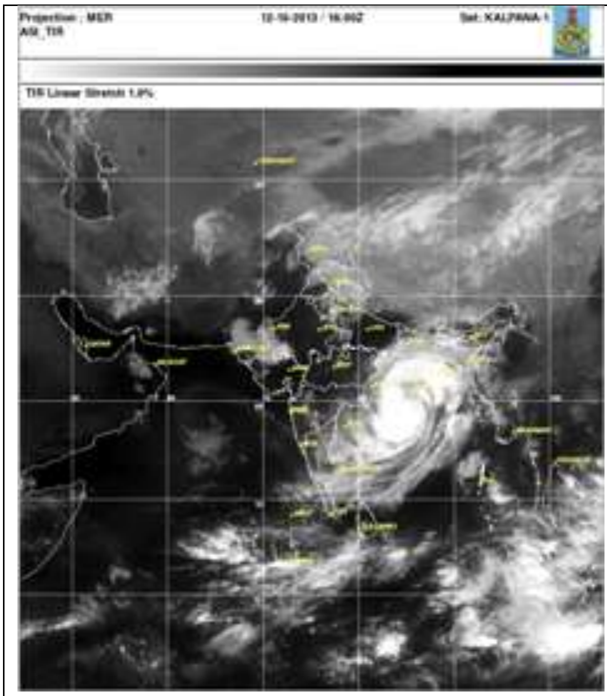
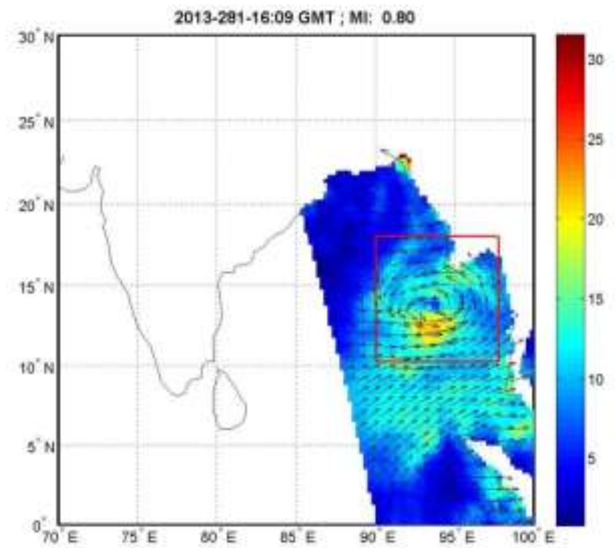
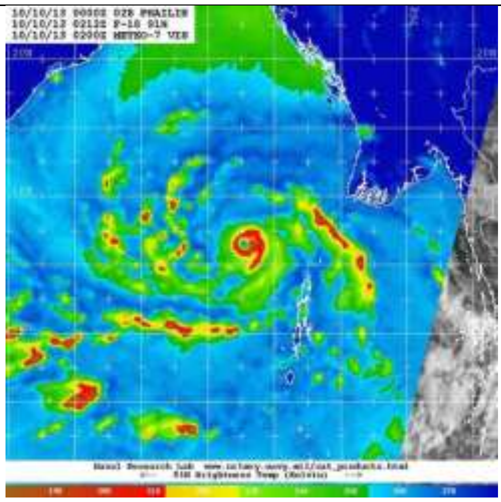
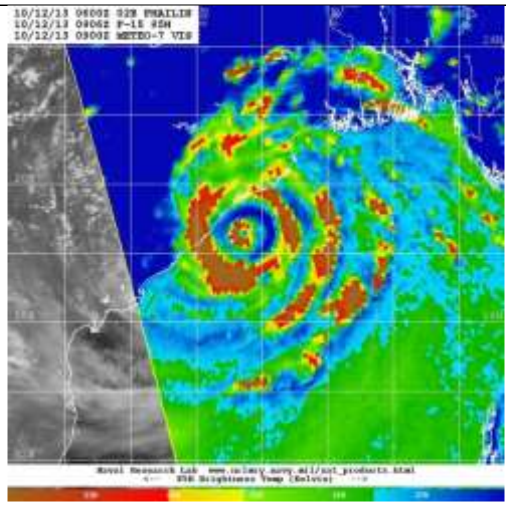
	
IR Imagery	1609 UTC, 08.10.2013

Fig.2.2.1(e) Typical satellite imageries in different stages in cyclone, Phailin

Microwave imagery	**Microwave imagery**
	
0212 UTC , 10.10.2013	0906 UTC, 12.10.2013
Wind Shear	**24 hrs Shear Tendency**

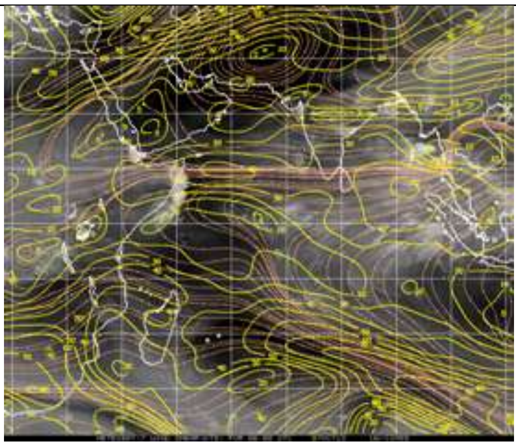
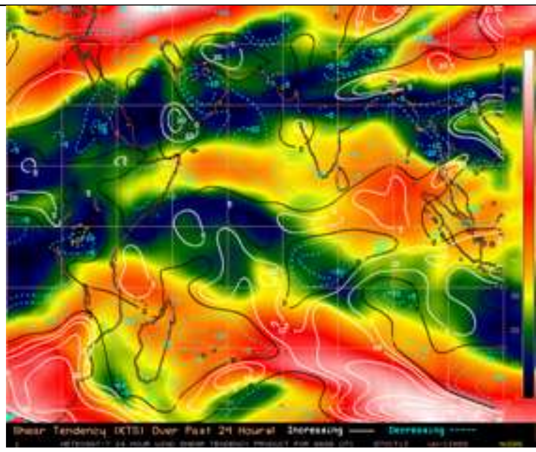
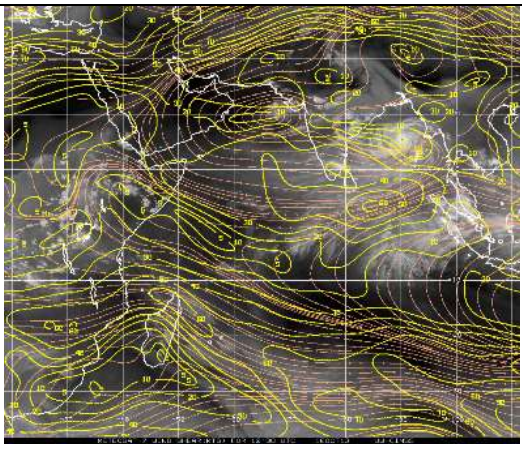
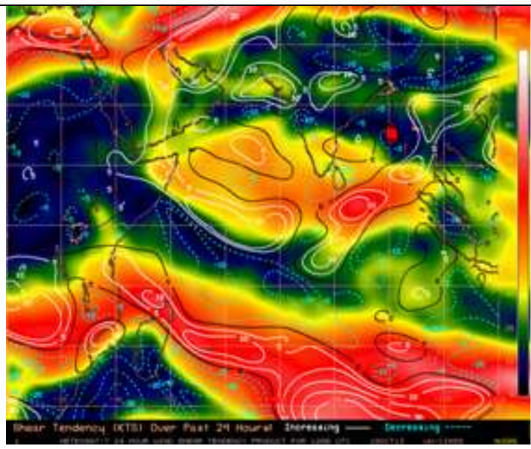
	
0600 UTC, 07.10.2013	0600 UITC, 07.10.2013
	
1200 UTC, 10.10.2013	1200 UTC, 10.10.2013

Fig.2.2.1(f). Typical microwave imageries, wind shear and shear tendency on 10 October 2013

As the buoys were away from the track of the system, satellite observations played a vital role in tracking of the system. After the landfall also Satellite Application Unit of Satellite Meteorology Division provided centre and expected intensity for better monitoring of the system. Monitoring of the system was mainly done by using half hourly Kalpana-1 imageries but satellite imageries of international geostationary satellites Meteosat-7 and MTSAT and microwave & high resolution images of polar orbiting satellites DMSP, NOAA series, TRMM, Metops were also considered.

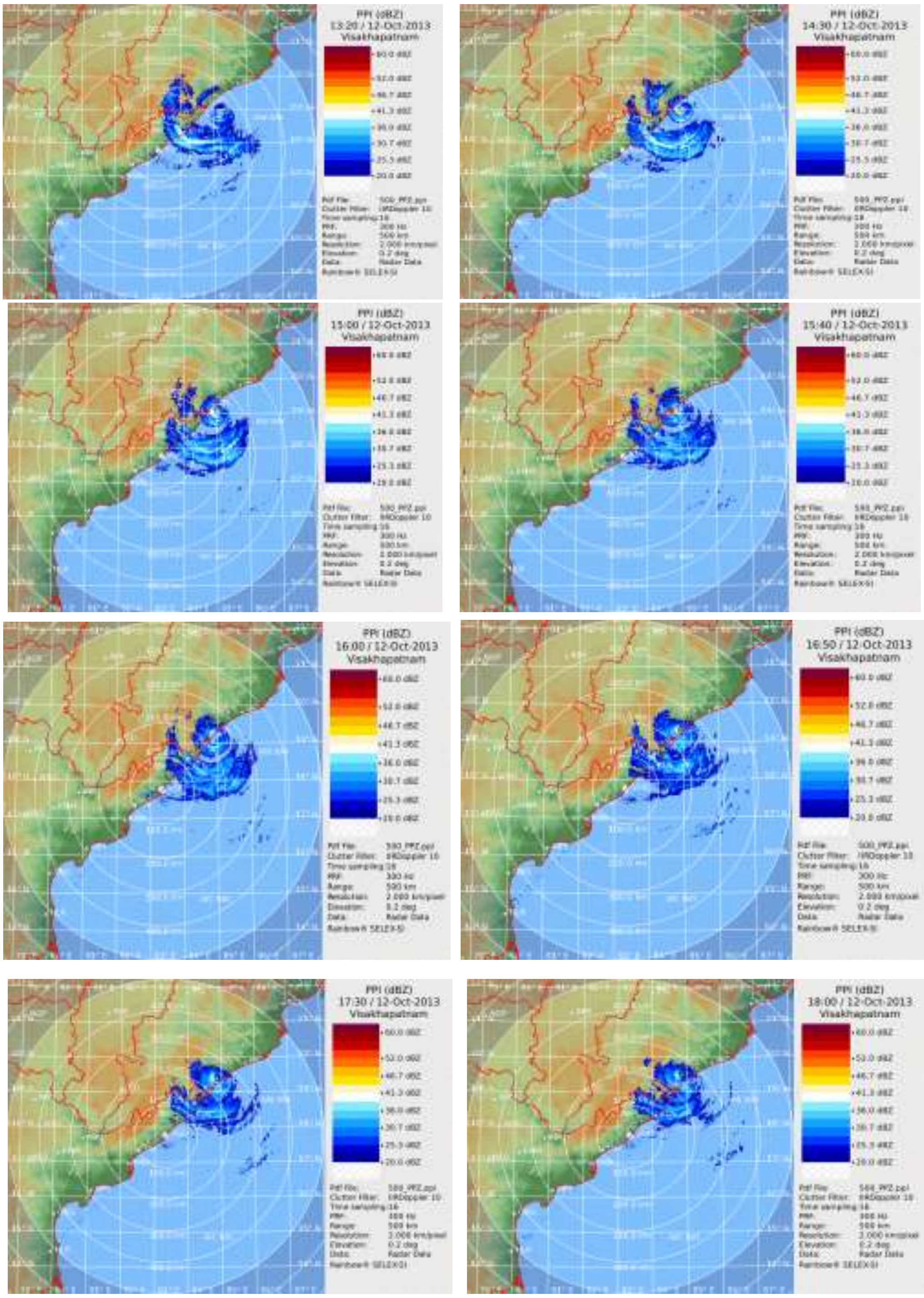


Fig.3 : Visakhapatnam RADAR imageries based on 1320,1430, 1500, 1540 UTC, 1600 , 1650, 1730, 1800 UTC of 12th October 2013

2.2.5.2 Features observed through Radar

The initial cloud echoes observed at 2100UTC of 11th October, 2013 in Special 400 PPI Scan. The Eye appeared first at 0000UTC of 12th. The first radar based bulletin was issued by Doppler Weather Radar (DWR) station, Visakhapatnam at 0100UTC and bulletins continued at 30 minutes interval till the VSCS PHAILIN crossed the Odisha coast near Gopalpur. The bulletins were issued based on maximum reflectivity (Max. Z) product with effect from 0730 UTC of 12th October. The Maximum wind speed of 60mps at 4Kms height was reported at 1410 UTC (Table 3). A few DWR imageries are shown in Fig.2.2.3. The eye was visible during 0120

UTC to 1755 UTC of 12 October 2013. The eye diameter gradually decreased and was about 15-20 km at the time of landfall.

Table2.2.2 Position Of Cyclone Phailin based on DWR, Visakhapatnam

SN	Date and time (UTC)	Lat deg N	Long deg E	Range kms	Azimuth deg	Radial wind speed (mps)/ eye dia (km)	Shape of eye & confidence
1	12.10.13 0120z	17.647	86.258	309	91.5	-/NA	Almost closed eye fair
2	12.10.13 0220z	17.794	86.094	291	88.4	-/NA	Almost closed eye Good
3	12.10.13 0320z	17.868	85.950	277	86.7	-/NA	Almost closed eye Good
4	12.10.13 0350z	17.912	85.899	270	85.6	-/36.5KM	Almost closed eye Good
5	12.10.13 0420z	17.927	85.838	265	85.2	-/33.0KM	Almost closed eye Good
6	12.10.13 0450z	17.971	85.778	258	84.0	-/32.0KM	Almost closed eye Good
7	12.10.13 0520z	17.971	85.748	255	83.9	-/27.2KM	Almost closed eye Good
8	12.10.13 0600z	18.058	85.734	255	81.7	40/30.0KM	Almost closed eye Good
9	12.10.13 0640z	18.145	85.720	255	79.5	40/30.0KM	Almost closed eye Good
10	12.10.13 0800z	18.420	85.587	248	72.0	40/NA	Almost closed eye Good
11	12.10.13 0950z	18.599	85.261	223	64.7	58/24.0KM	Almost closed eye Good
12	12.10.13 1100z	18.599	85.261	223	64.7	58/26.0KM	Almost closed eye Good
13	12.10.13 1140z	18.671	85.262	227	62.9	57/27.5KM	Almost closed eye Good
14	12.10.13 1200z	18.679	85.262	227	62.9	57/26.0KM	Almost closed eye Good
15	12.10.13 1310z	18.897	85.208	234	56.7	57/24.0KM	Almost closed eye Good
16	12.10.13 1410z	18.997	85.094	231	52.8	60/18.0KM	Almost closed eye Good
17	12.10.13 1455z	19.071	85.032	231	50.3	58/18.0KM	Almost closed eye Good
18	12.10.13 1525z	19.144	85.024	235	48.5	57/20.0KM	Almost closed eye Good
19	12.10.13 1555z	19.192	84.982	236	46.7	51/20.0KM	Almost closed eye Good
20	12.10.13 1635z	19.282	84.934	238	44.1	45/16.0KM	Eye over land Good
21	12.10.13 1725z	19.415	84.853	243	40.5	42/NA	Eye over land Fair
22	12.10.13 1755z	19.454	84.842	48 (from the coast)	-	42/NA	Eye over land Fair

2.2.5.3 Estimated Central Pressure and Maximum Wind

The estimated central pressure of the system gradually decreased from genesis stage on 8th October to 10th morning. There was sharp decrease then till 11th morning due to rapid intensification of the system. It became lowest (940 hPa) at 0300 UTC of 11th October and continued so till the landfall (Table 1). During decay, the rise in central pressure was rather rapid than that in genesis stage. Similar was the variation in estimated maximum wind, as it gradually increased from 8th to 10th morning and then rapidly increased till 11th morning. It reached maximum value of 115 knots at 0300 UTC of 11th and continued so till the landfall.

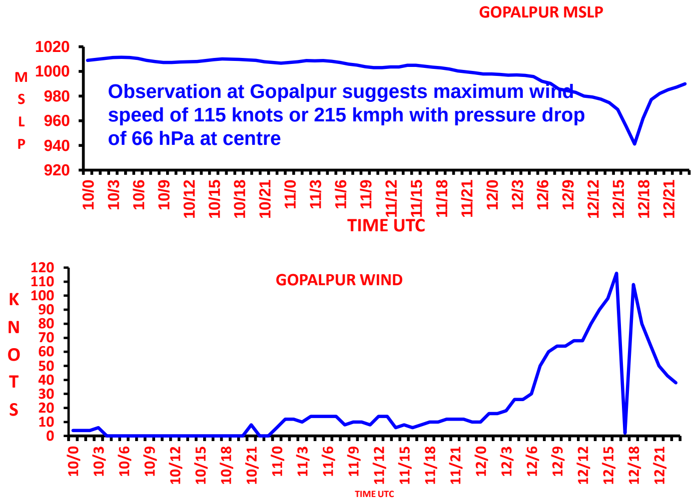


Fig.2.2.4 Variation of mean sea level pressure and wind over Gopalpur during the passage of cyclone

The pressure and wind variation over Gopalpur (point of landfall) are shown in Fig.2.2.4. It is worth mentioning that the eye of the cyclone passed over Gopalpur around 1700 UTC, when it experienced variable wind of about 2 knots for a few minutes followed by strong gale wind due to rear sector of the cyclone lying over the station. The estimated maximum wind speed over Gopalpur was about 115 knots (215 kmph) at the time of landfall.

2.2.6. Realized Weather

2.2.6.1 Heavy rainfall due to Phailin

The VSCS, Phailin caused very heavy to extremely heavy rainfall over Andaman & Nicobar Islands, Odisha and isolated heavy to very heavy rainfall over North Coastal AP, West Bengal, Jharkhand, Bihar, Chhattisgarh and Sikkim. Maximum rainfall occurred over Odisha. The rainfall was higher over north Odisha than over south Odisha (Fig.5). The rainfall departures over central and northeastern India during the period of 12-14 October 2013 are shown in Fig.2.2.5-6. It indicates that the rainfall extended upto sub-Himalayan West Bengal and Sikkim.

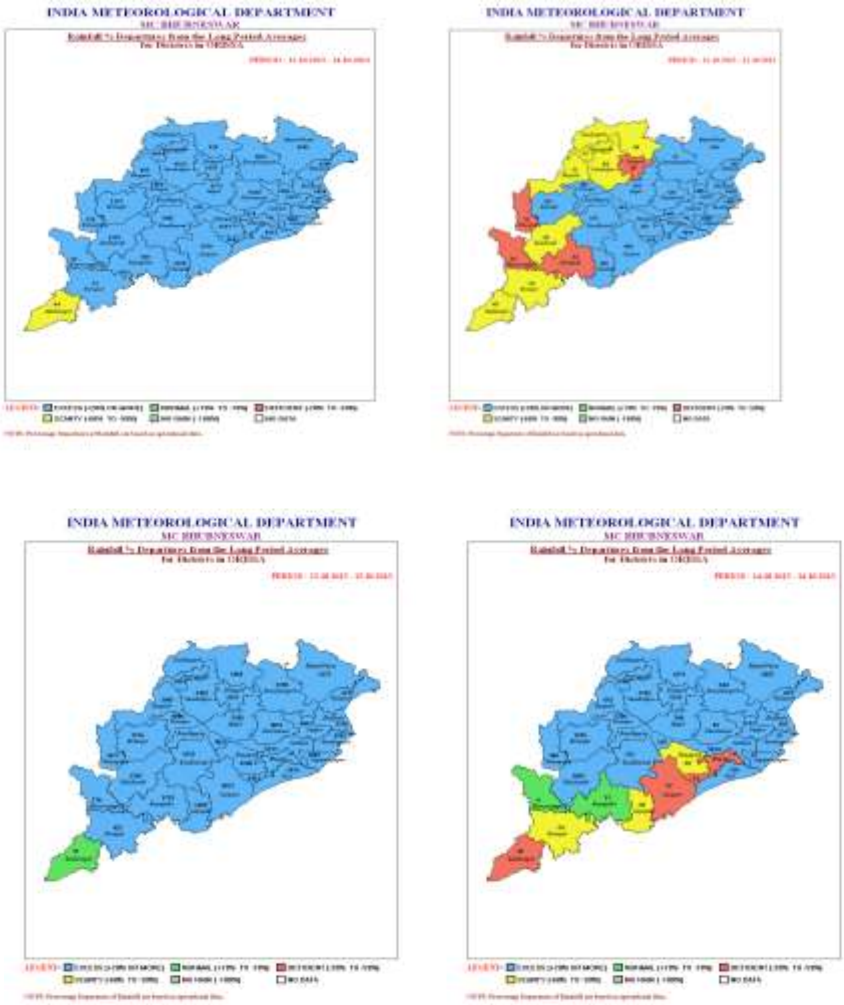


Fig.2.2.5. Rainfall departure over Odisha during 12-14 October 2013

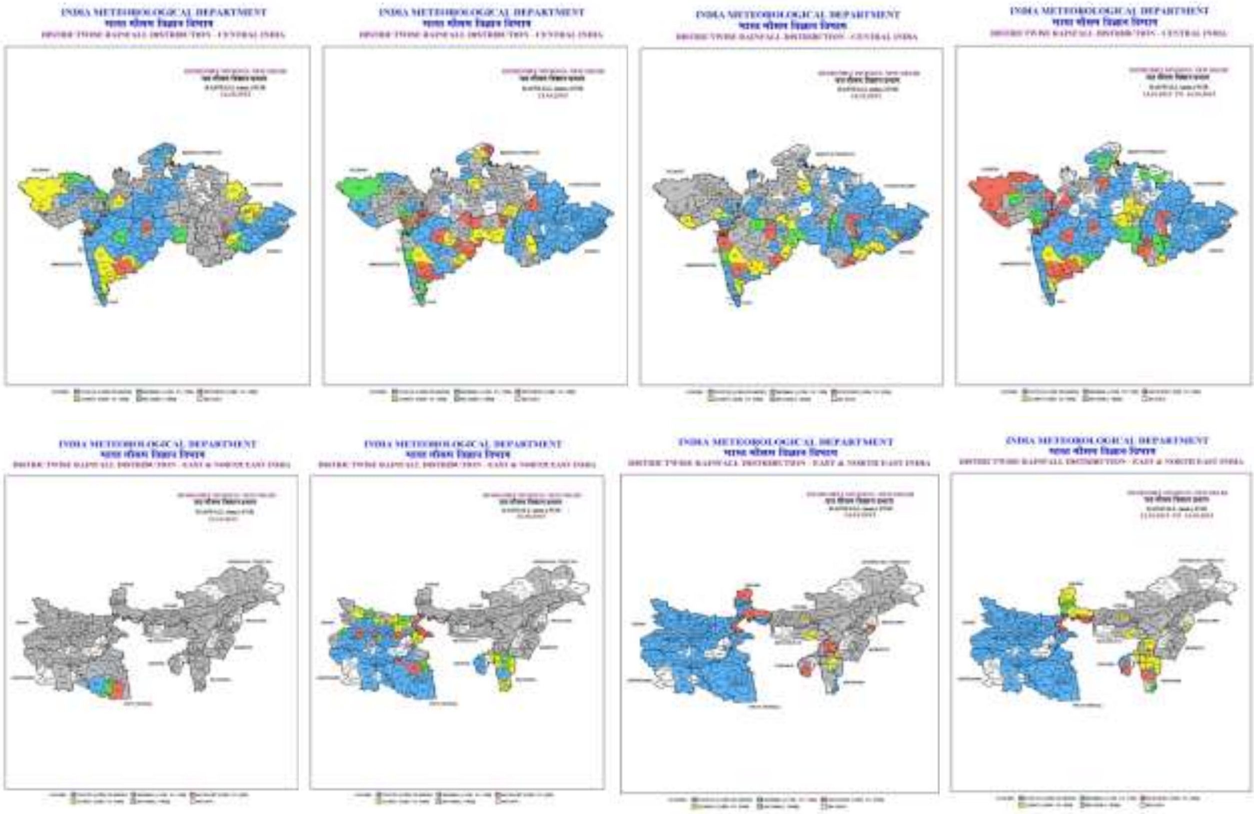


Fig 2.2.6. Rainfall departure over central and northeast India during 12-14 October 2013

The station-wise daily 24 hr cumulative rainfall (7 cm or more) during 8-15 October recorded in districts of different states at 0830 hrs IST of date are given below. States and districts are highlighted.

08-10-2013

(i) Odisha

Bargarh - Bijepur, Paikmal – 8 each, Ambabhona - 11, **Jharsuguda -** Kolabira (ARG) – 8, **Puri:** Puri - 11

(ii) Chhattisgarh

Janjgir : Champa – 8, **Jashpur:** Jashpurnagar-**7, Korba : K**atghora- 8, **Raigarh: S**arangarh-9

(iii) Jharkhand

Latehar : Balumath – 9,

(iv) Andaman & Nicobar Islands

North & Middle Andaman- Maya bandar – 24, **South Andaman**- Port Blair – 9

(v) Gangetic West Bengal

Hooghly- Harinkhola – 10, **North 24 Parganas-** Barrackpur (IAF) -7,

09-10-2013

(i) Odisha

Kendrapara- Derabis (ARG), Dattamundai-9 each, **Mayurbhanj-** Baripada -9, **Puri -** Satyabadi ARG) -7

(ii) Andaman & Nicobar Islands

North & Middle Andaman - Long Island, Maya Bandar – 34 each
South Andaman - Port Blair -7

10-10-2013

(i) Odisha

Ganjam - Belaguntha (Arg), Jagannath Prasad (ARG)- 9 each, **Keonjhargarh - S**wam-Patna - 8, **Sonepur - Ul**lunda (ARG) -7

(ii) Coastal Andhra Pradesh

Krishna - Vijayawada (A.P).-8,**Vizianagaram**- Srungavarapukota -8, **West Godavari -** Narsapuram- 8

(iii) Andaman & Nicobar Islands

A & N Island - Iaf Carnicobar – 8, Car Nicobar - 10,
North & Middle Andaman - Maya Bandar - 16

11-10-2013

(i) Telangana

Adilabad- Chinnoor – 7, **Karimnagar-** Kaleswaram - 7

12-10-2013

(ii) Odisha

Balasore - Soro -7, **Bhadrak** - Akhuapada – 8, **Jagatsinghpur** - Jagatsinghpur (AWS), Kujanga (AWS)-9 each, J**ajpur**-Korei (AWS)-8, **Puri-** Puri -7, Brahmagiri (AWS)-8,

13-10-2013

(i) Odisha

Angul - Banarpal (ARG), Chendipada-8 each, Rajghat-9, Kaniha (ARG)-9, Angul, Athmalik -11 each, Talcher- 12, Pallahara, Tikarpara-17 each, **Balasore -** Balasore-11, Nh5 Gobindpur-13, Jaipur-26, **Bargarh -** Bijepur-7, Chandbali-12, Akhuapada-14, **Cuttack -** Niali (ARG), Mahanga (ARG), Tigiria (ARG)-9 each, Cuttack, Salepur (ARG), Nischintakoili (ARG)-11each, Athgarh-12, Naraj-13, Narsinghpur-14, Mundali-25, Banki (ARG)-38, **Deogarh -**Reamal-9, **Dhenkanal -** Altuma (CWC)-7,Hindol-23, **Gajapati -** Nuagada Arg, R.Udaigiri-19 each,Mohana-20, **Ganjam -** Rambha (AWS)-14, Purushottampur-18, (Gopalpur reported rainfall till 0900 UTC of 12th Oct. and cumulative rainfall was about 09 cm till 1330 IST and after that reading could not be taken due to damage of raingauge by cyclone.) **Jagatsinghpur-** Raghunathpur (ARG)-7, Balikuda (ARG), Paradeep Cwr-.8 each, Jagatsinghpur (AWS) , Tirtol (ARG)-9 each**,** Alipingal- 10, **Jajpur-** Jajpur-7, Sukinda, Binjharpur Arg-9 each, Jenapur- 10, Bari (ARG) -12, Chandikhol (ARG) - 15, Danagadi (ARG) , Korei (ARG) -19 each,

Kalahandi - Madanpur Rampur-11, Lanjigarh-12, Narla (ARG) -13, **Kandhamal -** Kotagarh- 8, G Udayagiri (AWS), Tikabali- 13 each, Phulbani, K Nuagaon (ARG) -14 each, Raikia (ARG) - 15 , Phiringia Arg-16, Daringibadi-17, Baliguda-9, **Kendrapara –** Rajkanika- 9, Derabis (ARG), Kendrapara- 11 each, Pattamundai-15, **Keonjhargarh -**Harichandanpur (ARG)-7, Champua-9, Swam-Patna, Telkoi-10 each, Anandpur-11, Jhumpura, Ghatagaon-14 each, Keonjhargarh-15, Daitari-16, , Joda (ARG)-19, **Khurda -** Barmul-13, Bhubaneswar (Aero), Bolagarh (ARG), Balipatna (ARG)-17 each, Banpur-20, **Mayurbhanj** - Jamsolaghat-11,Thakurmunda-13, Baripada, Rairangpur-14 each, Tiring, Betanati (ARG), Udala- 15 each, Samakhunta(AWS)-17, Bangiriposi-21, Balimundali-31, **District: Nayagarh -** Gania (ARG) - 12, Daspalla- 14, Khandapara-17, Nayagarh- 18, Odagaon Arg -21, Ranpur- 30 **Puri -** Puri-12, Nimpara - 15, **Rayagada -** Muniguda (ARG) - 8, **District: Sambalpur -** Batagaon, Jujumura (ARG), Airakhol-11each.

(ii) Coastal Andhra Pradesh

Srikakulam- Mandasa, Palasa -10 each, Sompeta – 11, Itchapuram -20,

Jharkhand

Bokaro - Tenughat – 7, **Dhanbad-** Papunki – 7, **Giridih-** Dumri- 9, **Pakur -** Hiranpur - 7
Ranchi - Ranchi Aero – 7, **West Singbhum -** Chaibasa - 20

(iii) Gangetic West Bengal

Purulia- Phulberia – 7,

14-10-2013

(i) Odisha

Balasore-Jaipur-9, **Cuttack-** Salepur Arg-9, **Jajpur-**Chandikhol Arg-9, Korei Arg-16
Mayurbhanj - Balimundali, Thakurmunda- 9 each, Bangiriposi, Baripada-11 each, Jamsolaghat- 14, **Sundargarh-**Tensa-11

(ii) Jharkhand

Bokaro - Bokaro, Tenughat- 15 each, **Dhanbad -** Panchet , Putki -10 each, Papunki -16, **East Singbhum-**Jamshedpur, Jamshedpur Aero – 10 each, **Giridih -** Maithon -9, Nandadih – 11, Barkisuriya - 16, **Hazaribag-**Barhi – 9, **Jamtara-**Jamtara – 15, **Pakur -** Pakur, Pakuria – 7 each, Maheshpur -8, Hiranpur -9, **Palamu -** Japla -11, Panki- 13

(iii) Bihar

Araria - Forbesganj – 7, Araria - 10, **Arwal-** Kuratha – 10, Kinjar - 11, Arwal - 12,

Aurangabad-Palmerganj – 9, **Banka-**Banka – 13, **Begusarai-** Sahebpur Kanal – 13, Kodawanpur/C.Bii -22, **Bhagalpur-** Sabour – 9 Bhagalpur-11, Colgaon - 12, **Bhojpur-**Koilwar – 9, **Darbhanga-** Kamtaul- 10, Hayaghat- 14, **Gaya -** Gaya Aero -15,Bodh Gaya- 17, **Jahanabad –** Makhdumpur-8, Jahanabad -9, **Jamui -** Sono-9, Jamui-12, Garhi-13, Jhajha - 14, **Katihar -** KatiharNorth, Manihari- 10 each,K**hagaria-** Khagadia-10, Baltara -12, **Madhepura-**Murliganj-10, Udai Kishanganj-15 **Madhubani-**Jhanjharpur-10, **Monghyr -** Monghyr-13, **Muzaffarpur -** Sahebganj , Saraiya – 8 each, Rewaghat, Minapur-9 each, Benibad, Muzaffarpur-11each, **Nalanda-**Bihar Shrif-9, Ekangersarai -12, **Nawada-**Hisua, Nawada-7 each, Rajauli- 9, **Patna-** Patna Aerodrome-8, Sripalpur-9, **Purnea-** Purnea – 11, **Rohtas-** Dehri – 9, **Saharsa-**Sirmari B. Pur – 10, **Samastipur-** Samastipur-11, Rosera-14, Hasanpur - 16, **Saran-**Chapra-11, **Sheikhpura-**Barbigha-8, **Sitamarhi-**Belsand-9, **Siwan-**Siswan-8, **Supaul-** Bhimnagar, Nirmali-8 each, Basua-10, **Vaishali-**Vaishali-9,

(iv) Sub-Himalayan West Bengal and Sikkim (SHWB & SIKKIM)

Malda-Ratua Arg 7

(v) Gangetic West Bengal

Bankura- Bankura- 10, Bankura(Cwc) - 10 Kansabati Dam – 7, **Burdwan-** Asansol(Cwc) – 12, **Hooghly-** Bagati – 9, **Kolkata-** Alipore – 8, **North 24 Parganas -** Barrackpur(Iaf) – 8, **Purulia-** Phulberia - 9, Kharidwar - 13, Simula , Tusuma -15 each, Purihansa - 18, **West Midnapore-** D.P.Ghat – 9

15-10-2013

Bihar: Katihar/North-24, Kursela-24, Purnea-23, Madhipura-17, Murliganj-16, Barahara-15, Chargharia-15, Udai Kishanganj-14, Bhagalpur-14, Colgaon-12, Araria-11, Manihari-11, Sabour-11, Chanpatia-10, Phulparas-8, Koilwar-7, Ramnagar-7, Taibpur-7, Jainagar-7, Basua-7,

Sub-Himalayan West Bengal & Sikkim: Gangarampur (ARG)-22, Darjeeling-18, Bagrakote-16, Champasari-13, Murti-13, Kalimpong-13, Pedong-13, Malda-13, Siliguri (ARG)-13, Jalpaiguri-12, Dinhata (ARG)-12, Gajoldoba-12, Namchi (AWS)-12, Domohani-11, Gangtok-11, Sevoke-11, Soreng (ARG)-11, Bagdogra Iaf-10, Damthang-10, Khanitar-9, Neora-9, Mekhliganj (ARG)-9, Mathabhanga-9, Singla Bazar-9, Tadong-8, Chepan-8, Nagarkata-8, Gyalsing (AWS)-8, Cooch Behar-7, Pundibari (AWS)-7,

Gangetic West Bengal: Narayanpur-7,

Odisha: Astaranga (ARG)-9,

2.2.6 Gale Wind

Maximum wind 115 knots (215 kmph) has been estimated to have occurred over the region near landfall based on the observations from the Doppler weather Radar, Visakhapatnam and the observations from Gopalpur and Puri in Odisha.

2.2.8 Storm Surge

According to survey report, maximum storm surge of 2-2.5 meters above the astronomical tide has been reported in the coastal areas of Ganjam district. The coastal inundation has been reported maximum upto 500 metre to one km in the low lying areas of Ganjam district.

2.2.9 Damage due to Cyclone 'Phailin'

The VSCS, PHAILIN mainly affected Odisha and coastal Andhra Pradesh. Details of the damage are given below.

2.2.9.1 Odisha

Districts Affected: Angul Balasore, Bhadrak, Bolangir, Cuttak, Ganjapati, Ganjam, Jagatsinghpur, Jajpur, Kamdhamal, Kendrapara, Keonjhar, Khurda, Koraput, Mayurbhanj, Nayagarh, Puri

Block Affected (Nos.)	: 151
GPs Affected(Nos.)	: 2015
Village Affected(Nos.)	: 18117
ULB Affected (Nos.)	: 43
Population Affected (Nos.) due to flood & cyclone	: 12396065
Human Casualty due to cyclone	: 21
Human Casualty due to flood	: 17
Crop area affected (hect)	: 668268
Person evacuated due to cyclone	: 983642
Person evacuated due to flood	: 171083
Cattle evacuated	: 31062
House damaged	: 419052

2.2.9.2. Coastal Andhra Pradesh

Districts affected	: Srikakulam, Vizainagaram, Visakhapatnam
Village affected	: 294
Human death	: 01
Persons evacuated	: 134,426
Paddy crop inundated	: 6192

2.3 Severe Cyclonic Storm 'Helen' over Bay of Bengal (19-23 Nov 2013)

2.3.1 Introduction

A severe cyclonic storm Helen crossed Andhra Pradesh coast close to south of Machilipatnam (near lat. 16.1°N and long. 81.2°E) between 0800-0900 UTC of 22nd Nov. 2013 as a cyclonic storm with a wind speed of 80-90 kmph gusting to 100 kmph. The salient features of this storm are as follows:

(i) It moved west-southwestward 12 hrs before landfall
(ii) It weakened rapidly after the landfall and hence caused less rainfall over coastal Andhra Pradesh. Under its influence rainfall at most places with isolated heavy to very heavy rainfall occurred over coastal Andhra Pradesh.

Brief life history and other characteristic features of cyclone are described in the following sections.

2.3.2. Monitoring and Prediction

The severe cyclonic storm Helen was monitored & predicted continuously since its inception by the India Meteorological Department. The forecast of its genesis, track, intensity, point & time of landfall, as well as associated adverse weather like heavy rain, gale wind & storm surge was predicted exceedingly well with sufficient lead time which helped the disaster managers to maximize the management of cyclone in an exemplary manner. At the genesis stage, the system was monitored mainly with satellite observations, supported by meteorological buoys and coastal and Island observations. As the system lay within range of DWR, Machilipatnam and Visakhapatnam, it was continuously monitored by the radar in addition to the observations from satellite and coastal observations. Data from conventional observatories and Automatic Weather Stations (AWSs) were also used. While coastal surface observations were taken on hourly basis, the half hourly INSAT/ Kalpana imageries and every 10 minute DWR imageries, available microwave imageries and scatteometry products were used for monitoring of the system. Various national and international NWP models and dynamical-statistical models including IMD's global and meso-scale models, dynamical statistical models for genesis and intensity were utilized to predict the genesis, track, intensity and landfall of the storm. Tropical Cyclone Module, the digitized forecasting system of IMD was utilized for analysis and comparison of various models guidance and decision making process and warning product generation.

2.8.3 Genesis

The remnant of the tropical storm (Podul) contributed to the development of a trough over the Bay of Bengal near the Andaman Islands on 16th November. It became organised as a low pressure area over the east central Bay of Bengal on 17th with the active intertropical convergence zone. It became well marked on 18th over the central Bay of Bengal and concentrated into a depression over the west central Bay of Bengal in the early morning of 19th Nov. 2013 with centre near lat. 14.5^{0}N and long. 86.5^{0}E, about 600 km east-southeast of Machillipatnam. The genesis took place due to favourable location of the low pressure system with warmer sea surface temperature (28-29^{0}C), low to moderate vertical wind shear of horizontal winds (10-20 knots), increase in lower level convergence from 18th to 19th November along with upper level divergence. The upper level divergence was provided by the anticyclonic circulation which lay to the northeast of the system centre and associated ridge ran along 16.0^{0}N. The Madden Julian Oscillation (MJO) index lay in phase 2 with amplitude less than 1.

2.3.4 Intensification and movement

The depression moved west-northwestwards and intensified into a deep depression in the night of 19th Nov. 2013 and further into a cyclonic storm, 'Helen' in the morning of 20th Nov. at about 330 km east-southeast of Machilipatnam. It then moved north-northwestwards till 1200 UTC of 21st and intensified into a severe cyclonic storm in the early morning of 21st Nov. at a distance of 260 km east-southeast of Machilipatnam. On 22nd November, It moved initially westwards and then west-southwestwards and crossed Andhra Pradesh coast close to south of Machilipatnam (near lat. 16.1°N and long. 81.2°E) between 0800-0900 UTC of 22nd Nov. 2013 as a cyclonic storm with a wind speed of 80-90 kmph gusting to 100 kmph. It then weakened gradually while moving west-southwestwards across Andhra Pradesh and lay as a low pressure area over coastal Andhra Pradesh and neighborhood in the early morning of 23rd Nov. 2013. As the system moved towards the coast, it experienced decreasing vertical wind shear. The vertical wind shear was low to moderate (5-15 knots) on 20th morning when the system intensified into a cyclonic storm. The low to moderate vertical wind shear continued till 20th leading to further intensification of the system into severe cyclonic storm in the early morning of 21st. Thereafter the vertical wind shear increased gradually becoming moderate on 21st (10-20 knots) and moderate to high (15-25) knots on 22nd Nov. As a result the system weakened slightly and crossed coast on 22nd Nov. as a cyclonic storm. Over land surface, it weakened further due to interaction with land surface and cut off in moisture supply.

The system initially moved northwestwards till 20th morning under the influence of the upper tropospheric steering ridge which ran along 16.0^{0}N in association with the anticyclonic circulation lying to the northeast of the system centre. On 20th Nov. the system came closer to the steering ridge leading to north-northwesterly movement till 1200 UTC of 21st Nov. After that the northerly movement of the system got restricted and started moving nearly westward under the influence of the anticyclonic circulation at middle levels located to the northeast and northwest of the system centre. As the system came closer to the coast the steering anticyclonic circulation over India i.e. to the northwest of the system centre became more dominant leading to west-southwestward movement from 22nd Nov. The track of the system is given in Fig.2.1 and the best track position and other parameters are given in Table 2.3.1. The DWR Machilipatnam radar imagery, typical satellite imagery and IMD GFS MSLP and wind at 850, 500 and 200 hPa are shown in fig.2.3.1-3 respectively. The location of centre of the system as observed by DWR Visakhapatnam is given in Table 2.3.2.

Table 2.3.1 Best track positions and other parameters of the Severe Cyclonic Storm 'Helen' over the Bay of Bengal during 19-23 November, 2013

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
19-11-2013	0000	14.5/86.5	1.5	1004	25	3	D
	0300	14.5/86.0	1.5	1004	25	3	D
	0600	14.5/85.5	1.5	1004	25	3	D
	1200	15.0/85.0	1.5	1004	25	3	D
	1500	15.0/85.0	2.0	1002	30	5	DD
	1800	15.0/84.5	2.0	1002	30	5	DD
20-11-2013	0000	15.0/84.0	2.0	1002	30	5	DD
	0300	15.0/84.0	2.5	1000	35	8	CS
	0600	15.2/84.0	2.5	1000	40	8	CS
	0900	15.2/84.0	2.5	1000	40	8	CS
	1200	15.3/83.9	3.0	998	45	10	CS
	1500	15.3/83.9	3.0	998	45	10	CS
	1800	15.4/83.7	3.0	996	45	10	CS
	2100	15.5/83.6	3.0	996	45	10	CS
21-11-2013	0000	15.6/83.5	3.0	994	50	15	SCS
	0300	15.8/83.4	3.0	992	50	17	SCS
	0600	15.9/83.3	3.5	990	55	17	SCS
	0900	16.0/83.1	3.5	990	55	17	SCS
	1200	16.1/82.9	3.5	990	55	17	SCS
	1500	16.1/82.7	3.5	990	55	17	SCS
	1800	16.2/82.7	3.5	990	55	17	SCS
	2100	16.2/82.3	3.5	990	55	17	SCS
22-11-2013	0000	16.2/81.9	3.5	990	55	17	SCS
	0300	16.2/81.7	3.5	990	55	17	SCS
	0600	16.2/81.3	3.5	990	55	17	SCS

	The system crossed Andhra Pradesh coast close to south of Machilliptnam near $16.1^{0}N/81.2^{0}E$ between 0800-0900UTC						
	0900	16.1/81.2	-	1000	40	8	CS
	1200	15.9/80.7	-	1002	30	5	DD
	1800	15.9/80.4	-	1004	25	3	D
23-11-2013	0000	The system weakened into a well marked low pressure area over coastal Andhra Pradesh and neighbourhood.					

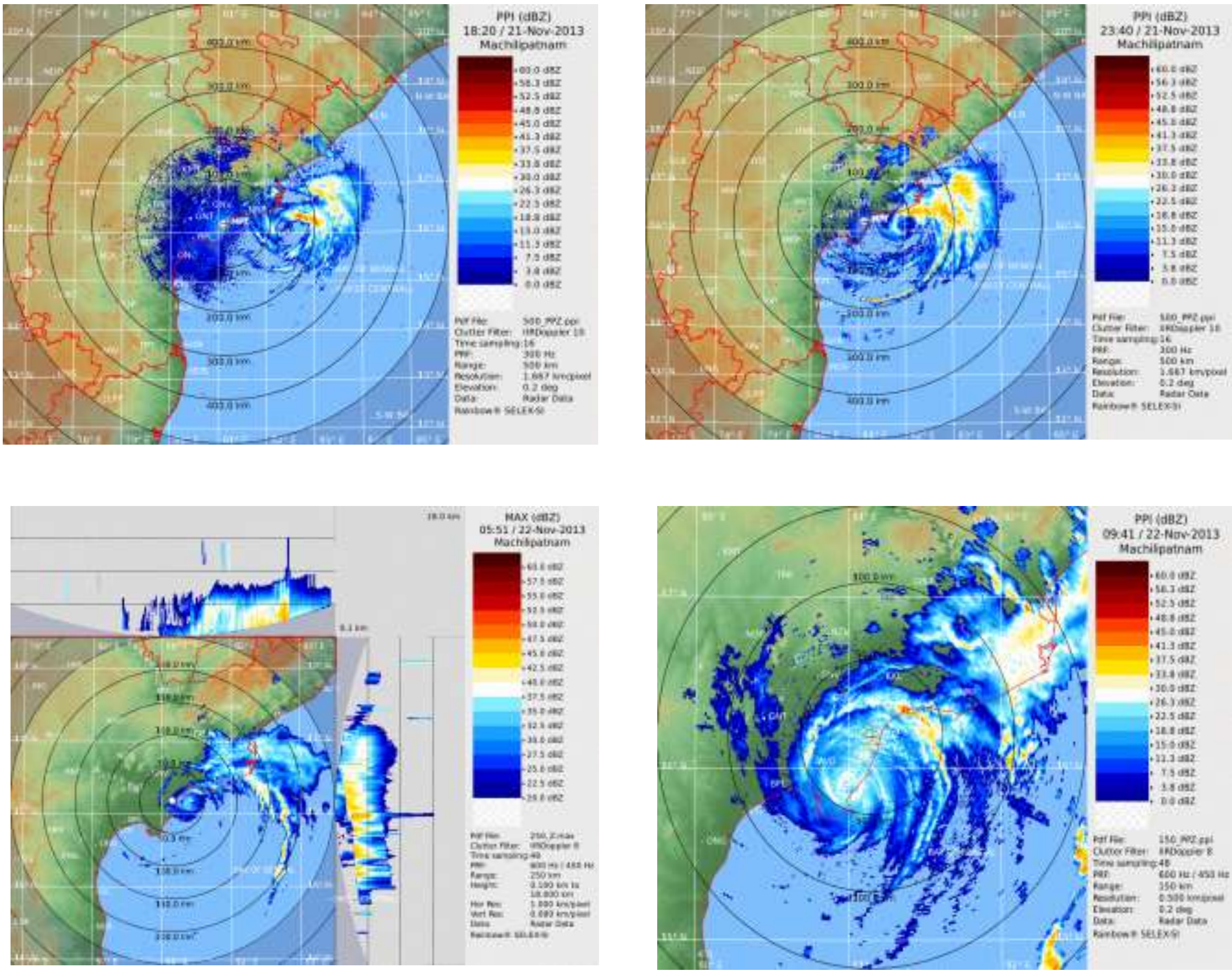


Fig.2.3.1 Typical Radar imageries of DWR Machilipatnam at 1800 UTC of 21st and 00, 06 & 10 UTC of 22nd November 2013.

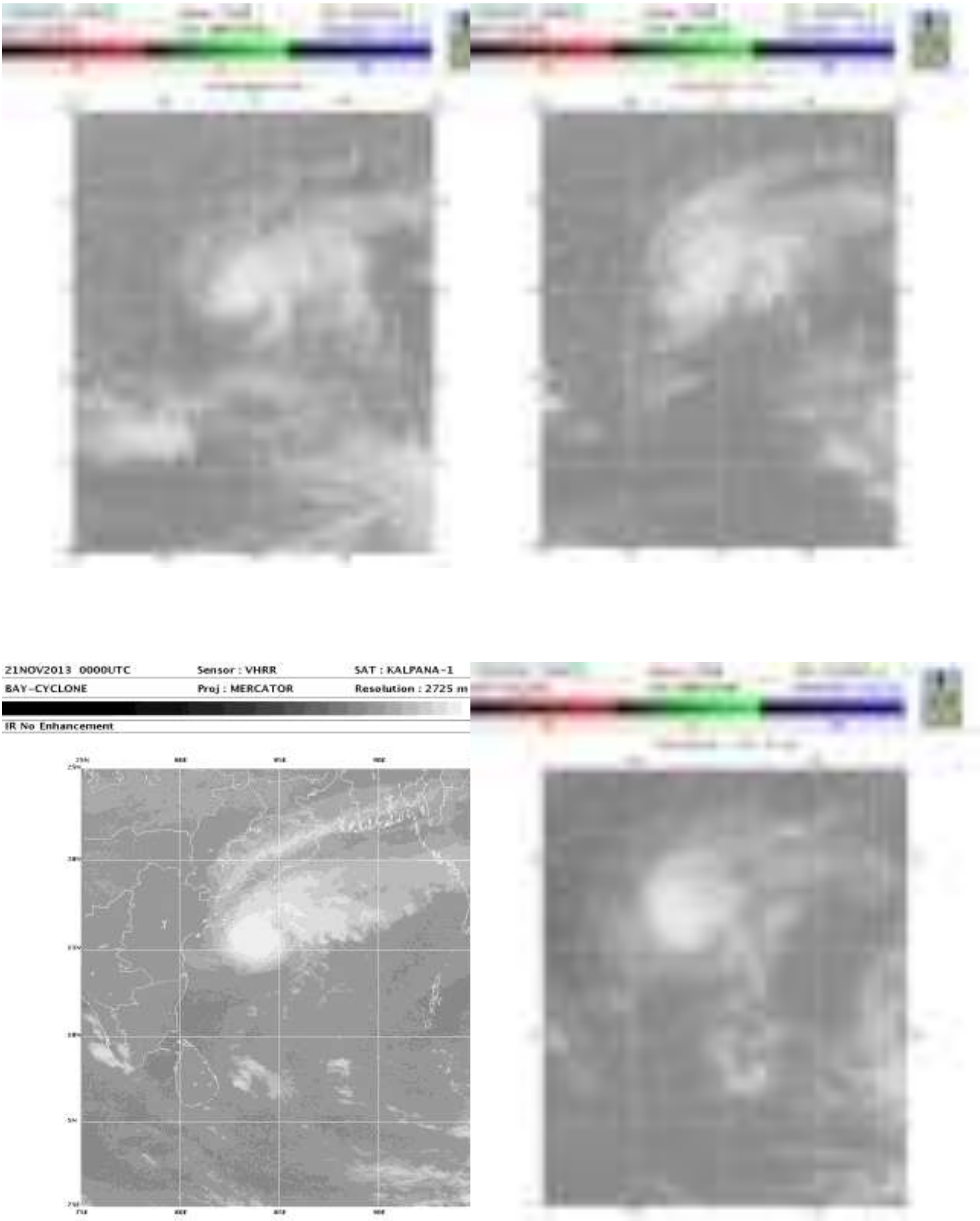


Fig.2.3.2 Typical Kalpana-1 Satellite imageries of severe cyclonic storm Helen at 1500 UTC of 19th, 0300 UTC of 20th, 0000 UTC of 21st and 0500 UTC of 22 November 2013.

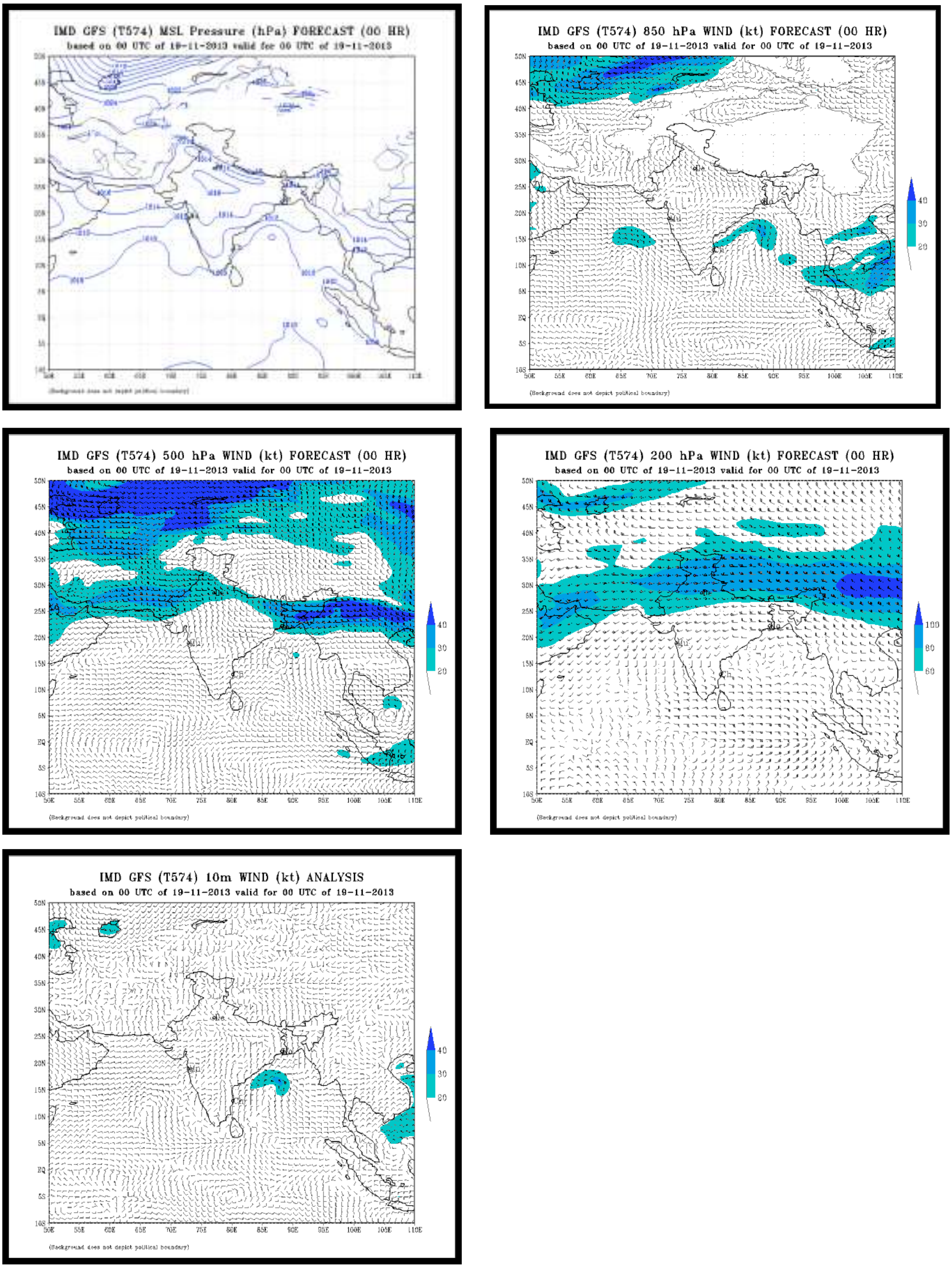


Fig.2.3.3 (a) IMD GFS MSLP and winds at 850, 500 & 200 hPa levels analysis and 10meter wind based on 00 UTC of 19th November, 2013.

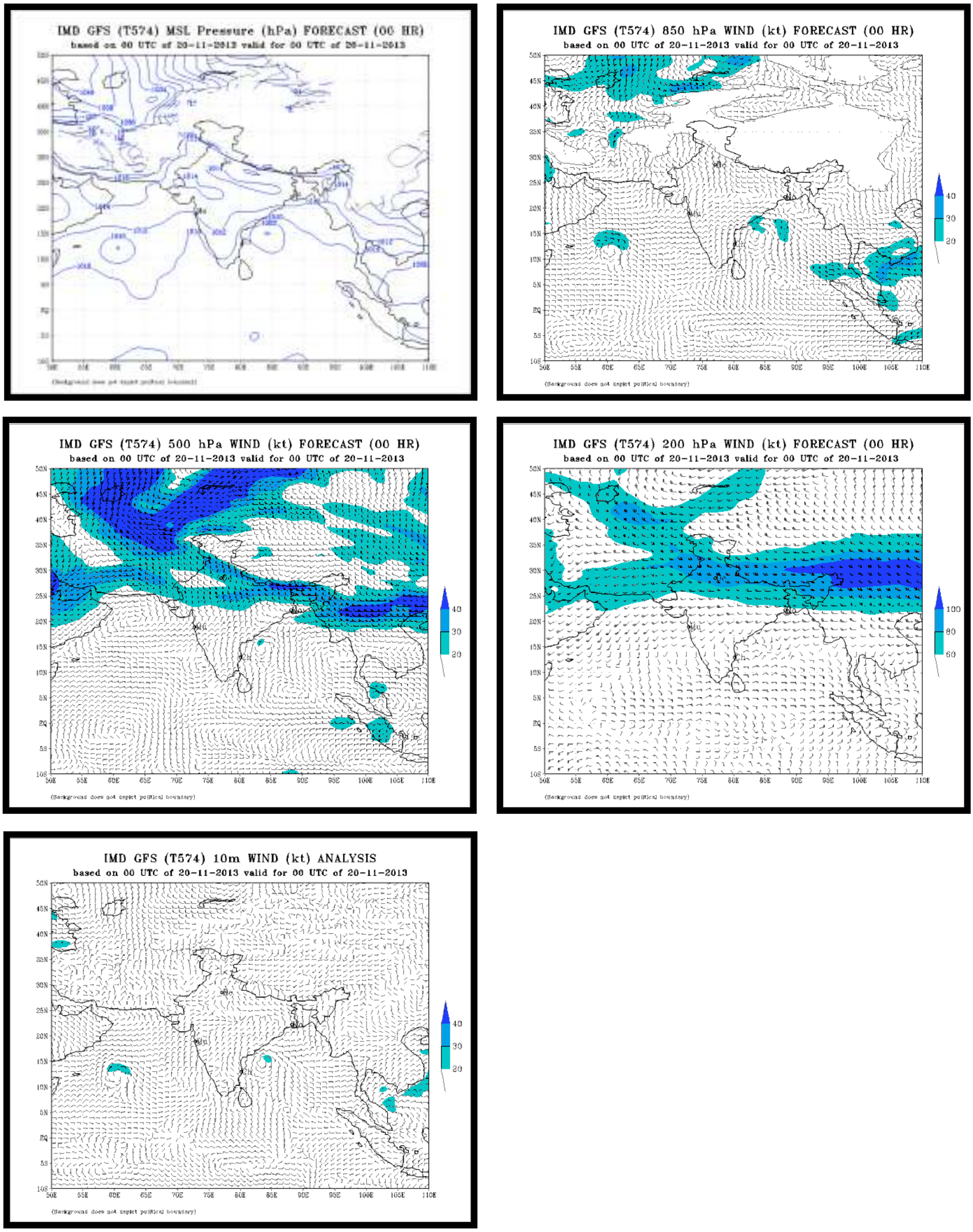


Fig.2.3.3(b) IMD GFS MSLP and winds at 850, 500 & 200 hPa levels analysis and 10meter wind based on 00 UTC of 20th November, 2013.

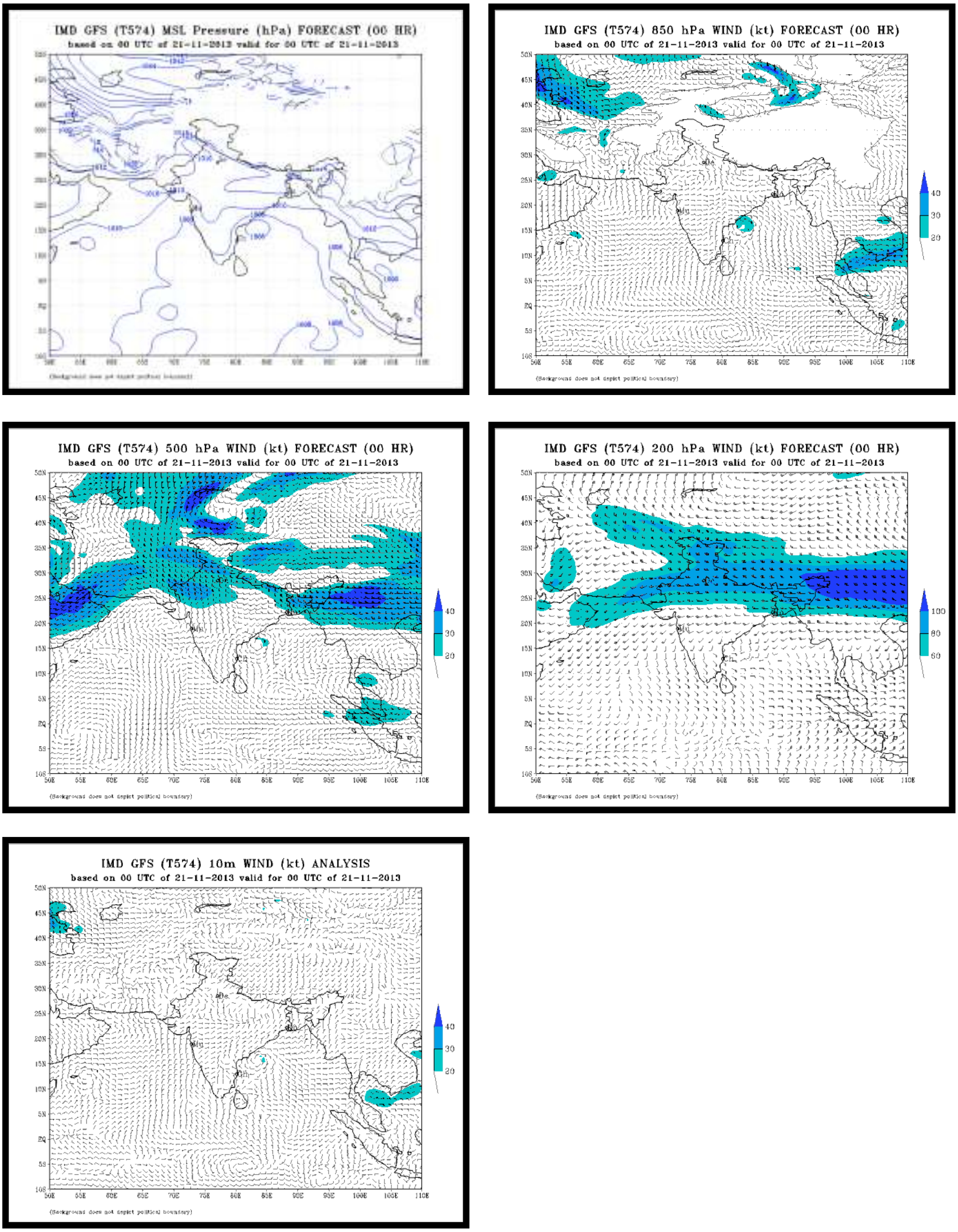


Fig.2.3.3(c) IMD GFS MSLP and winds at 850, 500 & 200 hPa levels analysis and 10meter wind based on 00 UTC of 21st November, 2013.

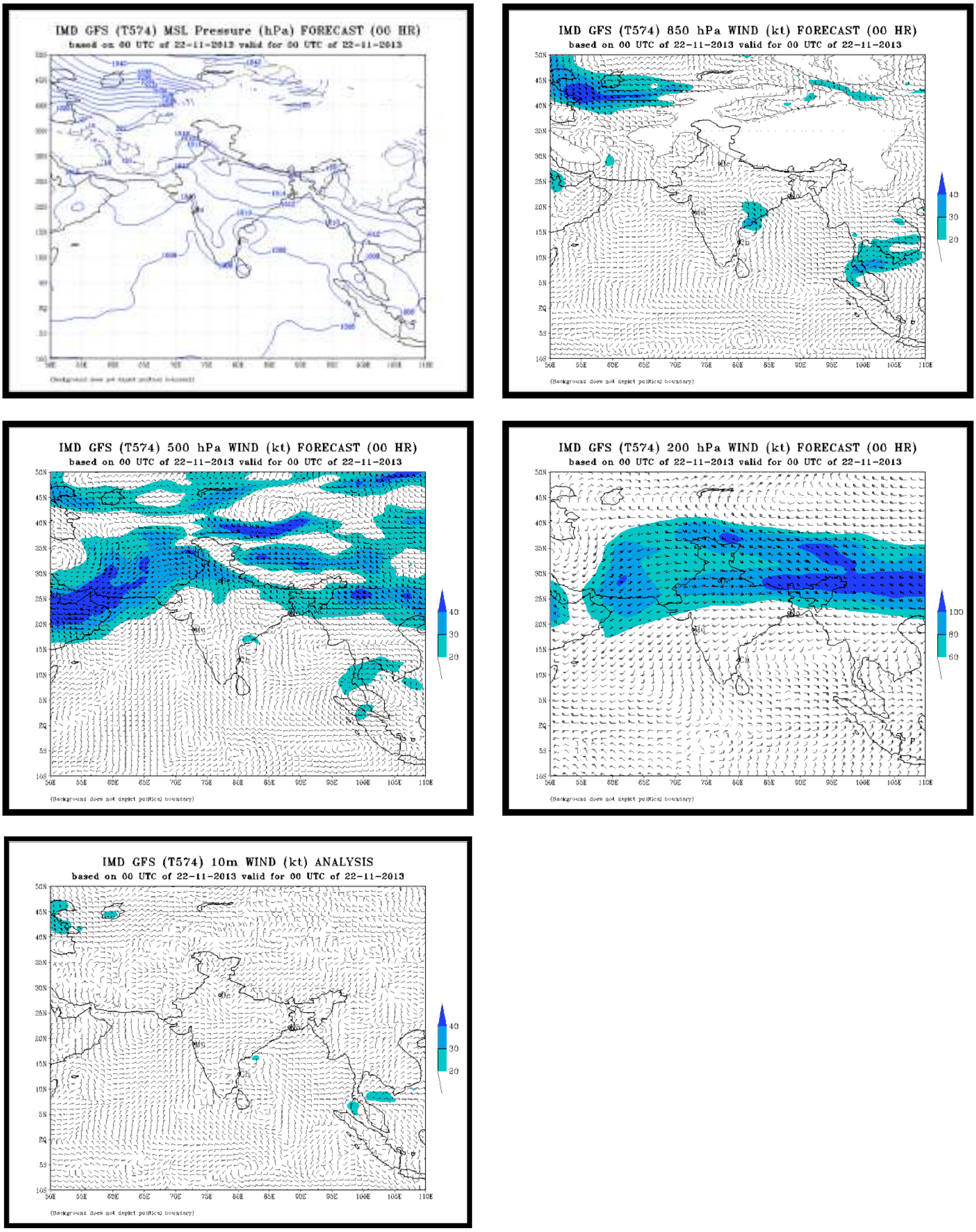


Fig.2.3.3 (d) IMD GFS MSLP and winds at 850, 500 & 200 hPa levels analysis and 10meter wind based on 00 UTC of 22st November, 2013.

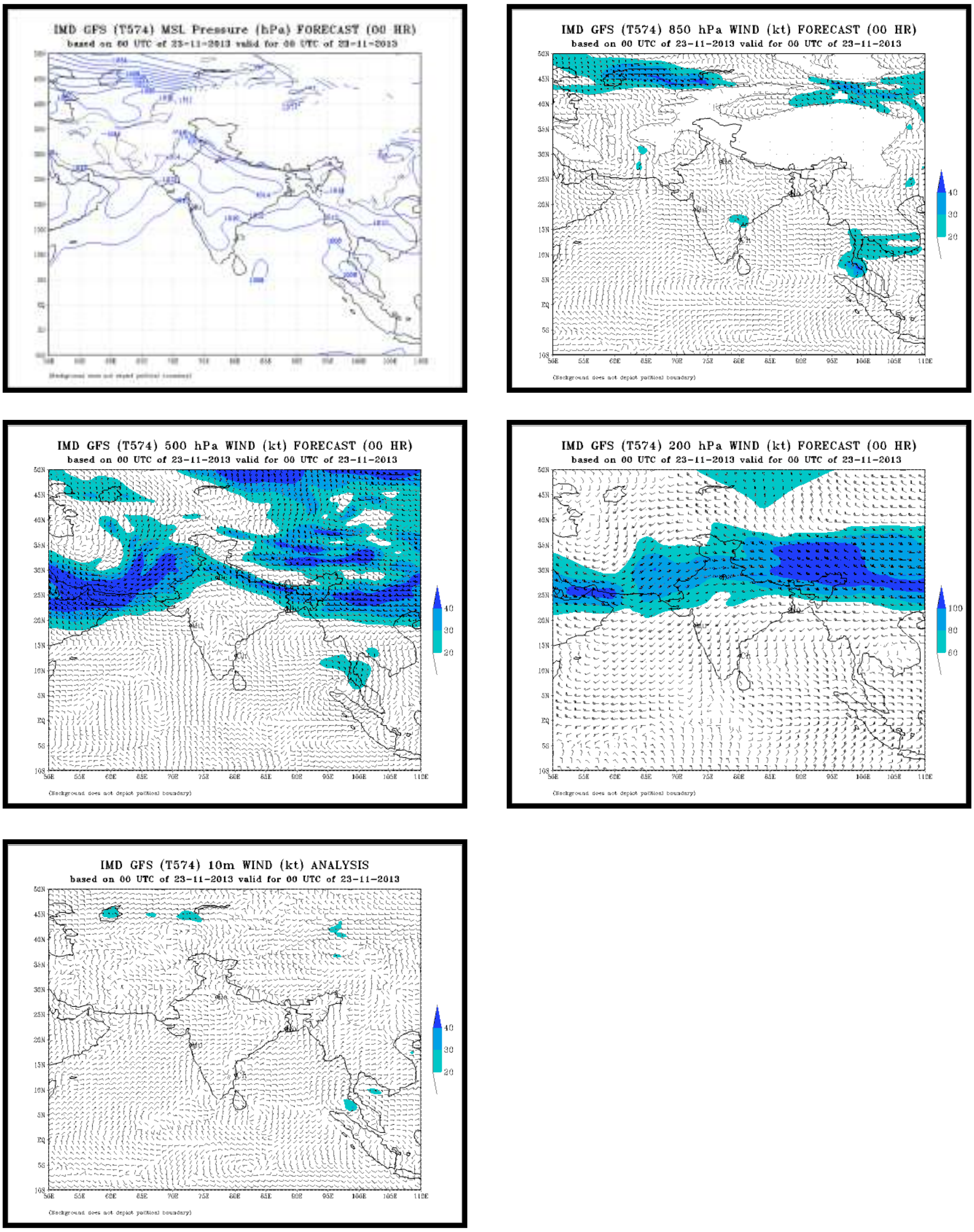


Fig.2.3.3(e) IMD GFS MSLP and winds at 850, 500 & 200 hPa levels analysis and 10meter wind based on 00 UTC of 23rd November, 2013.

Table 2.3.2. Centre of Cyclone HELEN based on DWR, Visakhapatnam

Date/Time (UTC)	Intensity	Lat/Long N/E
19.11.13/0000	Depression	14.5/86.5
19.11.13/0300	Depression	14.5/86.0
19.11.13/0600	Depression	14.5/85.5
19.11.13/1200	Depression	15.0/85.0
19.11.13/1500	Deep Depression	15.0/85.0
19.11.13/1800	Deep Depression	15.0/84.5
20.11.13/0000	Deep Depression	15.0/84.0
20.11.13/0300	Cyclonic Storm	15.0/84.0
20.11.13/0600	Cyclonic Storm	15.2/84.0
20.11.13/0900	Cyclonic Storm	15.2/84.0
20.11.13/1200	Cyclonic Storm	15.3/83.9
20.11.13/1800	Cyclonic Storm	15.4/83.7
20.11.13/2100	Cyclonic Storm	15.5/83.6
21.11.13/0000	Severe Cyclonic Storm	15.6/83.5
21.11.13/0300	Severe Cyclonic Storm	15.8/83.4
21.11.13/0600	Severe Cyclonic Storm	15.9/83.3
21.11.13/0900	Severe Cyclonic Storm	16.0/83.1
21.11.13/1200	Severe Cyclonic Storm	16.1/82.9
21.11.13/1500	Severe Cyclonic Storm	16.1/82.7
21.11.13/1800	Severe Cyclonic Storm	16.2/82.5
21.11.13/2100	Severe Cyclonic Storm	16.2/82.3
22.11.13/0000	Severe Cyclonic Storm	16.2/81.9
22.11.13/0300	Severe Cyclonic Storm	16.2/81.7
22.11.13/0600	Severe Cyclonic Storm	16.2/81.3
22.11.13/0800-0900	Cyclonic Storm	16.1/81.2
22.11.13/0900	Cyclonic Storm	16.1/81.0
22.11.13/1200	Deep Depression	15.9/80.7
22.11.13/1800	Depression	15.9/80.4

2.3.5 Realized Weather:

a. Surface Wind: Gale wind speed reaching of 80-90 kmph gusting to 100 kmph prevailed along and off Andhra Pradesh coast at the time of land fall.

b. Rainfall: Chief amounts of 24 hrs. Rainfall (7 cm or more) ending at 0300 UTC from 19th November to 23rd November, 2013 are given below:

19 November 2013

Andaman & Nicobar Islands: Maya Bandar-7

Tamilnadu & Puducherry: Sankarapuram-10, Mayiladuthurai-8 Karaikal-7, Kodavasal-7, Kerala: Piravom-8

20 November 2013 - Nil

21 November 2013
Tamilnadu & Puducherry: Colachel-12, Thuckalay-9, Eraniel-8

22 November 2013
Coastal Andhra Pradesh: Visakhapatnam-11
Tamilnadu & Puducherry: Sivagiri-9
Kerala: Nedumangad-7, Alappuzha-7

23 November 2013
Coastal Andhra Pradesh: Gudivada-13, Vijayawada A.P.-10, Visakhapatnam Ap-10, Masulipatnam-9, Visakhapatnam-7

24 November 2013
Telangana: Narayan Khed-12
Tamilnadu & Puducherry: Watrap-15, Rajapalayam-14, Nanguneri-10, Sivakasi-9, Sivagiri-8, Colachel-8, Uttamapalayam-7, Sankarankoil-7, Coastal Karnataka: Dharmasthala-7
South Interior Karnataka: Bangalore-11, Devanhalli-9, K.R.Nagara-7, Kottigehara-7, Arkalgud-7, Kerala: Punalur-9, Kurudamannil-9.

2.3.6. Damage Report:

The cyclone, Helen caused considerable damage over coastal Andhra Pradesh, especially over Krishna, west & east Godavari districts. It uprooted trees and electrical poles and damaged crops (paddy, banana & coconut etc). The typical damage photographs are shown in Fig. 2.3.4 Number of human death was 11 due to this system.

Fig.2.3.4. Damage over Machilipatnam and Koduru due to SCS Helen.

2.4 Very Severe Cyclonic Storm VSCS ‘Lehar’(23-28 November, 2013)

2.4.1 Introduction

A depression formed over south Andaman sea on 23rd evening and it intensified into a cyclonic storm, **Lehar** in the early morning of 24th November 2013 near Latitude 10.0°N and longitude 95.0°E. Moving northwestward, it crossed Andaman & Nicobar Islands near Port- Blair around 0000 UTC of 25th November as a severe cyclonic storm. On 25th morning it emerged into southeast Bay of Bengal and moved west-northwestward, intensified into a very severe cyclonic storm in the early hours of 26th Nov. However while moving west-northwestwards over westcentral Bay of Bengal, it rapidly weakened from 27th afternoon and crossed Andhra Pradesh coast close to south of Machilipatnam around 0830 UTC of 28th Nov. 2013 as a depression.

The salient features of this system are given below:

(i) It was the first severe cyclonic storm to cross Andaman and Nicobar Islands after November, 1989.

(ii) It had second landfall near Machilipatnam as a depression.

(iii) It rapidly weakened over the sea from the stage of very severe cyclonic storm to depression in 18 hrs.

Brief life history and other characteristics of the system are described below:

2.4.2 Monitoring and Prediction

The very severe cyclonic storm, ‘LEHAR’ was monitored mainly with satellite supported by meteorological buoys, coastal and island observations and Doppler Weather Radar(DWR), Machilipatnam. The half hourly INSAT/KALPANA imageries, hourly coastal observations and every 10 minutes DWR imageries and products were used for monitoring of cyclonic storm.

Various numerical weather prediction (NWP) models and dynamical-statistical models including IMD’s global and meso-scale models were utilized to predict the track and intensity of the storm. The Tropical Cyclone Module in the digitized forecasting system of IMD was utilized for analysis and comparison of various NWP models and decision making process. However, there was large divergence in NWP model guidance with respect to genesis and intensification of the system. There was more unanimity in the NWP models with respect to track prediction.

2.4.3 Genesis

A remnant of tropical depression over south China Sea moved across Malay peninsula and lay as a low pressure area over south Andaman Sea on 21st November, 2013. It became well marked over the same area on 22nd and concentrated into a depression over south Andaman Sea near latitude 08.5°N and longitude 96.5°E about 550 km south-southeast of Port Blair at 1200 UTC of 23rd November, 2013. The genesis was detected with the Ocean Sat-II winds and the observation from the coast of Thailand in addition to satellite imageries. The genesis was associated with upper troposphere ridge which ran along 13° N and provided adequate upper level divergence through Poleward outflow. The lower level convergence and relative vorticity increased over the area from 22nd to 23rd November. The sea surface temperature was 28-29°C and Ocean thermal energy was 60-80 kJ/cm^2. The vertical wind shear of horizontal wind was moderate (10-20 knots). The Madden Julian oscillation (MJO) index lay in Phase 3 i.e. over east equatorial Indian Ocean. Past studies indicate that the Phase 3 is favorable for genesis of depression.

2.4.4 Intensification and movement

Due to the favourable atmospheric and Oceanic condition as mentioned above, the depression over south Andaman Sea moved northwestwards, intensified into a deep depression at 1800 UTC of 23rd and further into a cyclonic storm, 'Lehar' at 0300 UTC of 24th November and lay centred near latitude 10.0°N and longitude 95.0° E. It further intensified into a severe cyclonic storm, continued to move northwestwards and crossed Andaman & Nicobar Island near Port Blair around 0000 UTC of 25th November, 2013. It then emerged into southeast Bay of Bengal, moved west-northwestwards and intensified into a very severe cyclonic storm at 2100 UTC of 26th November, 2013 over southeast Bay of Bengal near latitude 12.5° N and longitude 91.0°E. It attained the maximum intensity of 75 knots at 1800 UTC of 26th November, 2013 and the same intensity continued till 0300 UTC of 27th November, 2013 when it lay over central Bay of Bengal.

As the westcentral Bay of Bengal was colder with Ocean thermal energy less than 50 KJ/cm^2 and there was entrainment of dry and cold air from central and northern parts of India into the cyclone field and vertical wind shear of horizontal wind increased and became high, the very severe cyclonic storm started to weaken rapidly from the afternoon of 27th November, 2013. It weakened into a severe cyclonic storm at 1200 UTC of 27th November and lay centred near latitude 14.5°N and longitude 85.0°E. It further weakened into a cyclonic storm at 1800 UTC of 27th November, 2013 with centre near latitude 15.0°N and longitude 84.0°E over westcentral Bay of Bengal. It weakened into a deep depression at 0000 UTC of 28th November, 2013 with centre near latitude 15.5°N and longitude 82.0°E. At this time the vertical wind shear was high (about 20 knots). It weakened into a depression and crossed Andhra Pradesh coast near latitude 15.9°N and longitude 81.1°E (close to south of Machilipatnam) around 0830 UTC of 28th November, 2013. It weakened into a well marked low pressure area over coastal Andhra Pradesh and adjoining Telengana at 1800 UTC of 28th November, 2013.

The system moved northwestwards/west-northwestwards as it lay to the south of the upper tropospheric steering ridge which moved northward from its position near latitude 13.0°N on the day of genesis to latitude 17°N on the day of landfall. The best track position and other parameters of the Very Severe Cyclonic Storm 'Lehar' over the Bay of Bengal is given in Table 2.4.1 and the track of the very severe cyclonic storm 'Lehar' is given in Fig 2.1. Visakhapatnam & Machilipatnam RADAR imageries, Satellite imageries and IMD GFS MSLP and wind at 850, 500 and 200 hPa levels are shown in Fig. 2.4.1-3 respectively. The position of the cyclone 'Lehar' based on DWR, Visakhapatnam is shown in Table 2.4.2.

Table 2.4.1 Best track positions and other parameters of the Very Severe Cyclonic Storm 'Lehar' over the Bay of Bengal during 23-28 November, 2013

Date	Time (UTC)	Centre lat.^{0} N/ long.^{0} E	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
23-11-2013	1200	8.5/96.5	1.5	1004	25	3	D
	1800	9.0/96.0	2.0	1002	30	5	DD
24-11-2013	0000	10.0/95.0	2.5	999	35	7	CS
	0300	10.0/95.0	2.5	998	40	8	CS
	0600	10.5/94.5	2.5	998	40	8	CS
	0900	10.7/94.0	3.0	996	45	10	CS
	1200	11.0/93.5	3.0	996	45	10	CS
	1500	11.0/93.5	3.0	996	45	10	CS
	1800	11.5/93.0	3.0	996	45	10	CS
	2100	11.5/92.5	3.0	996	45	12	CS
25-11-2013	The system crossed Andaman & Nicobar island, south of Port Blair around 0000 UTC						
	0000	12.0/92.5	3.5	992	55	15	SCS
	0600	12.0/91.5	3.5	988	55	17	SCS
	0900	12.0/91.5	3.5	988	60	17	SCS
	1200	12.5/91.5	3.5	988	60	17	SCS
	1500	12.5/91.0	3.5	988	60	17	SCS
	1800	12.5/91.0	3.5	988	55	17	SCS
	2100	12.5/91.0	4.0	984	65	22	VSCS
26-11-2013	0000	12.5/90.5	4.0	982	70	24	VSCS
	0300	12.5/90.0	4.0	982	70	24	VSCS
	0600	12.5/89.5	4.0	982	70	24	VSCS
	0900	13.0/89.0	4.0	982	70	24	VSCS
	1200	13.0/88.5	4.0	982	70	24	VSCS
	1500	13.0/88.5	4.0	982	70	24	VSCS
	1800	13.1/88.0	4.0	980	75	26	VSCS
	2100	13.2/87.5	4.0	980	75	26	VSCS
27-11-2013	0000	13.5/87.0	4.0	980	75	26	VSCS
	0300	13.5/86.5	4.0	980	75	26	VSCS
	0600	14.0/86.0	4.0	982	70	24	VSCS
	0900	14.0/85.5	4.0	984	65	22	VSCS
	1200	14.5/85.0	3.5	988	55	17	SCS
	1500	14.5/84.5	3.5	988	55	17	SCS
	1800	15.0/84.0	3.0	996	45	10	CS
	2100	15.0/83.5	2.5	998	40	8	CS
28-11-2013	0000	15.5/82.0	2.0	1000	30	5	DD
	0300	15.7/81.7	2.0	1000	30	5	DD
	0600	15.7/81.3	2.0	1000	30	5	DD
	The system crossed Andhra Pradesh close to south of Machilipatnam near 15.9^{0}N/81.1^{0} E around 0830 UTC						
	0900	15.9/81.0	-	1002	25	4	D

	1200	16.0/80.8	-	1004	20	3	D
	1800	Weakened into a well marked low pressure area over coastal Andhra Pradesh and adjoining Telengana.					

Table 2.4.2 Position of Very Severe Cyclonic Storm 'LEHAR' based on DWR Visakhapatnam

Date	Time(UTC)	Intensity	Lat ^{O}N	Long^{O}E
23.11.13	1200	D	08.5	96.5
	1800	DD	09.0	96.0
	2100	DD	---	---
24.11.13	0000	CS	10.0	95.0
	0300	CS	10.0	95.0
	0600	CS	10.5	94.5
	0900	CS	10.5	94.0
	1200	CS	11.0	93.5
	1800	CS	11.5	93.0
	2100	CS	11.5	92.5
25.11.13	0000	SCS	12.0	92.5
	0300	SCS	12.0	92.0
	0600	SCS	12.0	91.5
	0900	SCS	12.0	91.5
	1200	SCS	12.5	91.0
	1500	SCS	12.5	91 .0
	1800	SCS	12.5	91.0
	2100	VSCS	12.5	91.0.
26.11.13	0000	VSCS	12.5	90.5
	0300	VSCS	12.5	90.0
	0600	VSCS	12.6	89.5
	0900	VSCS	13.0	89.0
	1200	VSCS	13.0	88.5
	1500	VSCS	13.0	88.5
	1800	VSCS	13.0	88.0
	2100	VSCS	13.2	87.5
27.11.13	0000	VSCS	13.5	87.0
	0300	VSCS	13.5	86.5
	0600	VSCS	14.0	86.0
	0900	VSCS	14.0	85.5
	1200	SCS	14.5	85.0
	1500	SCS	14.5	84.5
	1800	CS	15.0	84.0
	2100	CS	15.0	83.5
28.11.13	0000	DD	15.5	82.0
	0300	DD	15.7	81.7
	0600	DD	15.7	81.3
	0900	D	15.9	81.1

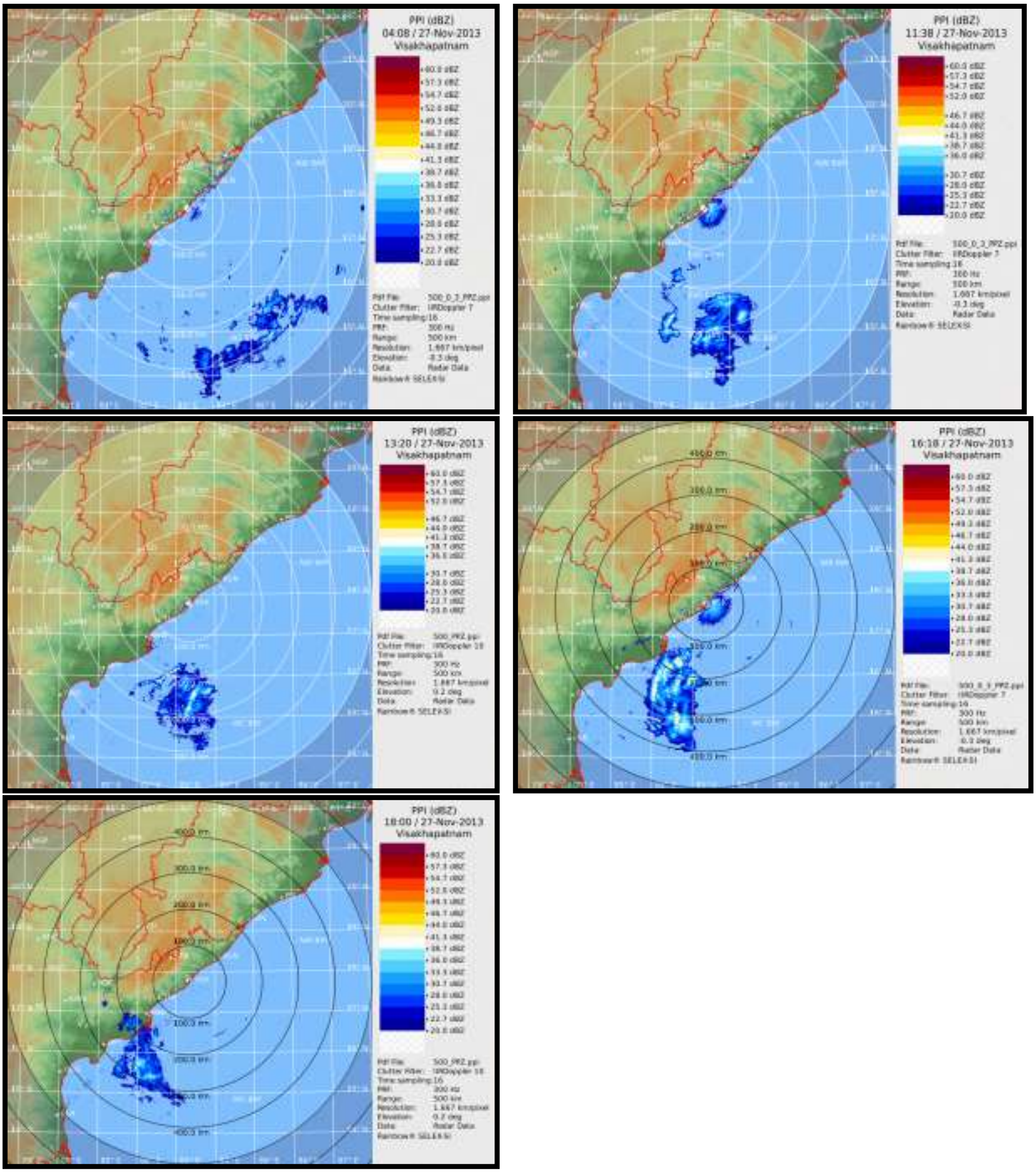


Fig.2.4.1(a) Visakhapatnam RADAR imageries based on 0400,1140,1320,1620 & 1800 UTC of 27th November, 2013

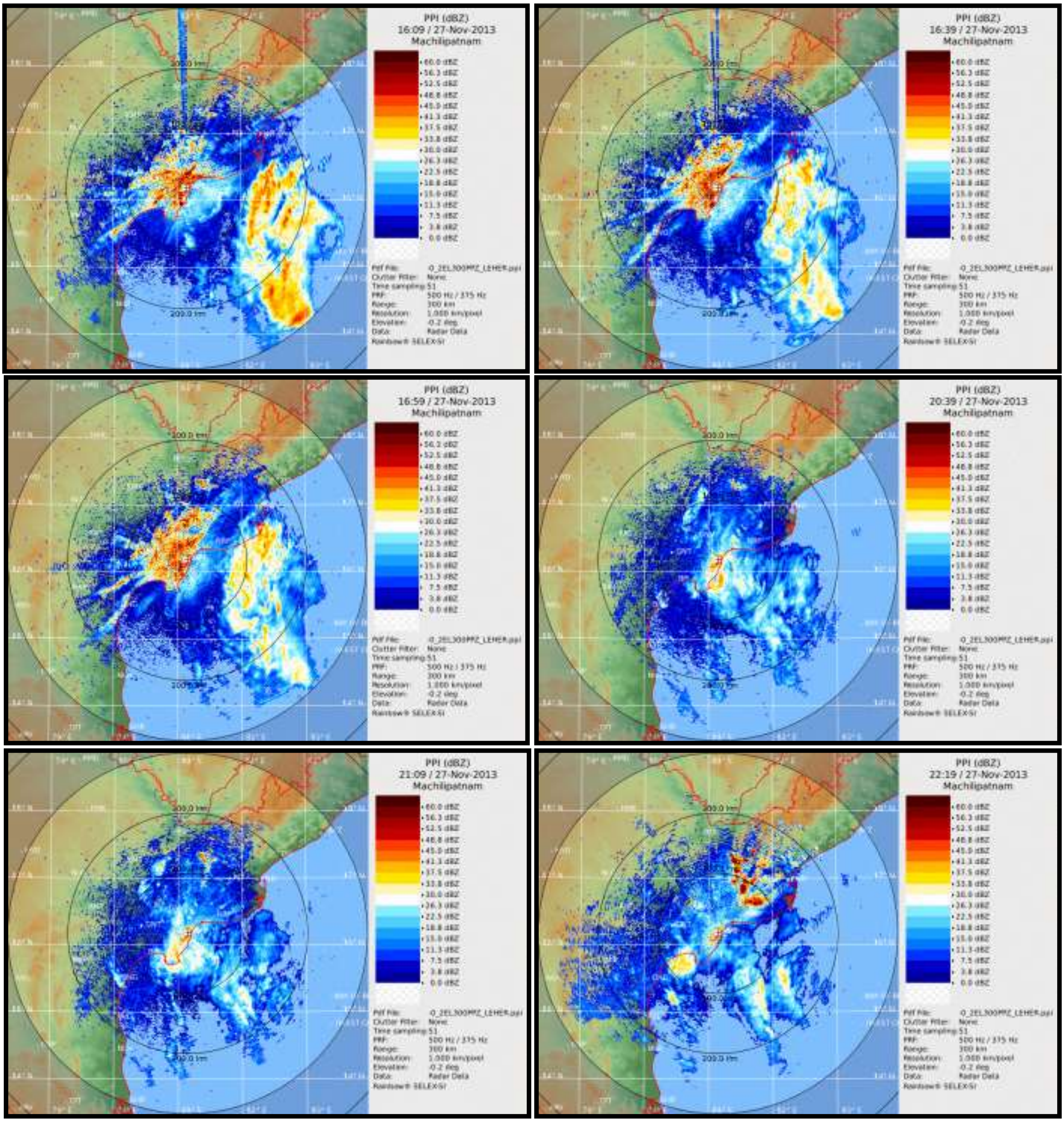


Fig. 2.4.1(b) Machilipatnam RADAR imageries on 27th November, 2013

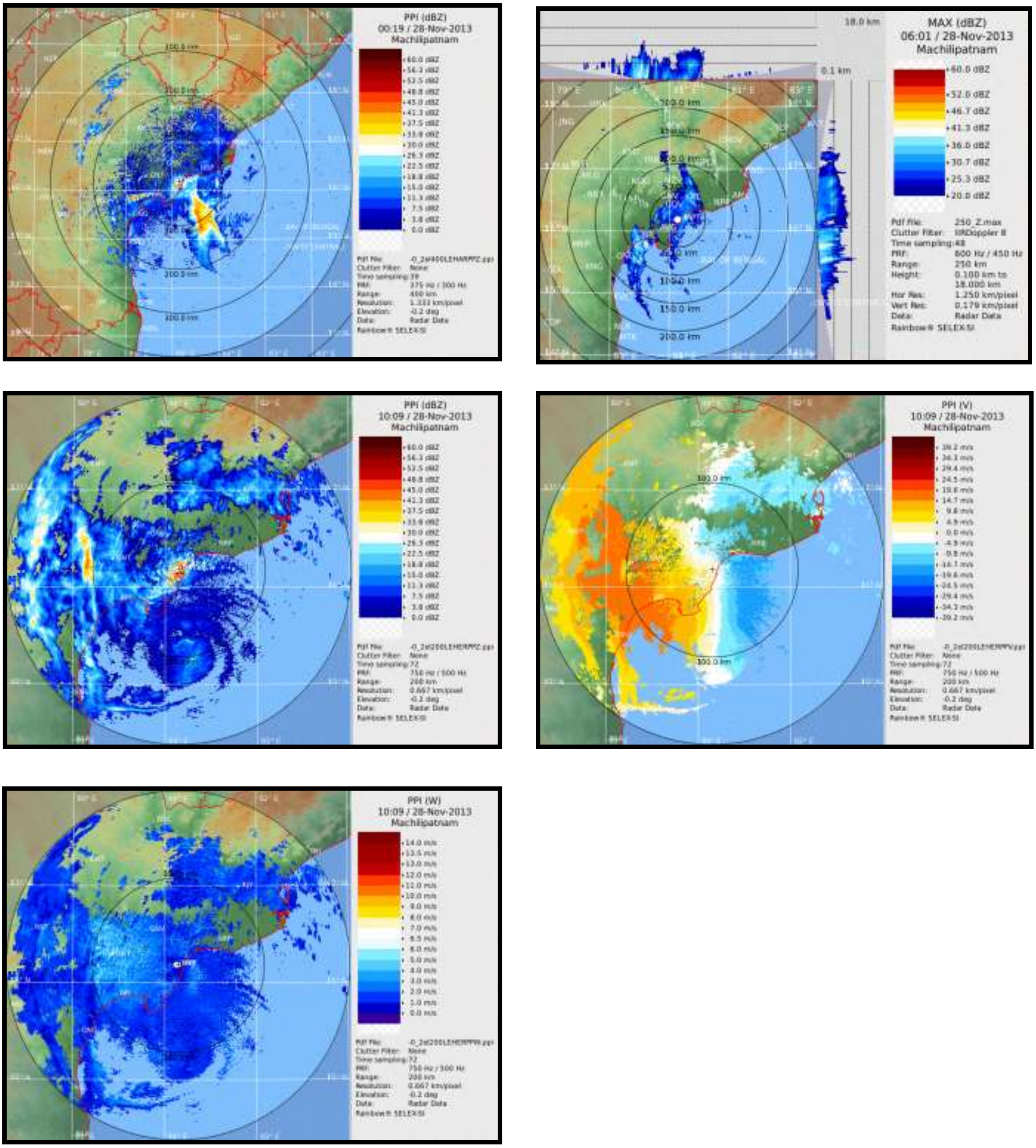


Fig.2.4.1(c) Machilipatnam RADAR imageries on 28th November, 2013

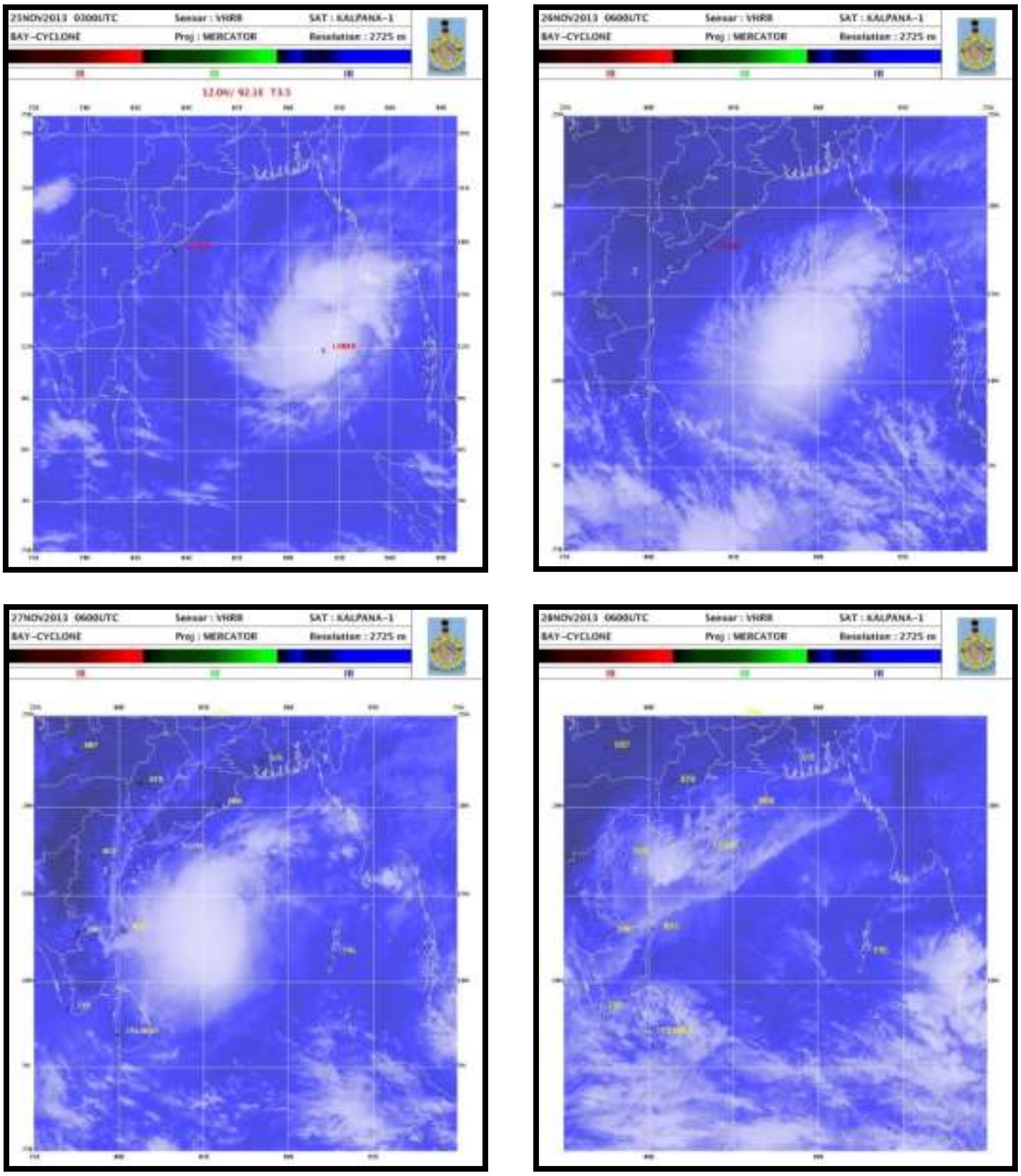


Fig. 2.4.2 Satellite imageries based on 0300 UTC of 25th and 0600 UTC of 26th, 27th and 28th November, 2013

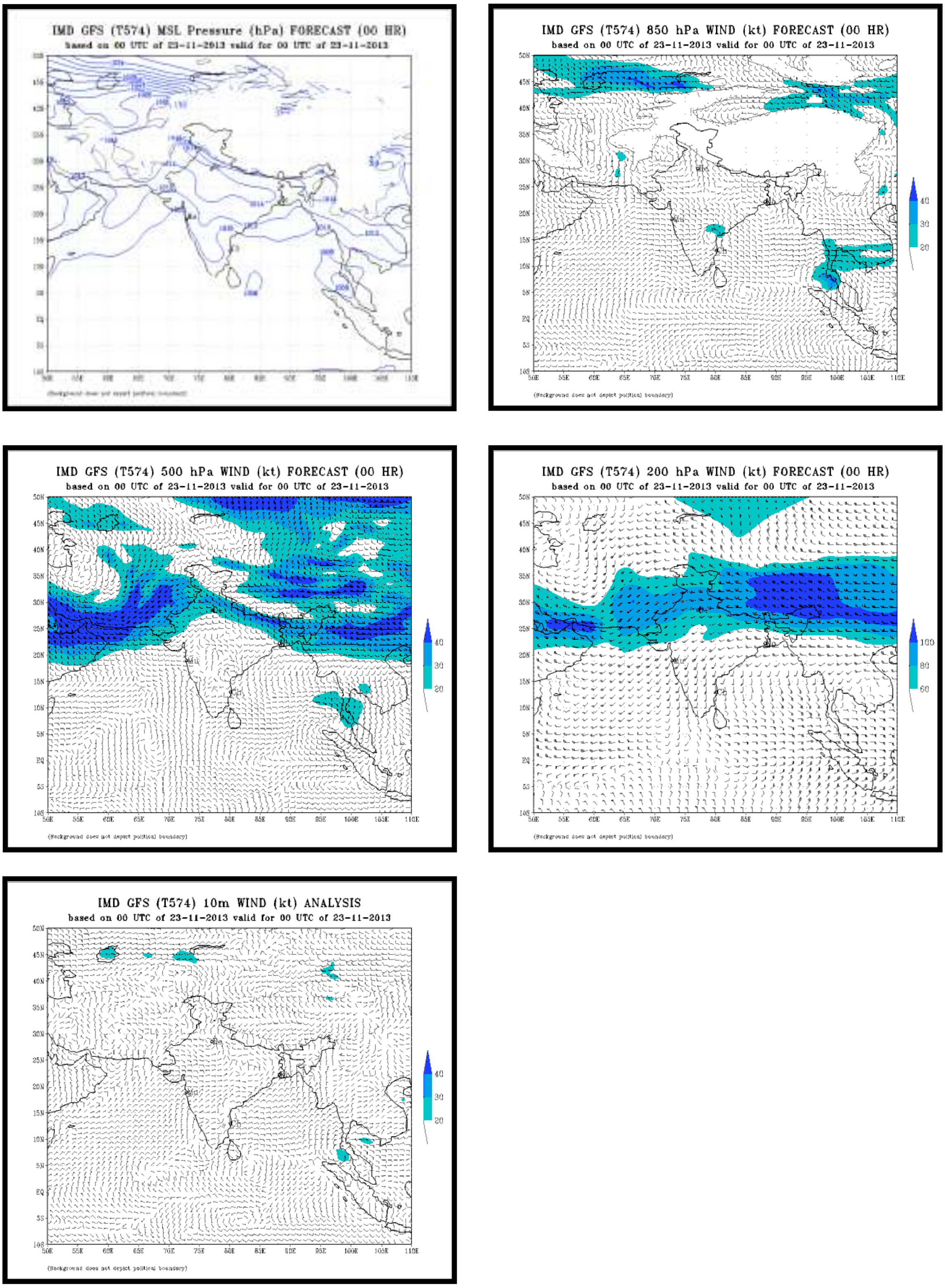


Fig.2.4.3 (a) IMD GFS MSLP and winds at 850, 500 & 200 hpa levels analysis and 10meter wind based on 00 UTC of 23rd November, 2013.

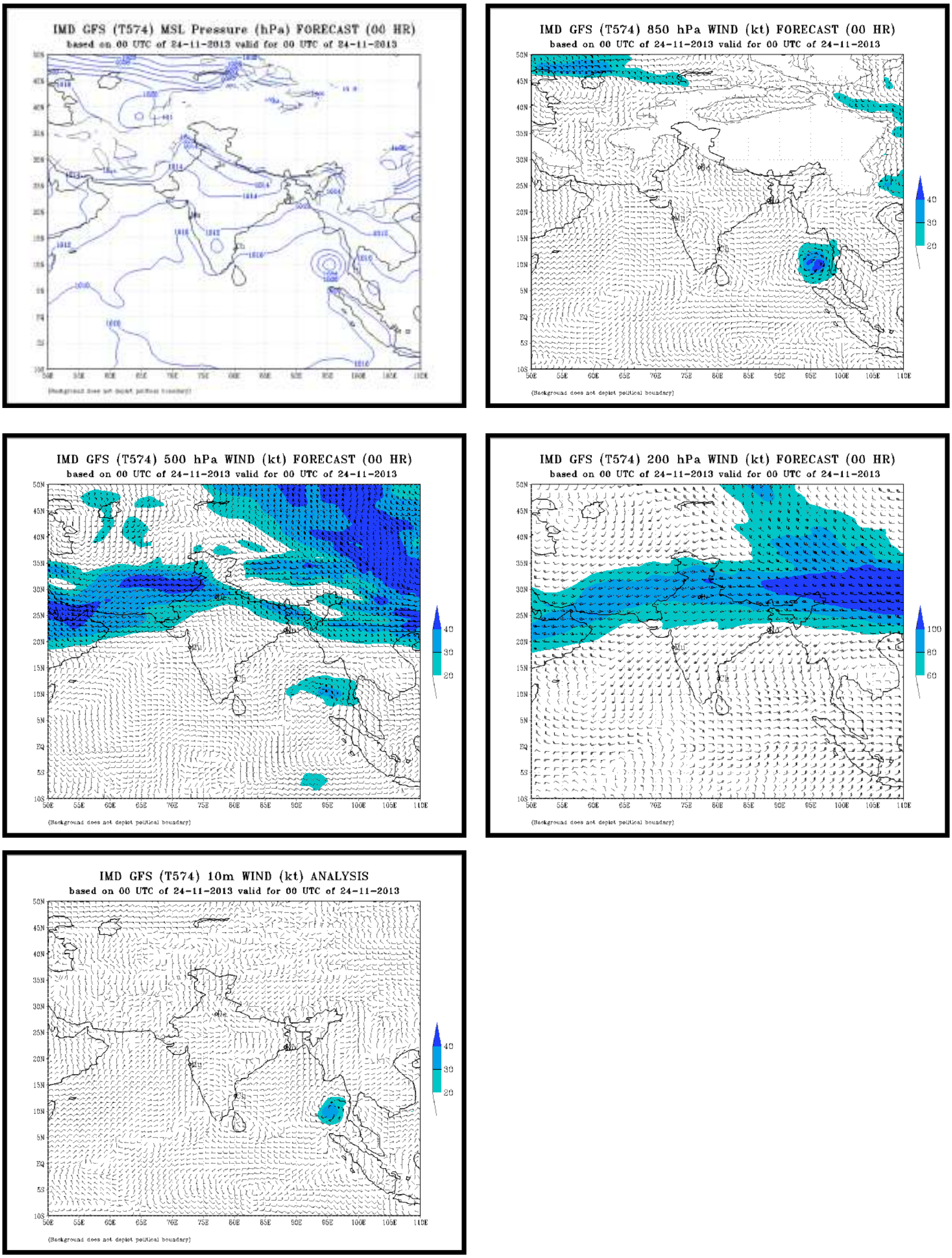


Fig.2.4.3(b) IMD GFS MSLP and winds at 850, 500 & 200 hpa levels analysis and 10meter wind based on 00 UTC of 24th November, 2013.

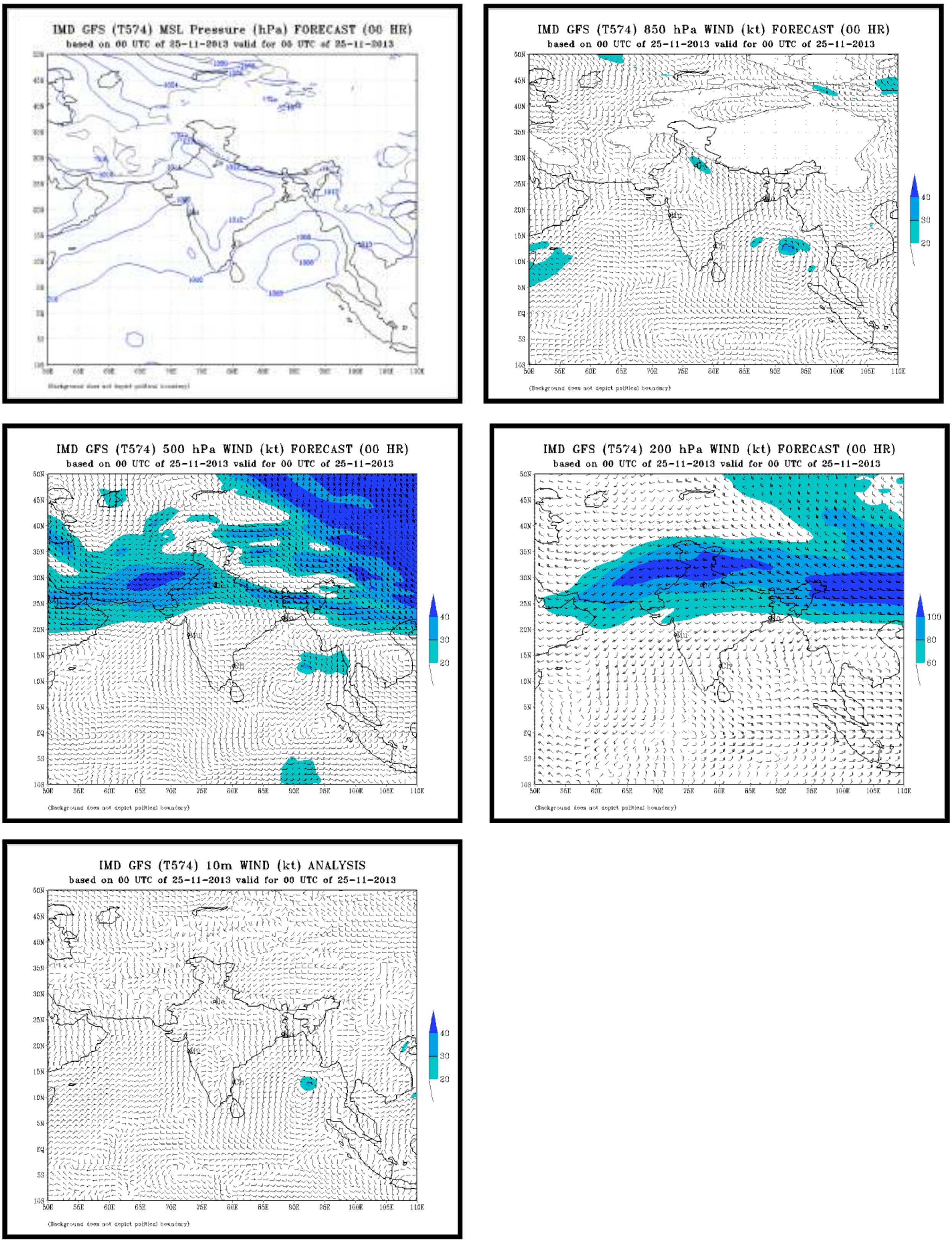


Fig.2.4.3(c) IMD GFS MSLP and winds at 850, 500 & 200 hpa levels analysis and 10meter wind based on 00 UTC of 25th November, 2013.

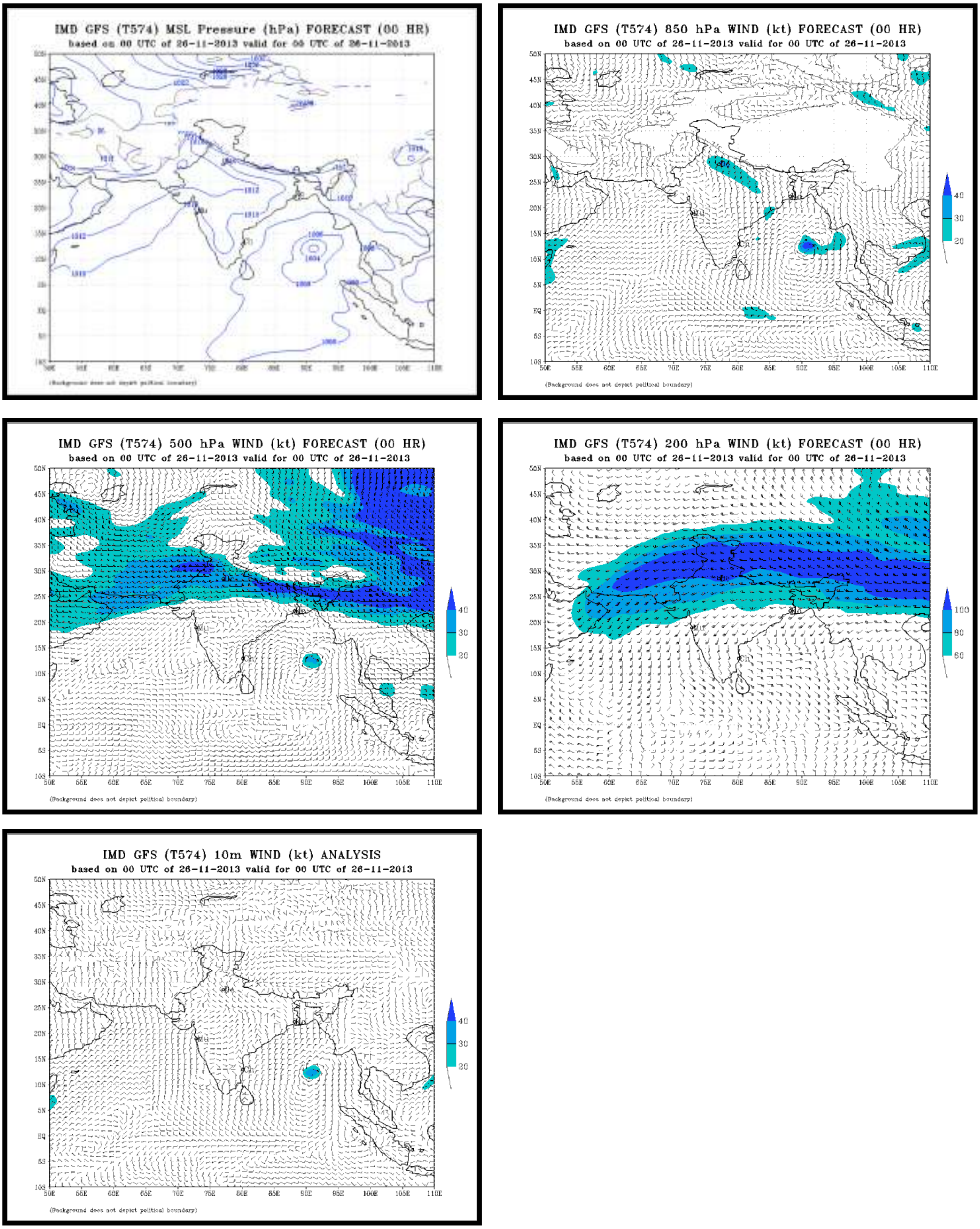


Fig.2.4.3(d) IMD GFS MSLP and winds at 850, 500 & 200 hpa levels analysis and 10meter wind based on 00 UTC of 26th November, 2013.

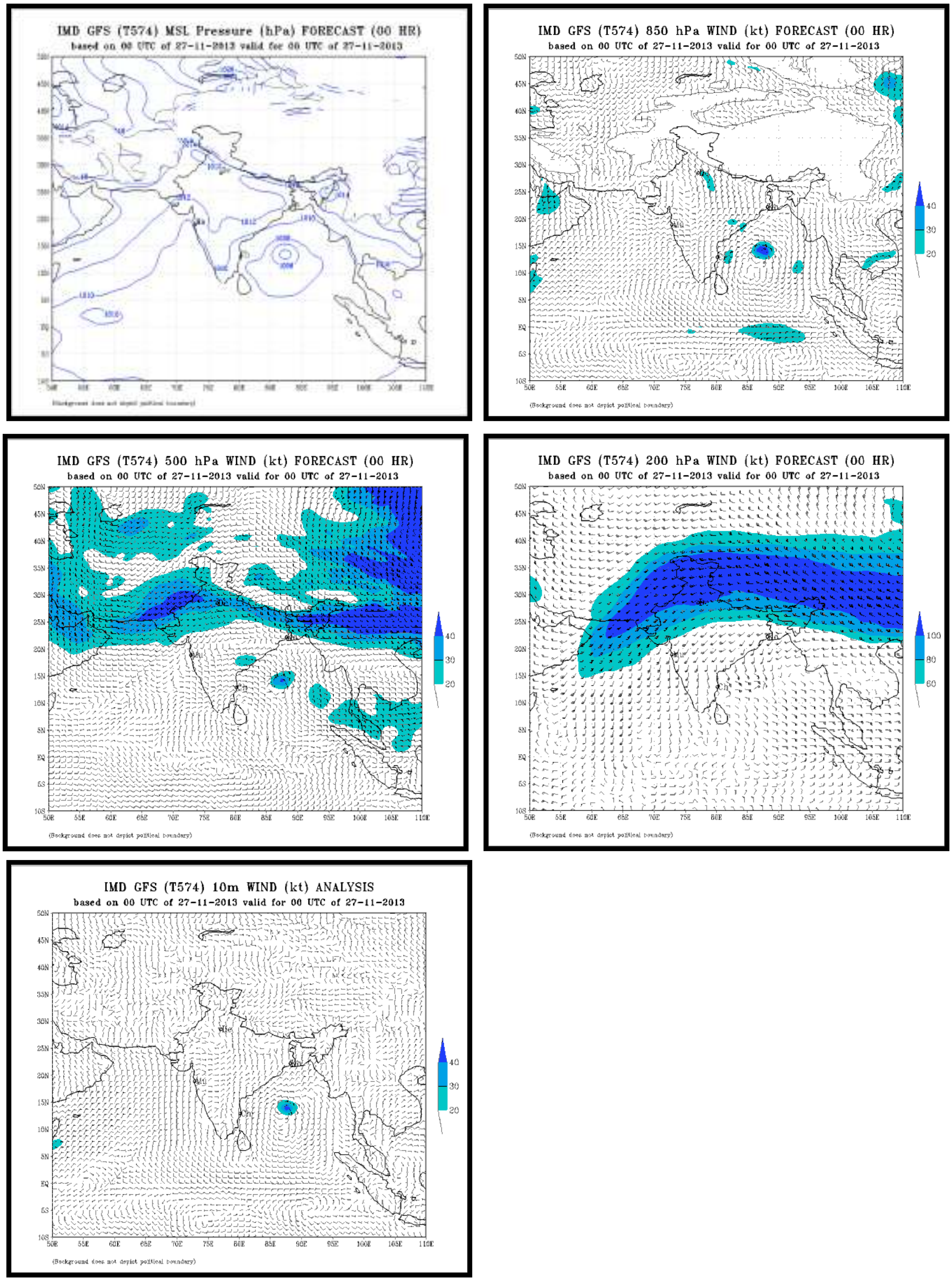


Fig.2.4.3(e) IMD GFS MSLP and winds at 850, 500 & 200 hpa levels analysis and 10meter wind based on 00 UTC of 27th November, 2013.

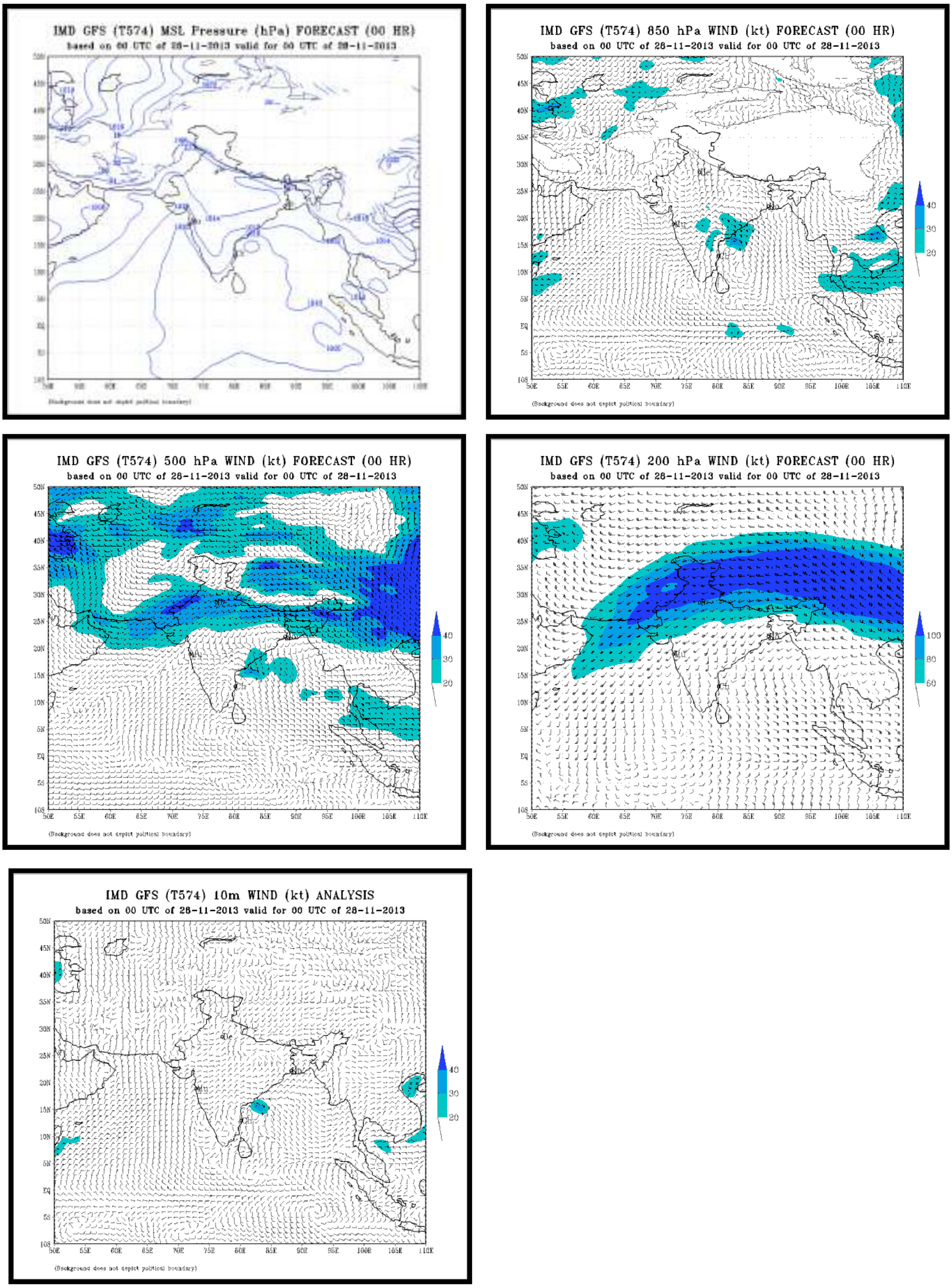


Fig.2.4.3(f) IMD GFS MSLP and winds at 850, 500 & 200 hpa levels analysis and 10meter wind based on 00 UTC of 28th November, 2013.

2.4.5 Realized Weather:

Chief amounts of 24 hrs. Rainfall (7 cm or more) ending at 0300 UTC from 23rd November to 29th November, 2013 are given below:
23 November 2013 - Nil
24 November 2013 – Nil
25 November 2013
Andaman & Nicobar Islands: Maya Bandar-24, Port Blair-21, Long Island-11,
26 and 27 November 2013 – Nil
28 November 2013
Kerala: Angadippuram-8,
29 November 2013
Coastal Andhra Pradesh: Macharla-7

2.4.6 Damage: No damage has been reported due to this system

2.5 Very Severe Cyclonic Storm 'Madi' (06-13 December 2013)

2.5.1 Introduction

A cyclonic storm 'Madi' formed over southwest Bay of Bengal on 7th December. It initially moved northwards intensified upto very severe cyclonic storm. After crossing Lat. 15^0 N it wekened due to unfavourable conditions and recurved southwestwards. It crossed Tamil Nadu coast near Vedaranyam around 1330 UTC of 12th Dec., emerged into Palk strait around 1500 UTC and again crossed Tamil Nadu coast near Tondi around 1700 UTC of 12th December 2013. It then emerged into southeast Arabian Sea as a well marked low pressure area in the early morning of 13th Oct. 2013. Salient features of the system are given below:

(i) It has a unique track with near northerly movement till 15.7^0N and then recurving southwestwards to Tamil Nadu coast.
(ii) It moved very slowly during its northward journey and speed peaked up gradually after the recurvature to southwest.
(iii) The genesis, track, intensification and weakening of the system was well predicted by IMD.
(iv) Most of the numerical weather prediction (NWP) models could predict genesis, track, intensification and weakening of the system. However there was large divergence about the place and time of recurvature from the northerly to southwesterly movement.

2.5.2 Monitoring and Prediction

The very severe cyclonic storm, MADI was monitored mainly with satellite supported by meteorological buoys, coastal and Island observations. It was monitored by Doppler Weather Radar (DWR), Chennai, Visakhapatnam and Machilipatnam. The half hourly INSAT/ Kalpana imageries, hourly coastal observations and every 10 minutes DWR imageries and products were used for monitoring of cyclone.

Various NWP models and dynamical-statistical models including IMD's global and meso-scale models were utilized to predict the track and intensity of the storm. The Tropical Cyclone Module in the digitized forecasting system of IMD was utilized for analysis and comparison of various NWP models and decision making process.

2.5.3 Genesis

A low pressure area from south China Sea moved across Malay peninsula and emerged into south Andaman Sea on 01st December, morning. Moving westwards it lay over southeast Bay of Bengal on 02nd December. Continuing its westwards movement, it lay over southwest Bay of Bengal off Sri Lanka coast on 03rd December, 2013. It persisted over the same region and became well marked on 04th December. It further concentrated into a depression in the morning of 06th December over southwest Bay of Bengal and lay centered near latitude 10.0°N and longitude 84.0°E, about 350 km northeast of Tricomalee (Sri Lanka). The genesis was declared using the sea surface wind observations based on ASCAT and OceanSat-II. Also the ship and buoy observations near the centre supported the genesis. A ship near latitude 11.9°N and Longitude 85.4°E reported wind speed of 080/23 knots. The sea surface temperature during genesis was about 26-28°C and ocean thermal energy was about 60-80 $KJ/cm^{2.}$ The vertical wind shear was moderate (10-20 knots). The lower level convergence and relative vorticity increased from 05th to 06th December, 2013, along with increase in upper tropospheric divergence. The Madden Julian Oscillation (MJO) index lay over the phase-3 i.e. equatorial Indian Ocean adjoining Bay of Bengal with amplitude less than1. Past studies indicate that phase 3 is favourable for genesis of the system.

2.5.4 Intensification and movement

As the system lay over the warmer sea surface region alongwith higher ocean thermal energy and low to moderate vertical wind shear, it gradually intensified into a deep depression at 1800 UTC of 06th December while remaining practically stationary over the region. The depression remained practically stationary, as it lay close to the upper troposphere ridge which ran along 10°N. It led to very slow northward movement afterwards. The deep depression further intensified into a cyclonic storm 'MADI' with centre near latitude 10.5°N and longitude 84.0°E at 0000 UTC of 07th December, 2013. It intensified into a severe cyclonic storm over the same region at 0900 UTC of 07th December, 2013. As it lay slightly to the north of the ridge, the severe cyclonic storm then moved slightly north-northeastwards and intensified into a very severe cyclonic storm at 0600 UTC of 08th December, 2013 near latitude 12.3°N and longitude 84.7°E.

As the very severe cyclonic storm moved to the north of 13.0°N i.e. to west central Bay of Bengal, it experienced colder sea surface temperature and low Ocean thermal energy (< 50 KJ/cm^2). Also the vertical wind shear of horizontal gradually increased and became high (20-30 knots). As a result, the very severe cyclonic storm weakened into a severe cyclonic storm at 1200 UTC of 09th December and lay centered near latitude14.6°N and longitude 84.7°E. It continued to move slowly north-northeastwards till 0900 UTC of 10th December as a severe cyclonic storm upto latitude 15.7°N and longitude 85.3°E under the influence of the upper tropospheric steering ridge which moved northward alongwith northward movement of system. However, due to gradual weakening of system, the steering level changed from upper troposphere to lower and middle troposphere. The influence of the upper tropospheric anticyclonic circulation to the east of system centre decreased and that of lower and middle level anticyclonic circulation lying to the west of the system centre (over central India) increased. As a result, the severe cyclonic storm re-curved westwards initially and then southwestwards commencing from 0900 UTC of 10th December.

At the same time, the animation of Total Precipitated Water (TPW) imageries indicated that the dry and cold air penetrated into the southwestern periphery of the cyclone. It gradually penetrated further towards the centre of the cyclone from the southern side. As a result, it isolated the core of the cyclone from the warm and moist air from the southeast sector. Hence due to combined impact of colder sea surface temperature, low Ocean thermal energy, high vertical wind shear and incursion of cold and dry air into the core of the cyclone, it gradually weakened into a cyclonic storm near latitude 14.6°N and longitude 84.6°E at 2100 UTC of 10th December 2013, further into a deep depression near latitude14.0°N and longitude 83.8°E at 0300 UTC of 11th December and into a depression near latitude 12.9°N and longitude 82.7°E at 1800 UTC of 11th December.

The depression crossed Tamil Nadu coast close to Vedaranyam around 1330 UTC of 12th December. It then emerged into Palk strait at 1500 UTC, moved west-southwards and again crossed Tamil Nadu coast near Tondi around 1700 UTC of 12th December. It continued to move west-southwestwards across south peninsula and weakened further into a well-marked low pressure area over southeast Andaman Sea and adjoining Kerala at 0000 UTC of 13th December, 2013. It may be mentioned that due to increased convection and organization as per Dvorak estimate the system showed temporary increase in intensity upto very severe cyclonic storm stage during the weakening phase on 10th December (0300-0900 UTC). The best track position and other parameters of the very severe cyclonic Storm 'MADI' over the Bay of Bengal is given in Table 2.5.1 and the track is given in Fig. 2.1. The DWR imageries are shown in Fig.2.5.1. The satellite imageries are shown in fig. 2.5.2. The IMD GFS model analyses are shown in Fig. 2.5.3.

Table 2.5.1 Best track positions and other parameters of the Very Cyclonic Storm 'MADI' over the Bay of Bengal during 06-13 Dec 2013

Date	Time (UTC)	Centre lat.^{0} N/ long. ^{0} E	C.I. NO	Estimated Central Pressure(hPa)	Estimated Maximum sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
06-12-2013	0300	10.0/84.0	1.5	1004	25	3	D
	0600	10.0/84.0	1.5	1004	25	3	D
	1200	10.2/84.0	1.5	1004	25	3	D
	1800	10.4/84.0	2.0	1002	30	5	DD
07-12-2013	0000	10.5/84.1	2.5	998	35	7	CS
	0300	10.5/84.1	2.5	998	35	7	CS
	0600	10.7/84.2	3.0	996	45	10	CS
	0900	10.8/84.3	3.5	992	55	14	SCS
	1200	11.0/84.4	3.5	992	55	14	SCS
	1500	11.0/84.5	3.5	992	55	14	SCS
	1800	11.2/84.5	3.5	990	55	16	SCS
	2100	11.5/84.6	3.5	990	55	16	SCS
08-12-2013	0000	11.8/84.6	3.5	988	60	18	SCS
	0300	12.0/84.6	3.5	988	60	18	SCS
	0600	12.3/84.7	4.0	986	65	20	VSCS
	0900	12.6/84.7	4.0	986	65	20	VSCS
	1200	13.0/84.7	4.0	986	65	20	VSCS
	1500	13.2/84.7	4.0	986	65	20	VSCS

	1800	13.4/84.7	4.0	986	65	20	VSCS
	2100	13.6/84.7	4.0	986	65	20	VSCS
09-12-2013	0000	13.8/84.7	4.0	986	65	20	VSCS
	0300	14.0/84.7	4.0	986	65	20	VSCS
	0600	14.3/84.7	4.0	986	65	20	VSCS
	0900	14.4/84.7	4.0	986	65	20	VSCS
	1200	14.6/84.7	3.5	988	60	18	SCS
	1500	14.7/84.7	3.5	988	60	18	SCS
	1800	14.8/84.8	3.5	988	60	18	SCS
	2100	14.8/84.8	3.5	988	60	16	SCS
10-12-2013	0000	15.0/85.0	3.5	988	60	16	SCS
	0300	15.3/85.3	4.0	988	65	16	VSCS
	0600	15.4/85.3	4.0	988	65	16	VSCS
	0900	15.7/85.3	4.0	988	65	16	VSCS
	1200	15.4/85.0	3.5	990	55	14	SCS
	1500	15.1/84.8	3.5	990	55	14	SCS
	1800	14.9/84.7	3.5	992	50	12	SCS
	2100	14.6/84.6	3.0	994	45	10	CS
11-12-2013	0000	14.3/84.2	3.0	996	40	8	CS
	0300	14.0/83.8	2.0	998	30	6	DD
	0600	13.7/83.5	2.0	998	30	6	DD
	0900	13.5/83.4	2.0	1000	30	5	DD
	1200	13.3/83.3	2.0	1000	30	5	DD
	1800	12.9/82.7	1.5	1000	25	4	D
12-12-2013	0000	12.5/82.0	1.5	1000	25	3	D
	0300	12.0/81.5	1.5	1000	25	3	D
	0600	11.5/81.2	1.5	1000	25	3	D
	0900	11.0/80.7	1.5	1000	25	3	D
	1200	10.5/80.0	1.5	1000	25	3	D
	The system crossed Tamil Nadu coast near Vedaranyam aound 1330 UTC and emerge into Palk straight and again crossed Tamil Nadu coast near Tondi around 1700 UTC						
	1800	10.0/78.8	-	1004	20	3	D
13-12-2013	0000	Weakened into a Well marked low pressure area over southeast Arabian Sea and adjoining Kerala.					

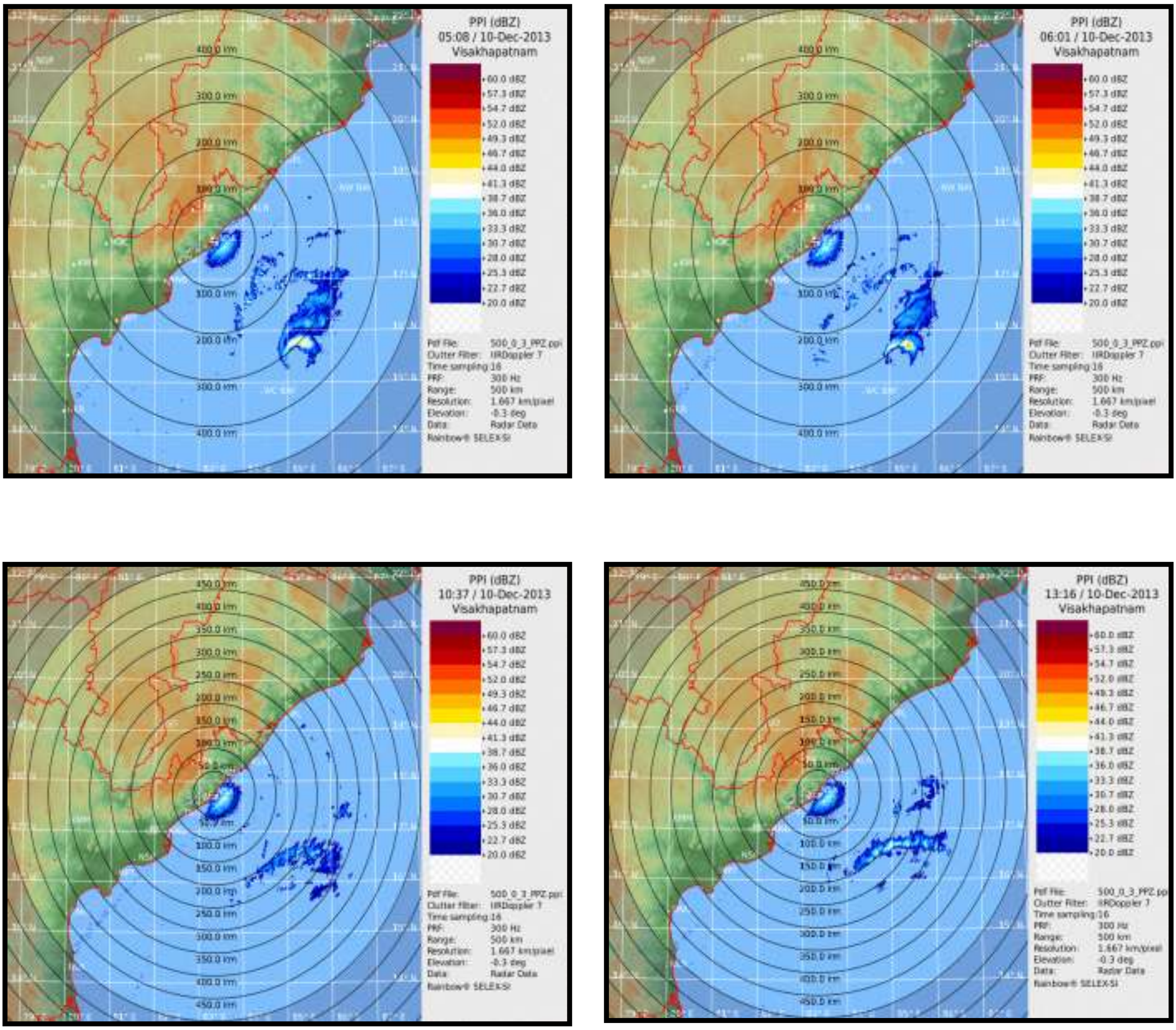


Fig. 2.5.1 Visakhapatnam RADAR imageries based on 0510, 0600, 1040 & 1320 UTC of 10th December, 2013

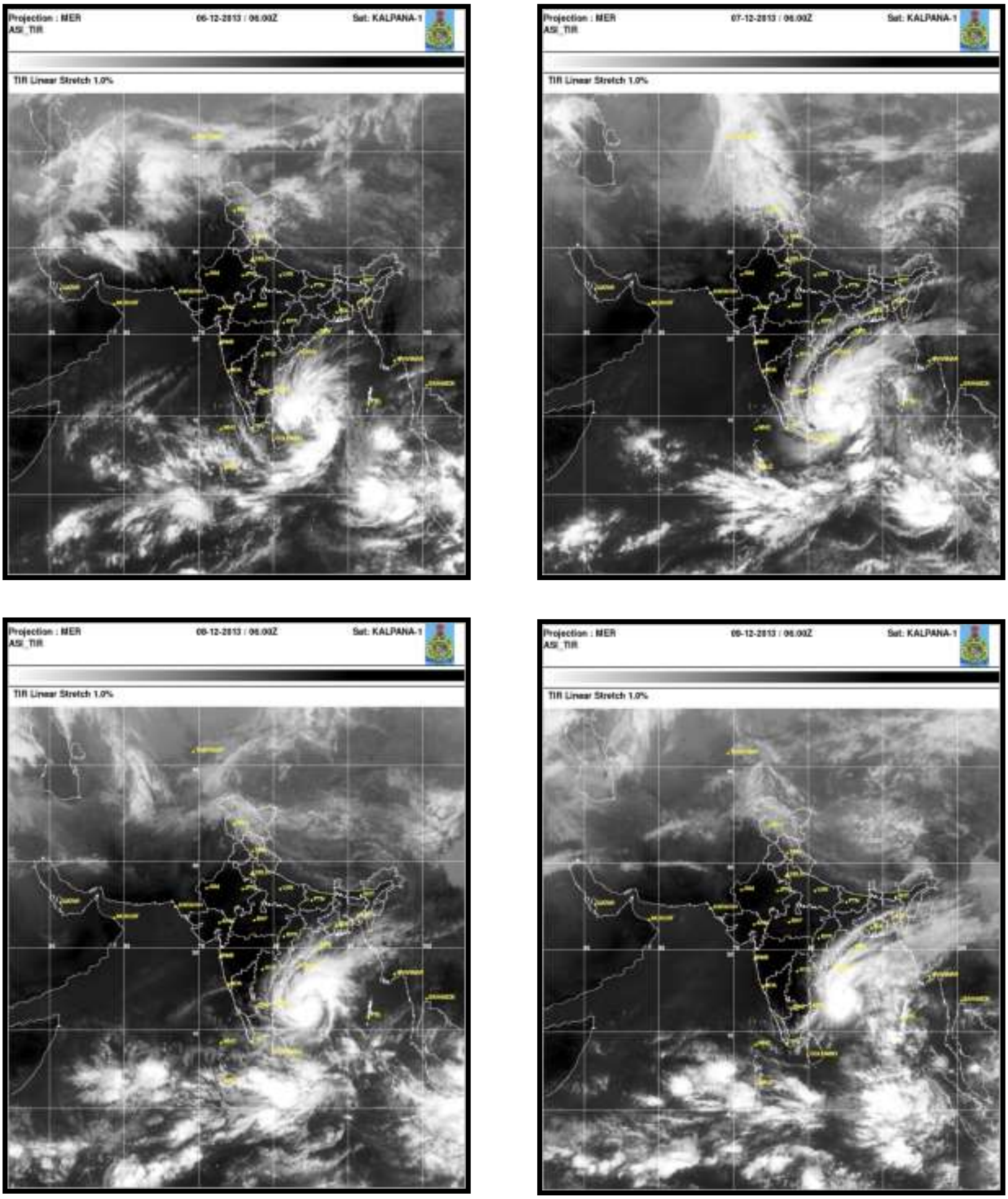


Fig. 2.5.2(a) Typical Kalpana-1 Satellite imageries of very severe cyclonic storm 'Madi' at 0600 UTC of 06th, 07th, 08th and 09th December 2013.

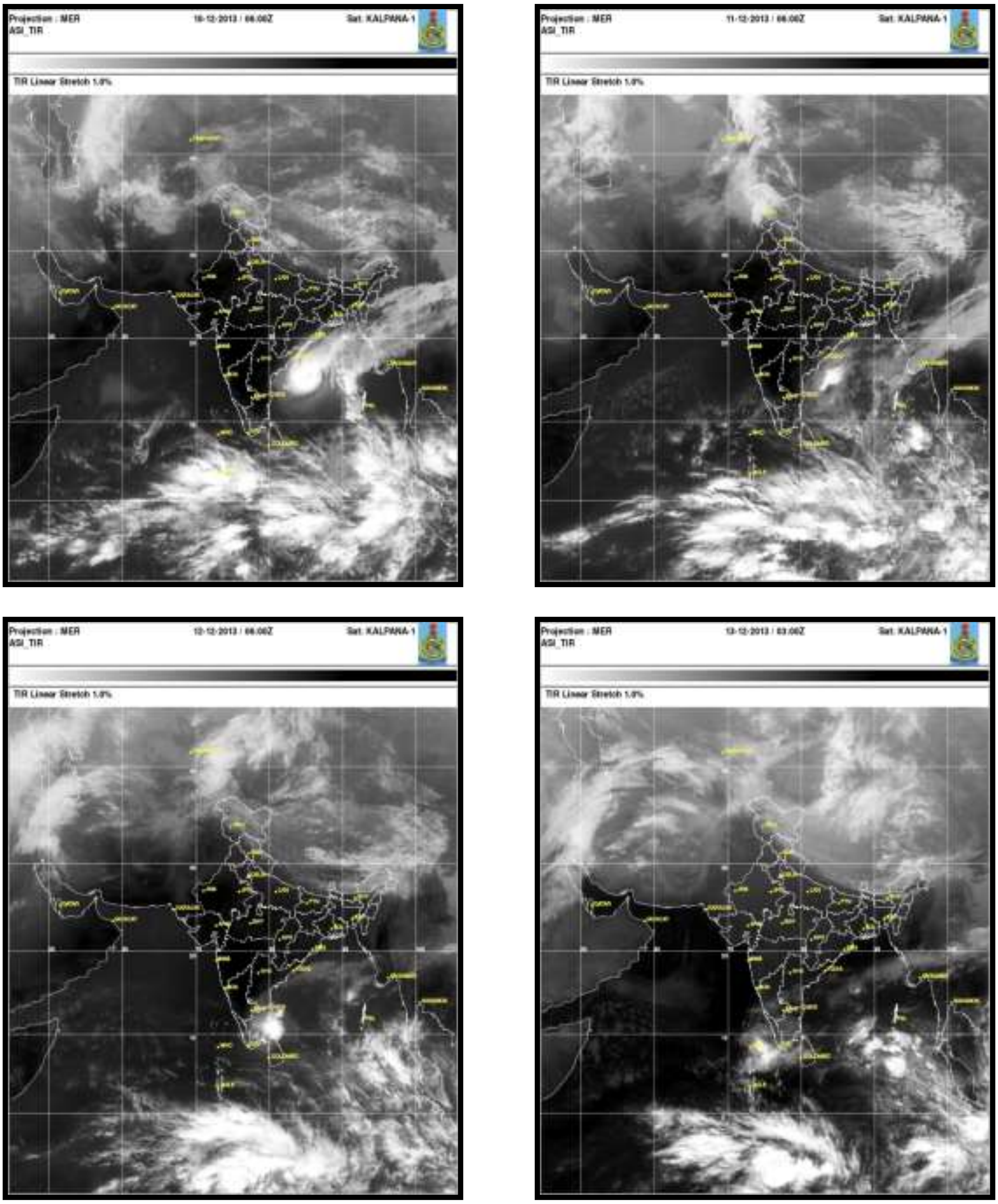


Fig.2.5.2(b) Typical Kalpana-1 Satellite imageries of very severe cyclonic storm 'Madi' at 0600 UTC of 10th, 11th, 12th and 0300 UTC of 13th December 2013.

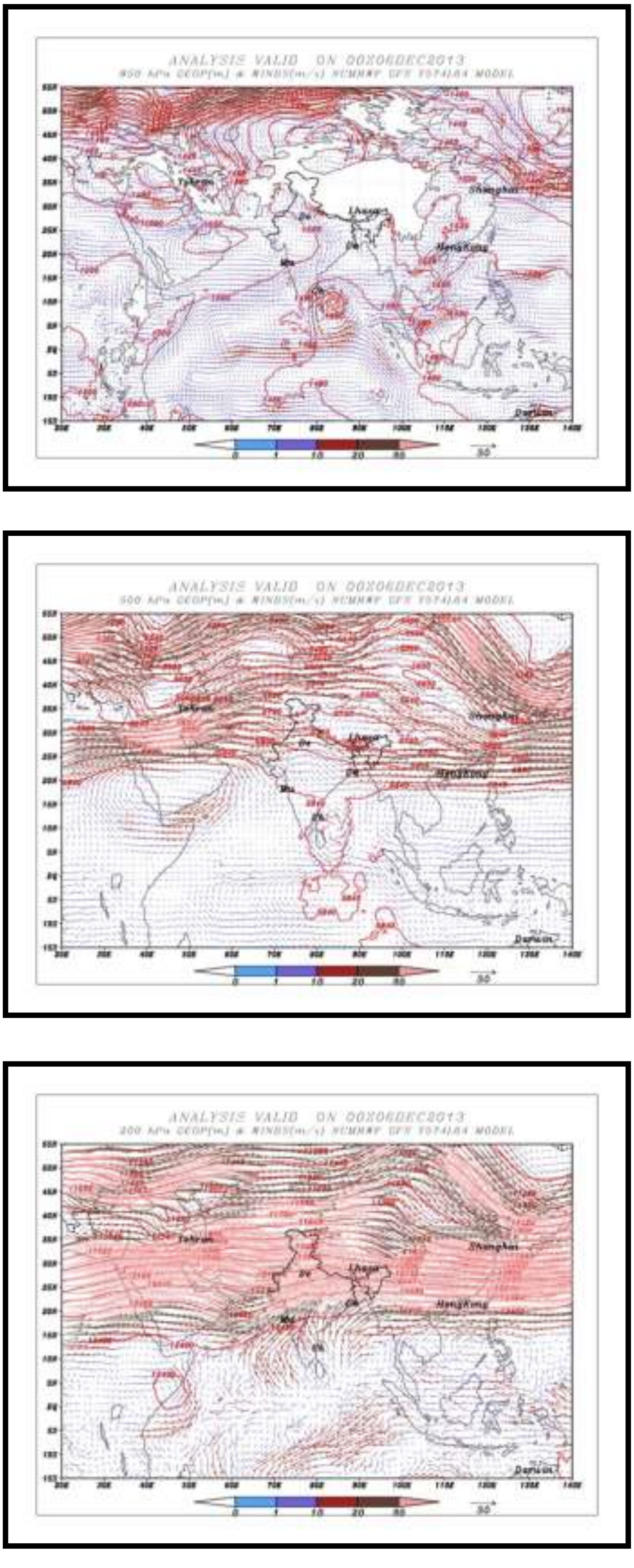


Fig. 2.5.3(a): NCMRWF GFS Analysis based on 00 UTC of 6th Dec. 2013 in association with VSCS MADI

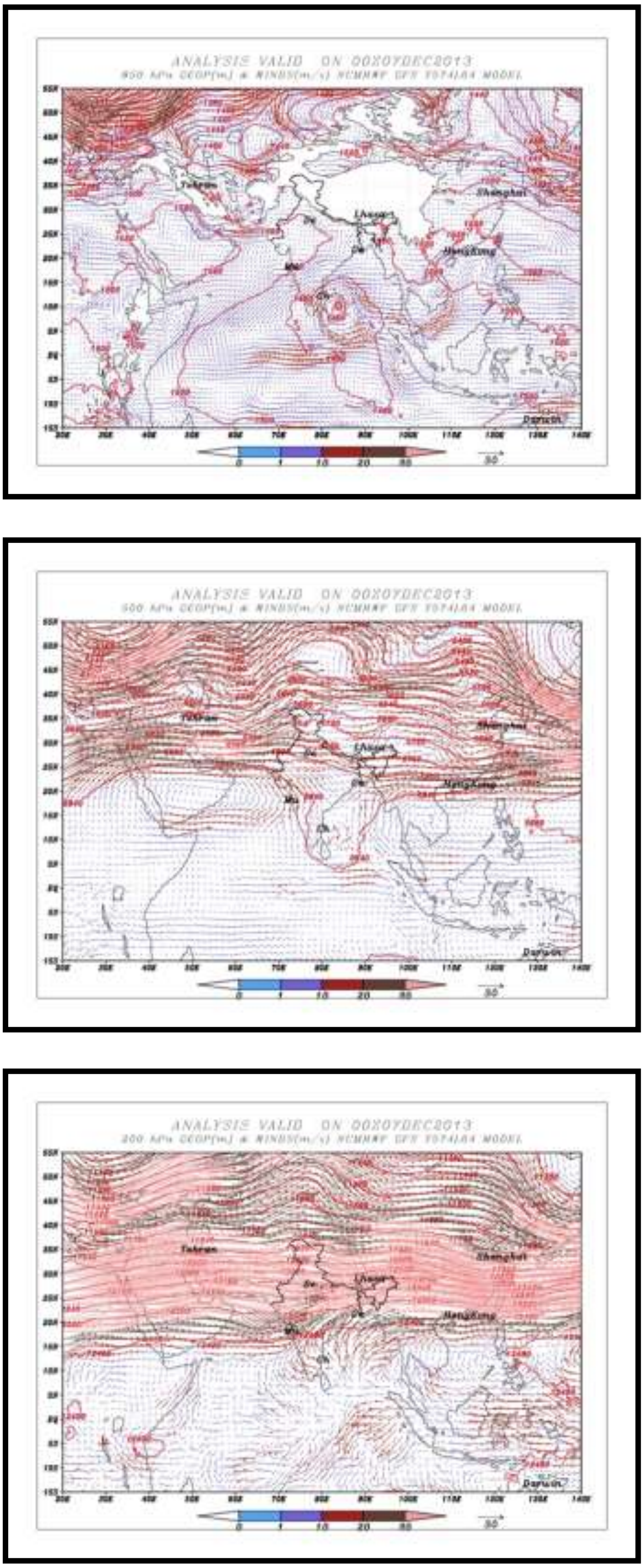


Fig 2.5.3(b) NCMRWF GFS Analysis based on 00 UTC of 7th Dec. 2013 in association with VSCS MADI

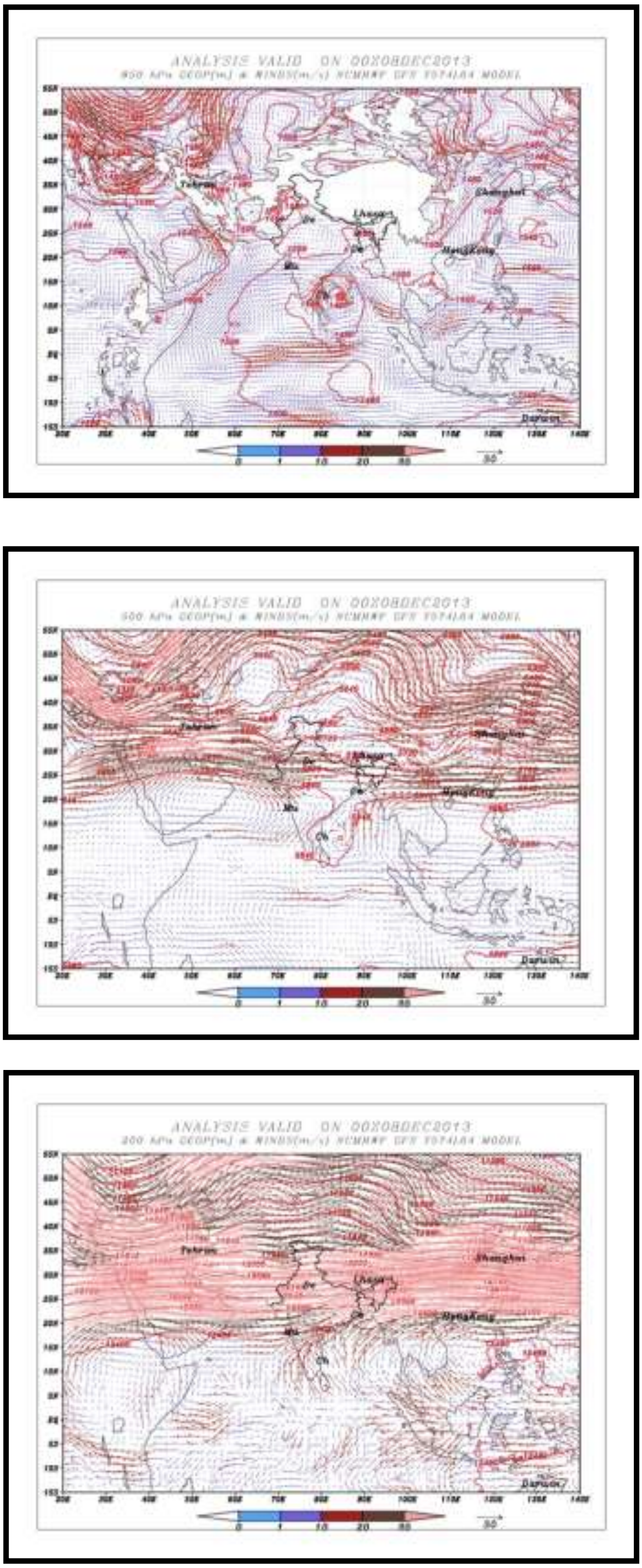


Fig 2.5.3(c) NCMRWF GFS Analysis based on 00 UTC of 8th Dec. 2013 in association with VSCS MADI

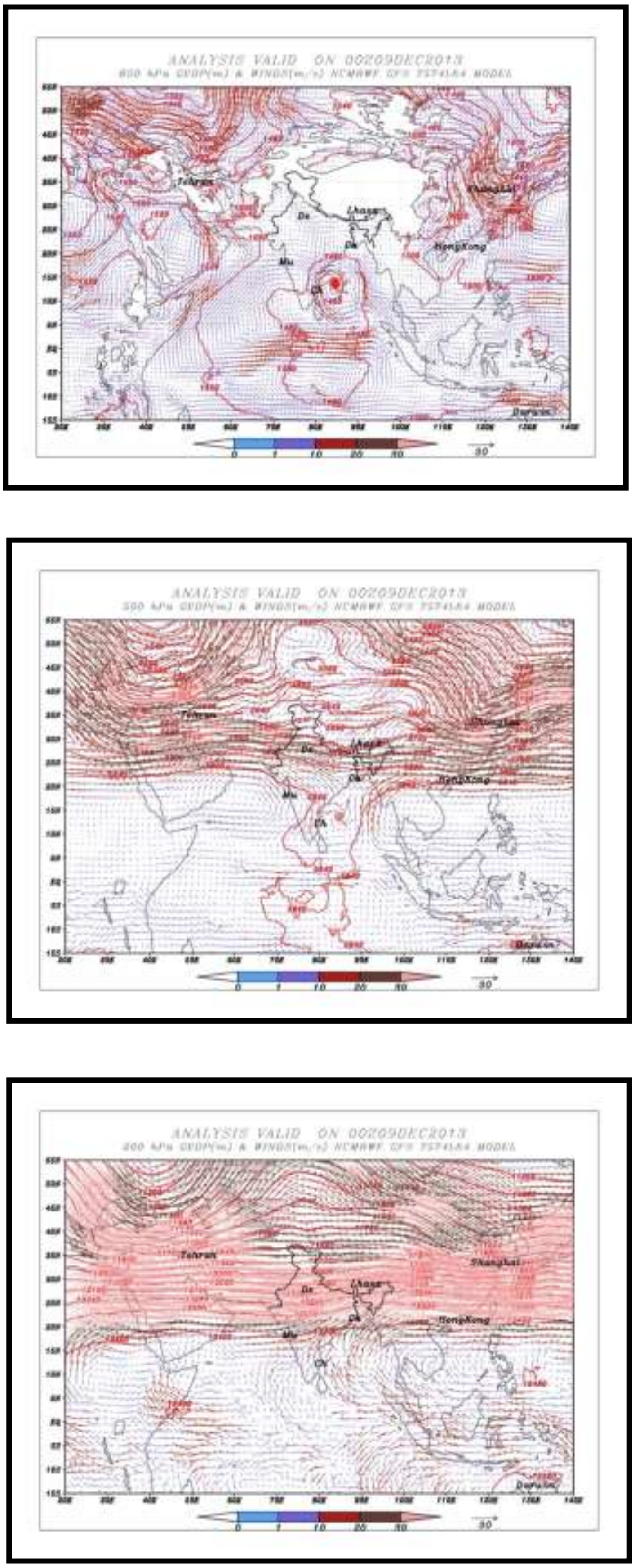


Fig 2.5.3(d) NCMRWF GFS Analysis based on 00 UTC of 9 Dec. 2013 in association with VSCS MAADI

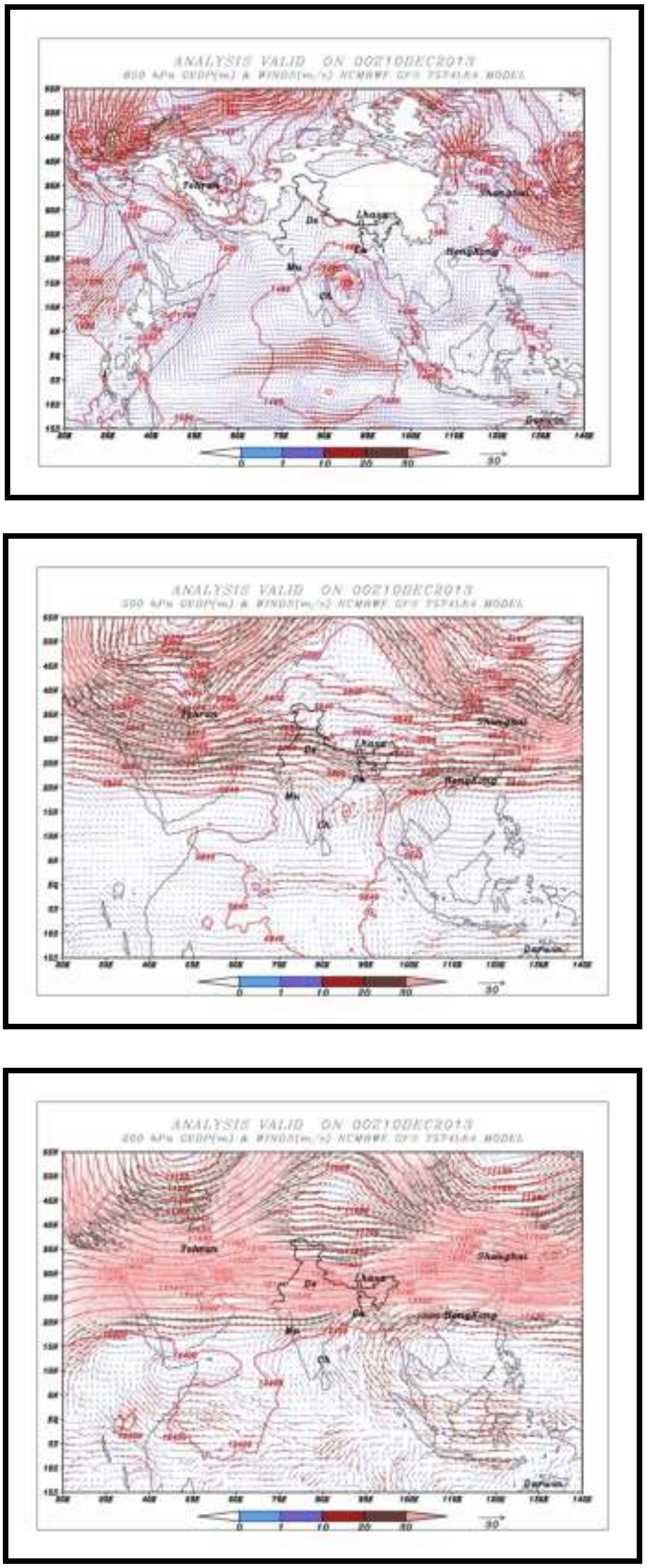


Fig 2.5.3(e) NCMRWF GFS Analysis based on 00 UTC of 10th Dec. 2013 in association with VSCS MAADI

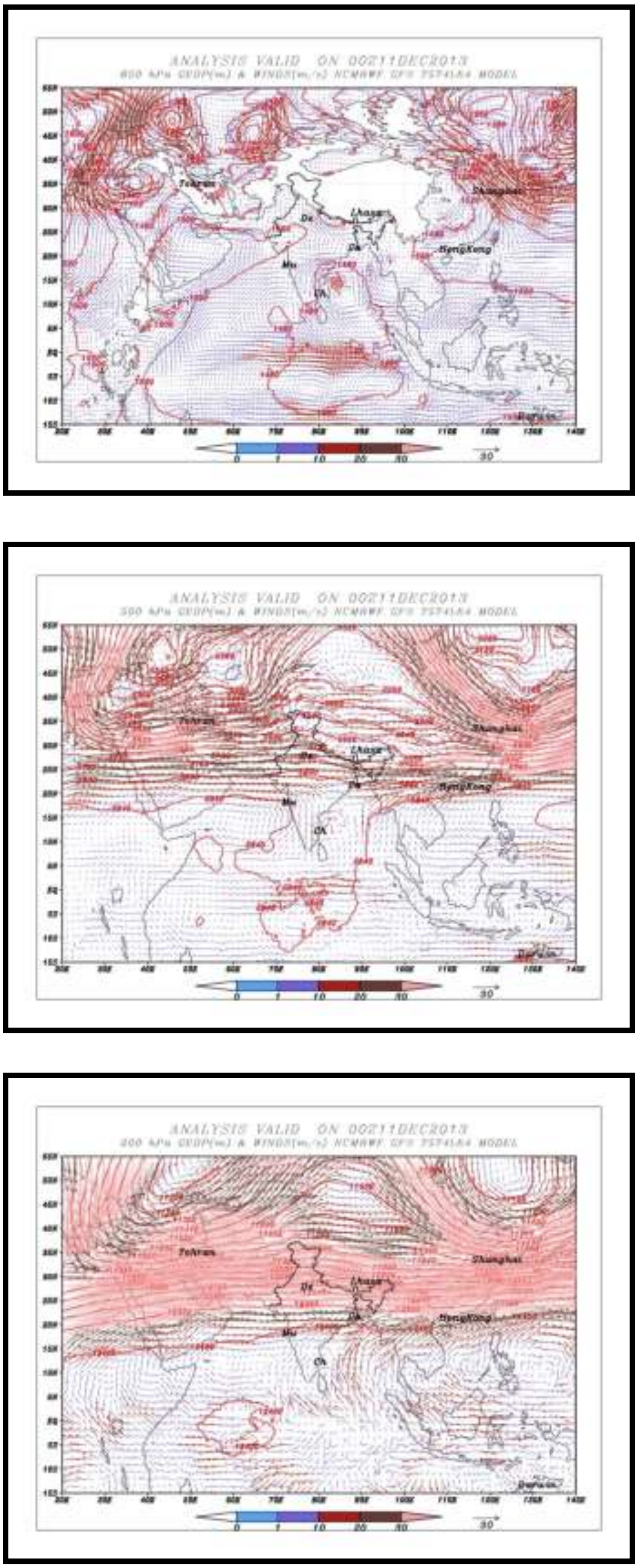
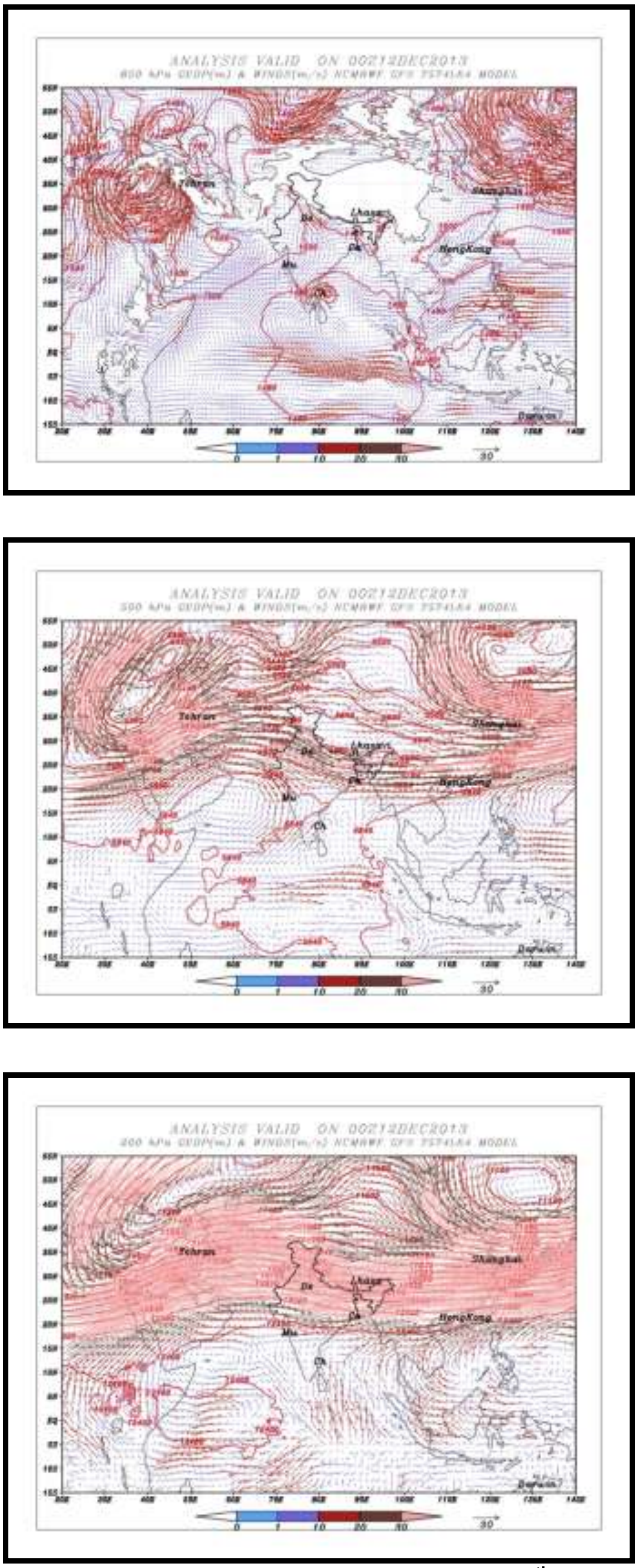


Fig 2.5.3(f): NCMRWF GFS Analysis based on 00 UTC of 11th Dec. 2013 in association with VSCS MAADI

Fig 2.5.3(g) NCMRWF GFS Analysis based on 00 UTC of 12th Dec. 2013 in association with VSCS MAADI



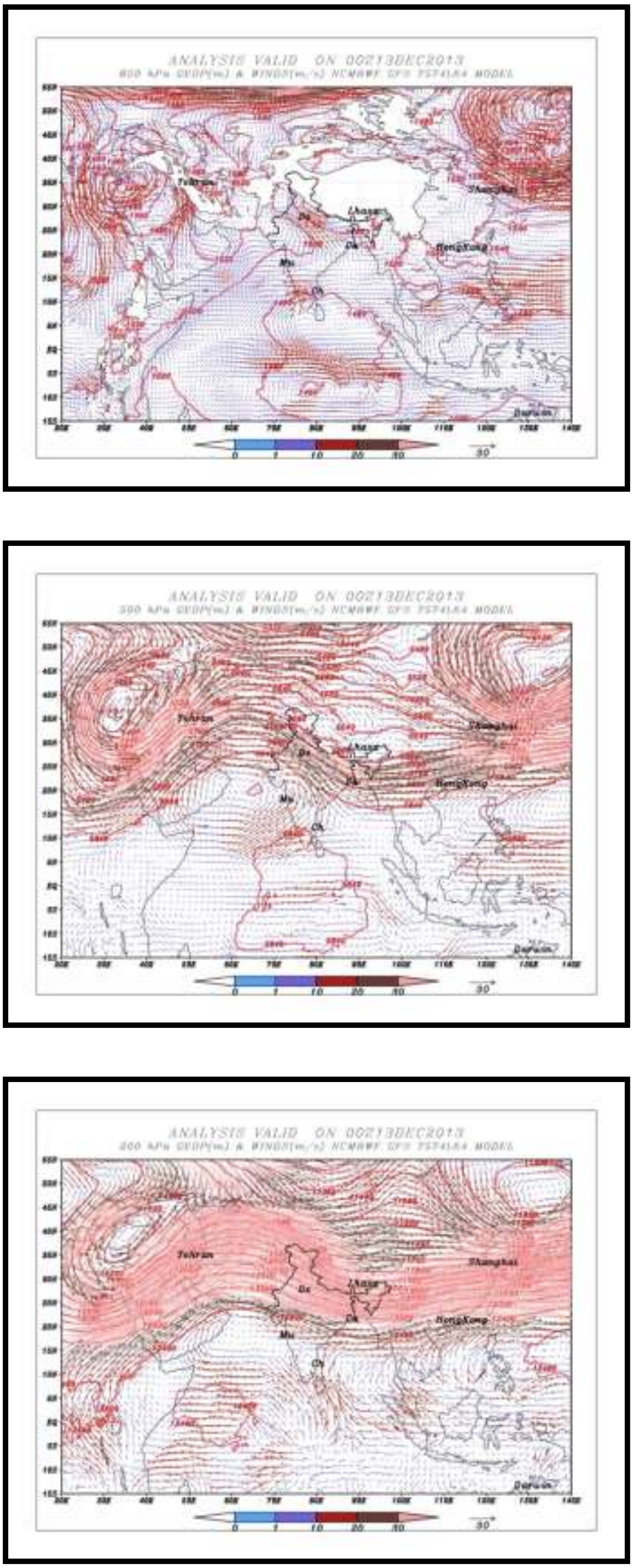


Fig 2.5.3(h) NCMRWF GFS Analysis based on 00 UTC of 13th Dec. 2013 in association with VSCS MAADI

2.5.5 Realised Weather

Chief amounts of 24 hrs. Rainfall (7 cm or more) ending at 0300 UTC from 06th December to 14th December, 2013 are given below:

7th December - Nil

8th DECEMBER 2013
ANDAMAN & NICOBAR ISLANDS: Hut Bay-9,

9th DECEMBER 2013
ANDAMAN & NICOBAR ISLANDS: Port Blair-10,

10th DECEMBER 2013-Nil

11TH DECMBER 2013-NIL

12TH DECEMBER 2013-NIL

13th DECEMBER 2013
Tamilnadu & Puducherry: Colachel-11, Tindivanam-11, Kallakurichi-11, Eraniel-11, Cheyyur-11, Pondicherry-10, Ulundurpet-9, Virudhunagar-9, Attur-8, Airport Madurai-7, Tirumangalam-7, Vilupuram-7,

14TH DECEMBER 2013-NIL

2.5.6 Damage: No damage has been reported due to this system

CHAPTER-III

1. Outcomes and Challenges of Forecast Demonstration Project (FDP) on Landfalling Cyclones over the Bay of Bengal

M. Mohapatra, D.R. Sikka* B. K. Bandyopadhyay and Ajit Tyagi

India Meteorological Department
Mausam Bhavan, Lodi Road, New Delhi-110003
*40, Mausam Vihar, New Delhi-110051

Abstract

A programme has been evolved for improvement in prediction of track and intensity of tropical cyclones over the Bay of Bengal resulting in the Forecast Demonstration Project (FDP). FDP programme is aimed to demonstrate the ability of various NWP models to assess the genesis, intensification and movement of cyclones over the north Indian ocean with enhanced observations over the data sparse region and to incorporate modification into the models which could be specific to the Bay of Bengal based on the in-situ measurements. FDP Programme is scheduled in three phases, viz., (i) Pre- pilot phase (15 Oct-30 Nov. 2008, 2009, (ii) Pilot phase (15 Oct. - 30 Nov., 2010 and 2011) and (iii) Final phase (15 Oct - 30 Nov., 2012-14). India is planning to take up aircraft probing of cyclones over the Bay of Bengal during 15 Oct. - 30 Nov., 2012-14 with hired aircraft and dropsonde experiments. To accomplish the above objective, the initiative was carried out with priorities on (i) observational upgradation, (ii) modernisation of cyclone analysis and prediction system, (iii) cyclone analysis and forecasting procedure, (iv) warning products generation, presentation & dissemination, (v) confidence building measures and capacity building.

Various strategies were adopted for improvement of observation, analysis and prediction of cyclone. Several national institutions participated for joint observational, communicational & NWP activities during the pre-pilot and pilot phases of FDP campaign during 2008-11. The comparison of observational systems before and after FDP indicates a significant improvement in terms of Radar, Automatic Weather Station (AWS), high wind speed recorders over the region. It has resulted in reduction in monitoring and forecasting errors. The performance of NWP models have increased along with the introduction of NWP platforms like IMD GFS, WRF, HWRF and ensemble prediction system (EPS). Salient features of achievements along with the problems and prospects of this project are presented and discussed in this paper. With repeated attempts, the aircraft probing of cyclones could not be possible till now. It is a major challenge for the future campaign during 2012-14.

Key Words : Tropical cyclone, Forecast Demonstration Project, Track, Intensity

2. Large-Scale Characteristics of Rapidly Intensifying Tropical Cyclones over the Bay of Bengal and a Rapid Intensification (RI) Index

***S. D. KOTAL and S. K. ROY BHOWMIK**
India Meteorological Department, NWP Division,
New Delhi-110003, India

Abstract

A rapid intensification index (RII) is developed for tropical cyclones over the Bay of Bengal. The RII uses large-scale characteristics of tropical cyclones to estimate the probability of rapid intensification (RI) over the subsequent 24-h. The RI is defined as an increase of intensity 30 kt (15.4 ms^{-1}) during 24-h, which represents approximately the 93rd percentile of 24-h intensity changes of tropical cyclones that developed over the Bay of Bengal during 1981-2010. It is found that 32% of all very severe cyclonic storms (VSCS) and all super cyclonic storms (SUCS) underwent RI phase at least once during their lifetime. Various large-scale variables associated with the RI cases are compared to those of non-RI cases. These comparisons show that the RI cases generally occur at higher latitude and are intensifying at a faster rate during the previous 12-h than the non-RI cases. The statistical analysis also shows that the RI cases are embedded in regions where the upper-level divergence, lower-level relative vorticity and relative humidity are more and vertical winds shear is less than certain threshold values of the respective variables. Finally, the initial wind speed of RI cases is higher and tends to move with a faster translational speed than the non-RI cases. The RII technique is developed by combining threshold (index) values of the eight variables for which statistically significant differences are found between the RI and non-RI cases. The probability of RI is found to be increases from 0% to 100% when the total number of indices satisfied increases from zero to eight.
Key words: Tropical cyclone, Rapid intensification, Probability, Vorticity, Divergence, Vertical wind shear, Bay of Bengal.

3. Comparison of Best Track Parameters of RSMC, New Delhi with satellite estimates over North Indian Ocean

Suman Goyal, M. Mohapatra and A K Sharma
India Meteorological Department,
Mausam Bhavan, Lodi Road, New Delhi-110003

Abstract

India Meteorological Department (IMD), as a Regional Specialized Meteorological Centre (RSMC) has the responsibility of monitoring and prediction of cyclonic disturbances (CDs) including depressions and tropical cyclone (TC); collection, processing and archival of all data pertaining to CDs and preparation of best track data over the north Indian Ocean (NIO). The process of post-season analysis of CDs to determine the best estimate of a CD's position and intensity along with other characteristics during its lifetime is described as "best tracking". The best tracking procedure has undergone several changes world-over including NIO due to

change in monitoring and analysis tools & procedure. However, the geostationary satellite remains the main tool for monitoring of location and intensity of CDs. There have been a few attempts to document the role and extent of satellite estimates in determining the best track location and intensity of CDs over the NIO. Hence, a study has been undertaken to compare the location and intensity of CDs based on best track parameters prepared by RSMC, New Delhi with those estimated by satellite division of IMD based on INSAT and Kalpana satellites.

The average difference in location of CDs over the NIO, BOB and AS is about 39, 40 and 37 km respectively. The difference in location is 50 km or less in about 65% of the total cases and about 6% of the cases have a difference of 100 km or more over the NIO as a whole. It is about 62% and 6% over the BOB and about 70% and 5% over the AS respectively. Difference in location gradually decreases with increase in T number. It is about 30 km when the intensity of the system is T4.0 or more (very severe cyclonic storms and above intensity) over the BOB, AS and NIO. Considering the spatial distribution of difference in location of CDs, it is higher near the coast and decreases as we move away from the coast. The intensity in the best track agrees with the satellite estimates in about 85.5% of the cases. While the satellite based intensity is underestimated (Satellite division estimated T number is less than best track T number) in 9.5% cases, it is overestimated (Satellite division estimated T number is greater than best track derived T number) in about 5% cases over the NIO. Considering the spatial distribution, the difference occurs mostly when the CD lies near the coast or the islands in the NIO like the difference in location.

Key Words: Tropical Cyclone, North Indian Ocean, Best Track, Intensity, Satellite

4. Rain drop size distribution characteristics of cyclonic and north east monsoon thunderstorm precipitating clouds observed over Kadapa (14. 4^{o} N, 78. 82^{o} E), Tropical semiarid region of India

S. BALAJI KUMAR and K. KRISHNA REDDY*

Semi-arid-zonal Atmospheric Research Centre (SARC), Yogi Vemana University, Kadapa-516003, Andhra Pradesh, India

Abstract

Raindrop size distributions (RSD) of "*JAL*" Cyclone induced precipitating clouds (2010-11-07) and North- East (NE) monsoon thunderstorm precipitating clouds (2010-11-16) were measured with a Particle Size and Velocity (PARSIVEL) disdrometer deployed at Kadapa (14.47°N; 78.82°E), a semiarid continental site in Andhra Pradesh state, India. From the observational results we find that stratiform precipitation is predominant than convective precipitation in cyclone induced precipitation clouds. Where as in the case of NE monsoon thunderstom precipitation convective cloud fraction is more than stratirom clouds. The cylone induced precipitation is associated with higher concentration of small drops (small and middrops) in stratiform region (convective region) than NE monsoon precipitation. The average mass weighted diameter, Dm of cyclone induced precipiation is less than the NE monsoon precipitation both in stratiform and convective cloud regions. The observed RSD are found distinctly vary from cyclonic and NE monsoon thunderstorm precipitating clouds.

Key words "JAL" Cyclone, Raindrop Size Distribution, Disdrometer, Rain Rate, Mean Diameter

5. Barotropic Energetics Analysis of Tropical Cyclone *Khai Muk*

S. Balachandran
India Meteorological Department
Regional Meteorological Centre, Chennai

Abstract

Analysis of dynamical conditions in respect of formation and growth of tropical cyclone *Khai Muk* over the Bay of Bengal during 11-14 November 2008 is discussed with focus on barotropic energy conversion at lower level. It is observed that the extension of subtropical easterlies from the Western Pacific in to central Bay of Bengal to the north and equatorial westerlies to the south of ITCZ during the above period constituted a large scale horizontal shear flow. This led to generation of cyclonic shear vorticity and initiation of disturbance which later developed in to tropical cyclone *Khai Muk.* The basic zonal flow in the lower troposphere was barotropically unstable as depicted by change of sign of meridional distribution of absolute vorticity which provided the kinetic energy for the growth of eddy. There existed positive correlation between mean zonal flow and the meridional gradient of absolute vorticity which favoured increase of eddy kinetic energy through barotropic eddy-mean flow interactions. Energetic analysis indicated that areas of high rate of positive change of eddy kinetic energy coincided with positive areas of barotropic conversion and the magnitude of barotropic conversion matched with local rate of change of eddy kinetic energy around the area of vortex generation. Barotropic energy conversion by meridional shear of basic zonal flow was an important energy source for the formation and initial growth of tropical cyclone *Khai Muk*.

Key words : Tropical cyclone, absolute vorticity, energetics, eddy kinetic energy, barotropic instability, barotropic conversion, Khai muk.

6. A case Study for cyclone 'Aila' for forecasting rainfall using satellite derived rain rate data

Habibur Rahaman Biswas, P.K.Kundu* and D. Pradhan

Regional Meteorological Centre, Kolkata
*Jadavpur University, Kolkata-700032

Abstract

Major threat to the life and property of people on the east coast of India, including West Bengal Coast, is due to very heavy rainfall from landfalling tropical cyclones originated over Bay of Bengal. Forecasting magnitude of rainfall from landfalling tropical cyclones is very difficult. Satellite derived rain rates over the raining areas of tropical cyclones can be used to forecast potential tropical cyclone rainfall accumulations. In the present study, an attempt has been made to estimate 24 hours rainfall over Coastal stations before landfall of tropical Cyclone 'Aila' using Tropical Rainfall Measuring Mission (TRMM) satellite rain rates data and observed storm

track of Aila. Forecast Tropical Rainfall Potential(TRaP), 24 hours prior to landfall for the tropical cyclone 'Aila' based on well known technique developed in USA, provides a good rainfall forecast especially for the coastal areas lying at the head of direction of the storm.

Key words: Rainfall forecast, Tropical Cyclone, TRMM, TRaP.

7. Studies on VLF Atmospherics during the Tropical Cyclone "AILA" and Several Monsoon period Thunderstorms over North-East India

Rakesh Roy, Anirban Guha*, Barin Kumar De and Abhijit Choudhury

Department of Physics, Tripura University,
Suryamaninagar-799 022, Tripura

Abstract:

The present work reports the characteristic variations in VLF atmospherics or sferics at four discrete frequencies recorded at the Department of Physics, Tripura University, during the period from April 2009 to October 2009. Data from 76 active thunder days over North-East India is considered for the present investigation. Results show several types of features in the variation of sferics during the monsoon period. These are termed as gradual fall gradual rise (GFGR), gradual rise sudden fall (GRSF), gradual rise gradual fall (GRGF), gradual fall sudden rise (GFSR), sudden rise gradual fall (SRGF), sudden rise sudden fall (SRSF), sudden fall sudden rise (SFSR), sudden fall gradual rise (SFGR) and spiky. During the Monsoon thunder active days, amongst all the patterns, GRGF occurred in most of the cases in all frequencies (average occurrence rate around 37% in each frequency). During our observational period, a severe tropical cyclonic storm named "AILA" (RSMC Designation BOB02, JTWC Designation 02B) occurred over the Bay of Bengal during 23-26 May 2009. Among several characteristic features during normal Monsoon period, SRSF (average occurrence rate around 86 % in each frequency) dominated the sferics on the 25 May, 2009, when the cyclone struck the coastal areas of the Bay of Bengal. The sferics of that day has been analyzed critically with respect to discrete frequency distribution of rise rate and fall rate of the intensity of the sferics. A comparison is made for all the patterns for the Monsoon days and the AILA cyclone active day. Our findings show substantial difference in the microstructure of clouds producing severe cyclonic storms like AILA and other thunderstorms during Monsoon seasons over North-East India. The possible interpretation of the observed variations in sferics is explained on the basis of the electrical activity that occurs inside a thunder-cloud especially during cyclonic activity.

Key words VLF atmospherics, Tropical cyclone, Monsoon cloud, Electrical activity inside thundercloud, Microstructure of cloud

8. Observational Aspects including Weather Radar for Tropical Cyclone Monitoring

S. RAGHAVAN

G1, Prathyeka Apts., 12, 1st Trust Link St.,
Mandaiveli, Chennai- 600028, India

Abstract

In the context of the Forecast Demonstration Project (FDP) of the India Meteorological Department (IMD), a review is made of the various observational facilities and techniques which can be deployed, for the detection tracking and understanding of tropical cyclones. The real test of the efforts in terms of technology is the performance of our forecasts in an operational context. The paper discusses the steps needed in this regard.

9. Recent Advances in Observational support from Space-based systems for Tropical Cyclones

R.C.Bhatia* and A.K.Sharma

India Meteorological Department, Lodi Road, New Delhi.
* Block 4/24, Old Rajinder Nagar, New Delhi

Abstract

Capabilities of meteorological satellites to provide vital observations on Tropical Cyclones (TC) are well known since more than last four decades. Most important are the frequent pictures of earth's cloud cover in the visible, IR and water vapour channels obtained from Geostationary meteorological satellites together with the capability of generating a number of quantitative products from these data. R&D efforts of last several years at the Cooperative Institute of Meteorological Satellite Studies (CIMSS), Wisconsin University, USA have culminated into development of an Advanced Dvorak's Technique (ADT) for automatic analysis of Tropical Cyclones. It is in operational use for analysis of North Atlantic and Carribean Sea cyclones. It has been used on experimental basis at Satellite Meteorology Center, IMD While the conventional Dvorak Technique (DT) works well over the Indian seas, experience of using ADT does not permit at present its use on operational basis over our region.

R&D efforts of last several years at CIMSS have also resulted in lot of improvements in the Quantitative products derived from the satellite data. These products have certainly improved the analysis of TC and have provided useful information for predicting the future intensity/movement of TCs. Quality of currently operational products from Indian satellite data is limited by the coarser resolution of the instruments. With the availability of much better quality of data from the new satellite of INSAT series from next year (2013) onward there is a good possibility of making further improvements in the quality of products. Data obtained from microwave based instruments also provides useful additional information for TC analysis. The warm core anomaly in the Upper Troposphere is a useful indicator of the TC intensity.

Key words: ADT, Quantitative Products, Warm core anomaly, INSAT-3D, Microwave instruments.

10. Estimation of intensity of tropical cyclone over Bay of Bengal using microwave imagery

T. N. Jha, M. Mohapatra and B. K. Bandyopadhyay

India Meteorological department
Mausam Bhawan, Lodi Road, New Delhi -110003.

Abstract

Microwave cloud imageries and derived products in the frequency of 85 GHz have been examined for five cyclones that occurred during FDP period (15 October- 30 November) of 2008-2010 over the Bay of Bengal to estimate the brightness temperature, brightness temperature anomaly, location of centre, maximum sustained wind (MSW) at surface level and estimated central pressure (ECP) associated with cyclones in their different stages of intensification like depression, deep depression, cyclonic storm, severe cyclonic storm, very severe cyclonic storm etc. Also the observed brightness temperature anomalies are compared with the theoretically derived brightness temperature anomalies based on the best track estimates of ECP and outermost pressure for these cyclones. The location of centre, ECP and MSW based on microwave imagery estimates have been compared with those available from the best track and Dvorak's estimates of India Meteorological Department and analyzed.

The difference in location of the centre of Cyclonic Disturbance (CD) as estimated by microwave imageries and best track estimates decreases with intensification of the disturbances and varies from about 25 km in depression (D) stage to 18 Km in very severe cyclonic storm (VSCS) stage whereas the difference is significantly higher in Dvorak estimate. The MSW based on microwave estimates is higher than that of best track estimates by about 28 knots during VSCS and 6-8 knots during D/cyclonic storm (CS)/severe cyclonic storm (SCS) stage. Considering relative difference with respect to best track estimates, the MSW is overestimated in microwave by about 12-15% in case of CS and SCS stage and by about 30% in VSCS stage while Dvorak's MSW overestimation reduced to 15-18% during CS,SCS and VSCS stages .Brightness temperature of the order of 230K is favourable for genesis (formation of D), 250K for its intensification into CS, 260K for intensification into SCS and 270K for its further intensification into VSCS stage over the Bay of Bengal. Detection of threshold value of brightness temperature may provide adequate lead time to forecast intensification of the system. Similarly, when brightness temperature anomaly exceeds 3K, CS intensify into SCS and 8K, it intensifies into a VSCS over Bay of Bengal.

Key Words : Cyclone, Microwave, Satellite, Bay of Bengal, Track, Intensity

11. A study on high resolution mesoscale modeling systems for simulation of tropical cyclones over the Bay of Bengal

U. C. Mohanty*, Krishna K. Osuri and Sujata Pattanayak

Centre for Atmospheric Sciences,
Indian Institute of Technology, Delhi,
Hauz Khas, New Delhi – 110016

Abstract

Landfalling tropical cyclone (TC) is one of the natural disasters producing extremely strong winds, torrential rains, floods influencing many kilometers from the point of landfall and storm surges that overwhelm miles of shores resulting loss of lives, and damages to properties. This disaster is higher in the regions covering Bay of Bengal (BoB). Therefore, the India Meteorological Department (IMD) initiated a field project, "Forecast Demonstration Project (FDP) of landfalling cyclones" over the BoB to acquire detailed understanding of genesis, intensity, and structure evolution of TCs so as for better TC forecasting. A comprehensive performance of state-of-the-art mesoscale modeling systems such as Advanced Research Weather Research and Forecasting (ARW), non-hydrostatic mesoscale model of WRF (NMM) and Hurricane Weather Research and Forecasting (HWRF) etc for the simulation of landfalling TCs during pilot phase of FDP (2008-2011) is presented. The study is not meant for the inter-comparison of different modeling systems. In the present study, six TCs namely Rashmi (2008), KhaiMuk (2008), Nisha (2008), Giri (2010), Jal (2010) and Thane (2011) are considered. Though different aspects of the TC such as track, intensity, structure and rainfall are studied in detail, this paper is mainly emphasized on the track and intensity prediction and associated errors.

Results indicates that the high resolution mesoscale modeling systems provide better guidance for TC forecast up to 72 hours. However, the track and intensity error is relatively more when these models are initialized with coarser resolution global analyses and forecast fields. This error can be significantly reduced with the assimilation of additional regional observations into model initial conditions. The track forecast errors are calculated with respect to IMD best track observations. In case of ARW system, the forecast errors are 138, 135 and 182 km from no-assimilation experiment. The assimilation of all available observations during FDP period into model initial condition decreases the errors 72, 99 and 126 km at 24, 48 and 72 hour, respectively with an improvement of about 47%. In case of NMM model, the mean (based on 30 sub-cases) track errors are improved by about 32%, 22%, 23%, 28%, 24% and 16% at 00, 24, 48, 72, 96 and 120 hrs, respectively with data assimilation experiments compared to no-assimilation experiment. The HWRF model improved the initial position and structure significantly because of its improved vortex-relocation and initialization procedures and hence captures the rapid intensification of the TC Giri in the subsequent forecast hour.

Key words Tropical cyclones, Forecast Demonstration Project, Bay of Bengal, Mesoscale models, Track, Intensity

12. Impact of cyclone bogusing and regional assimilation on tropical cyclone track and intensity predictions.

Manjusha Chourasia, R. G. Ashrit and John P George

National Centre for Medium Range Weather Forecasting (NCMRWF),
Ministry for Earth Sciences, A-50, Institutional Area, Phase-II
Sector-62, NOIDA, U.P., Pin : 201 309

Abstract

The aim of this study is to assess the impact of tropical cyclone bogusing in WRF assimilation and forecast system for cyclone track and intensity prediction in short range forecast. The impact is demonstrated in terms of track error, central pressure, and maximum sustained wind speed.

The study is based on the three cyclones; namely 'LAILA' (Bay of Bengal), 'GIRI' (Bay of Bengal) and 'PHET' (Arabian Sea), formed in the year 2010. The WRF model makes use of the operational NCMRWF T382L64 analysis and forecasts and the model is integrated upto 72 hr for producing the cyclone track and intensity forecast. Four sets of experiments were performed: (1) The control experiment (CNTL) in which neither assimilation nor cyclone bogusing is done. The model is initialized using interpolated global model analysis. (2) In assimilation experiment (VAR), model initial condition is prepared using WRF VAR data assimilation system (without cyclone bogusing). (3) The cyclone bogusing experiment (BOG) featuring cyclone bogusing alone without assimilation. In this case the model first guess is modified using cyclone bogusing and used as the initial condition. (4) In the forth experiment, the initial condition of the model is prepared with both cyclone bogusing followed with WRF data assimilation (BOGVAR).

Results indicate remarkable impact of cyclone bogusing on the initial condition. All three cyclones can be located in the initial conditions (00 UTC) of bogus (BOG and BOGVAR) experiments which were otherwise absent in no-bogus (VAR and CNTL) experiments. Significant reductions in track errors occurred in BOGVAR experiment. The maximum reduction in track error in BOGVAR compare to VAR is 76.8 % in 'LAILA', 87.3 % in 'GIRI' and 51.5 % in 'PHET' respectively. Maximum sustained wind speed and minimum central pressure are close to observations in BOGVAR compared to VAR for 'LAILA' and 'GIRI'.

Key words *TC (Tropical Cyclone), vortex relocation, rankine vortex, tc-bogusing, forecast track errors, WRF-VAR.*

13. Tropical Cyclone Genesis Potential Parameter (GPP) and it's application over the North Indian Sea

*S. D. Kotal and S. K. Bhattacharya

India Meteorological Department, NWP Division, New Delhi-110003, India

Abstract

An analysis of tropical cyclone genesis potential parameter (GPP) for the North Indian Sea is carried out. The genesis potential parameter developed by Kotal *et al*. (2009) is computed based on the product of four variables, namely: vorticity at 850 hPa, middle tropospheric relative humidity, middle tropospheric instability and the inverse of vertical wind shear at all grid points over the area. The GPP at a grid point is considered under the conditions that all the variables vorticity, middle tropospheric relative humidity, middle tropospheric instability and the vertical wind shear are greater than zero and it is taken as zero when any one of these variables is less or equal to zero. The variables are computed using the European Centre for Medium Range Weather Forecasts (ECMWF) model data. Forecast of the genesis parameter up to seven days is also generated on real time using the ECMWF model output (available at http://www.imd.gov.in/section/nhac/dynamic/Analysis.htm). Higher value of the GPP over a region indicates higher potential of genesis over the region. Region with GPP value equal or greater than 30 is found to be high potential zone for cyclogenesis. The analysis of the parameter and its effectiveness during cyclonic disturbances in 2010 affirm its usefulness as a predictive signal (4-5 days in advance) for cyclogenesis over the North Indian Sea and for determining potential for intensification of developing and non-developing systems at the early stages of development.

Key Words: Tropical cyclone, Cyclogenesis, Genesis potential parameter, Vorticity, Moisture variable, instability and vertical wind shear.

14. Extended Range Forecast of Tropical Cyclogenesis over the North Indian Ocean During 2010 Post-Monsoon Season

D. R. Pattanaik, M. Mohapatra, B. Mukhopadhyay and Ajit Tyagi

India Meteorological Department, New Delhi

Abstract

There were two cyclonic storms formed during the post monsoon season of 2010 viz., "Giri" a very severe cyclonic storm (VSCS) formed on 19th October and crossed the Myanmar coast on 22nd and the second system "Jal" a severe cyclonic storm (SCS) formed on 2nd November and crossed north Tamil Nadu-south Andhra Pradesh coasts, close to north of Chennai on 7th November, which caused lot of damage in Tamilnadu and south Andhra Pradesh coast associated with not only strong wind but also due to associated heavy rainfall.

The real time extended range forecasts are prepared based on the coupled model outputs from ECMWF, NECP and the 2 models ensemble (2MENS). The operational forecast for days 5-11 of weekly mean wind and relative vorticity based on 14th Oct, 2010 initial condition indicates cyclonic circulation at low level over the central Bay of Bengal during the period from 18-24 October associated with the very severe cyclone "Giri". The genesis of the cyclone "Jal" was very much captured in the 2MENS forecast valid for 12-18 days forecast based on the initial condition of 21st October, 2010. The 2MENS forecast valid for 1-7 November based on 28 and 21 October initial conditions (with forecast period of days 5-11 and days 12-18 respectively) also clearly indicated large positive rainfall anomalies over Tamil Nadu coast and adjoining coastal Andhra Pradesh region like that of observed rainfall anomalies. The study further indicates that the model forecasts weekly mean vorticity maximum and its anomaly of the order of 2.5 $\times 10^{-5}$ Sec^{-1} combined with a low level convergence and its anomaly of the order of -0.8 to -1.0 $\times 10^{-5}$ Sec^{-1} can lead to formation of a tropical cyclone. However, more number of cases need to be analysed to get the appropriate threshold values of these dynamical parameters.

Key words :Extended range forecast, Bay of Bengal, ensemble forecast, cyclogenesis, relative vorticity. Coupled model

15. Ocean Atmospheric Coupled Model to Estimate Energy and Path of Cyclone near the coast

Ramkrishna Datta
Regional Meteorological Centre, Kolkata,India.

Abstract

It is seen that in the Bay of Bengal or in the Gulf, most of the time the atmospheric phenomena like cyclone, hurricane etc move towards right to its motion. To study such occurrences; we have considered fluid dynamics of ocean coupled with atmospheric motion. In the present study we have considered the eye of the cyclonic system that consist of fluid dynamical source and fluid dynamical sink at a small distance apart, and thus constitute the fluid dynamical doublet of the object system. Then the fluid dynamical doublet of the object system and its image system has been considered with respect to a firm wall (here the sea shore). The fluid dynamical equation of complex potential with respect to the object system, the image system and the stream velocity have been undertaken. The complex potential of the object doublet, image doublet and the stream velocity have been considered. The velocity vector, consequently the pressure has been retrieve with the help of Bernoulli's equation of fluid motion. Then the minimum /maximum pressure on the wall that is on the sea shore has been calculated analytically. Thus It is found that on the basis of some prevailing conditions existing wind and energy the cyclone or hurricane move towards the sea coast or to the right of its motion .

Key words Fluid dynamical Source, Sink, Object doublet, image doublet and complex potential.

16 Numerical Simulation of Storm Surge Associated with Severe Cyclonic Storms in the Bay of Bengal during 2008-11

S. K. Dube, Jismy Poulose and A. D. Rao

Indian Institute of Technology, Hauz Khas,
New Delhi 110016

Abstract

Storm surge disasters cause heavy loss of life and property, damage to the coastal structures and the losses of agriculture in India and its neighborhood whenever a tropical cyclone approaches. About 300,000 lives were lost in one of the most severe cyclone that hit Bangladesh (then East Pakistan) in November 1970. The Andhra Cyclone devastated the eastern coast of India, killing about 10,000 persons in November 1977. Orissa coast of India was struck by a severe cyclonic storm in October 1999, killing more than 15000 people besides enormous loss to the property in the region. More recently the Nargis cyclone of May 2008 killed about 140,000 people in Myanmar as well as caused enormous property damage. These and most of the world's greatest human disasters associated with the tropical cyclones have been directly attributed to storm surges. Thus, provision of precise prediction and warning of storm surges is of great interest in the region. The main objective of the present paper is to highlight the recent developments in storm surge prediction model for the Bay of Bengal and the Arabian Sea. Paper also describes the performance of the model in forecasting/simulating the surges associated with severe cyclones formed in the Bay of Bengal during 2008 to 2011.

Chapter-IV

Summary of the Activities of PTC Secretariat during the Inter-sessional Period 2013-2014

PTC Secretariat activities during the intersessional period March 2013 to February 2014 are given as under:

- In connection to the organization of PTC Integrated Workshop (Bangkok, Thailand from 27-29 November, 2013) PTC Secretariat, with the kind support of NMHSs of the PTC Member Countries, updated the lists of focal points/experts for the PTC Working Groups on Hydrology (WG-H) and Disaster Risk Reduction (WG-DRR) and the same were circulated to all PTC Members. These lists are also available at the PTC website at:
- http://www.ptc-wmoescap.org/workingGroups.htm
- PTC Secretariat collected contributions from Member countries for PTC Newsletters and published PTC Newsletter "Panel News" (Issue No.35) and distributed the issue among the PTC Member countries, UNESCAP, WMO and the other concerned international organizations. The electronic version of the PTC Newsletters were also uploaded on the PTC website at the following web link: www.ptc-wmoescap.org/newsletters.
- As decided by PTC at its 40th Session (Colombo, Sri Lanka from 25 February to 01 March, 2013), WMO made arrangements with the Indian Institute of Technology (IIT), New Delhi for the attachment of two storm surge experts - one each from Maldives and Pakistan. PTC Secretariat extended invitation for this training to both countries through their PRs with WMO. The training for Storm Surge Experts was hosted by the Indian IIT, New Delhi during the period from 09 - 20 December, 2013 and 17-28 February, 2014 respectively. Financial support in lieu of travel and per diem was provided to the participants by the WMO and from the PTC Trust Fund (PTCTF).
- PTC has been collaborating with the Typhoon Committee (TC) in the implementation of joint project "Synergized Standard Operating Procedures (SSOP) for Coastal Multi-Hazards Early Warning System (SSOP) which is funded by ESCAP Multi-Donor Trust Fund for Tsunami, Disaster and Climate Preparedness in Indian Ocean and South East Asia. The beneficiary countries include Bangladesh, Cambodia, China, India, Lao PDR, Malaysia, Maldives, Myanmar, Pakistan, Philippines, Sri Lanka, Thailand and Viet Nam. Typhoon Committee in collaboration with PTC successfully conducted three in-Country Pilot Workshops in Philippines, Bangladesh and Pakistan.
- In connection to the organization of SSOP in-Country Pilot Workshop in Islamabad, Pakistan from 10-11 October, 2013, PTC Secretariat extended full cooperation to the TC and PTC joint expert team towards making the workshop successful.

- As decided by the PTC at its 40th Session (Colombo, Sri Lanka from 25 February -01 March, 2013), WMO in collaboration with UN-ESCAP made arrangements to organize 1st PTC Integrated Workshop in Bangkok, Thailand from 27-29 November, 2013. PTC Secretariat extended invitation to the Panel Members through their P Rs for seeking nominations of their focal points/experts for PTC Working Groups on Meteorology (WG-M), Hydrology (WG-H) and Disaster Risk Reduction (WG-DRR) for participation in the Workshop. Financial support in lieu of travel and per diem for the participants was arranged by the WMO from PTCTF and by the UN-ESCAP. PTC Secretariat invited necessary inputs/feedbacks from the experts of PTC Working Groups and prepared draft report for endorsement of Panel at its forty-first session.
- As per recommendation of PTC at its 40th Session (Colombo, Sri Lanka from 25 February - 01 March, 2013) WMO made arrangements with the RSMC, New Delhi for the attachment of three Tropical Cyclone Forecasters - one each from Myanmar, Sri Lanka and Thailand. PTC Secretariat extended invitation for the training to these countries through their PRs with WMO. The training for the Tropical Cyclone Forecasters was hosted by RSMC, New Delhi, India during the period from 17-28 February, 2014. Financial support in lieu of travel and per diem to the participants was provided by the WMO and from the PTC Trust Fund.
- In connection to the replacement of some of the existing tropical cyclones names in the Operation Plan (TCP-21) with the new names as proposed by the PTC Member Sri Lanka, PTC Secretariat collected consent / agreement from PTC Member States to the new names for their inclusion in the Operational Plan 2013 version accordingly.
- With the support of the Panel, the Secretary of the PTC represented the PTC during the 69th Session of the ESCAP which was held in Bangkok, Thailand from 25 April to 01 May, 2013.
- Information regarding financial support by WMO from the PTC Trust Fund and detailed breakup of expenses incurred by PTC Secretariat during the intersessional period (2013-2014) is attached as **Appendix V.**

Appendix-I

Terms of Reference of the PTC Working Group on Meteorology (WGM)

In order to coordinate efforts in the implementation of various programmes and activities related to meteorology with the aim to better support the socio-economic development process in the PTC region and to help accomplish the strategic goals and objectives as mentioned under the Meteorological Component of the Coordinated Technical Plan of the WMO/ESCAP Panel on Tropical Cyclones (PTC) for the Bay of Bengal and the Arabian Sea, the PTC has established the Working Group on Meteorology (WG-M) as decided during 39th Session of PTC (Myanmar, 5-9 March, 2012) with the following Terms of Reference and operational modalities.

Terms of Reference

The WG-M will promote cooperation among the Members in the implementation of various programmes and activities under the Meteorological Component of the PTC's Coordinated Technical Plan with the aim to support the socio-economic development process and enhance cooperation among the Members in all the five major components towards this end. The WG-M is expected to advise and assist the PTC in:

- Identifying priority issues and areas of cooperation in the Meteorological Component;
- Promoting and facilitating the exchange of experiences and knowledge on the latest developments and techniques related to the above issues and areas;
- Coordinating and implement priority activities and programmes of the PTC aiming at strengthening capacity of the Members in meteorology;
- Mobilizing resources to carry out priority activities of the PTC related to the Meteorological Component;
- Developing Annual Operating Plan (AOP) for meteorology and reporting on the activities under the AOP;
- Reporting overall progress in the implementation of the Meteorological Component of the PTC's Coordinated Technical Plan;
- Recommending to the PTC's priority areas, programmes and activities for cooperation in meteorological research by related experts of the Members; and
- Performing any other task as assigned by the PTC.

Membership

The WGM consists of the following members:

- Mr Shamsuddin Ahmed, Bangladesh as Chairperson
- Mr. Khalid Khamis Saif Al-Jahwari, Oman as Vice-Chair
- Mr Ali Shareef, Maldives as Vice-Chair
- Focal Points of other 5 Member countries

The PTC invites WMO and ESCAP to continue their involvement in the work of WG-M. The PTC also requests the other concerned agencies to participate in the activities of WG-M. The term of service on the WG-M is 1 year, which shall be automatically extended for similar durations unless modified or terminated by the PTC.

Operation modalities

In view of the limited financial resources of the PTC Trust Fund, the WG-M is expected to perform its work through email and other means. The WG-M shall hold meeting during the annual Session of PTC. The WG-M members, however, may also meet during the inter-sessional period, if so necessary.

Reporting requirements

The Chairperson of the WG-M is required to report to the PTC on overall progress in the implementation of the Meteorological Component of the Coordinated Technical Plan as well as on the activities with regards to the AOP for meteorology through the PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report may also include recommendations related to priority activities to be undertaken in the coming years.

Appendix-II

Terms of Reference of the PTC Working Group on Hydrology (WG-H)

In order to coordinate efforts on the implementation of various programmes and activities related to hydrology with the aim to better support the socio-economic development process in the PTC region and to help accomplish the strategic goals and objectives as mentioned under the Hydrological Component of the Coordinated Technical Plan of the WMO/ESCAP Panel on Tropical Cyclones (PTC) for the Bay of Bengal and the Arabian Sea, the PTC has established Working Group on Hydrology (WGH), as decided during 39th Session of PTC (Myanmar, 5-9 March, 2012) with the following Terms of Reference and operational modalities.

Term of Reference

The WGH will promote cooperation among the Members in the implementation of various programmes and activities under the Hydrological Component of the PTC's Coordinated Technical Plan with the aim to support the socio-economic development process and enhance cooperation among the Member in all the five major components towards this end. The WGH is expected to advise and assist the PTC in:

- Identifying priority issues and areas of cooperation in the Hydrological Component;
- Promote and facilitating the exchange of experiences and knowledge on the latest developments and techniques related to the above issues and areas;
- Coordinating and implement priority activities and programmes of the PTC aiming at strengthening capacity of the Members in hydrology and water resources;
- Mobilizing resources to carry out priority activities of the PTC related to the Hydrological Component;
- Developing Annual Operating Plan (AOP) for hydrology and reporting on the activities under the AOP;
- Reporting overall progress in the implementation of the Hydrological Component of PTC's Coordinated Technical Plan;
- Recommending to the PTC's priority areas, programmes and activities for cooperation in hydrological research by related experts of the Members; and
- Performing any other task as assigned by the PTC

Membership

All Member countries will be represented at the WGH.
Pakistan, Myanmar, Bangladesh will be the Chair and Vice-chairs of the WGH respectively.
The PTC invites WMO and ESCAP to continue their involvement in the work of WGH. The PTC also requests to other concerned agencies to participate in the activities of WG-H. The term of service on the WGH is 1 year subject to extension authorized by the PTC.

Operation Modalities

In view of the limited financial resources of the PTC Trust Fund, the WGH is expected to perform its work through email and other means. The WG members shall meet if necessary.

Reporting Requirements

The Chairperson of the WGH is required to submit annual report on WGH activities with regards to the implementation of Coordinated Technical Plan through PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report will include recommendations related to priority activities to be undertaken in the coming years.

Appendix-III

Terms of Reference of the PTC Working Group on DRR

In order to coordinate efforts on the implementation of various activities under the Disaster Risk Reduction (DRR) Component to better support the socio-economic development process in the Panel on Tropical Cyclones (PTC) Area and to help accomplish the DRR related goals and objectives in the Coordinated Technical Plan (CTP) 2009-2011, PTC established the Working Group on Disaster Prevention and Preparedness, later renamed to the Working Group on Disaster Risk Reduction (WGDRR), with the following Terms of Reference and operational modalities.

Terms of Reference

The WGDRR will promote cooperation among the PTC Members in the implementation of activities under the DRR Component of the PTC's Coordinated Technical Plan to support the socio-economic development process and enhance cooperation among the Members in all the five components towards this end, the WGDRR is expected to advise and assist the PTC:

- Identifying priority issues and areas of cooperation in the DRR Component;
- Promoting and facilitating the exchange of experiences and knowledge on the latest developments and techniques related to the above issues and areas;
- Coordinating and implementing priority activities of the AOP and programmes of the PTC aiming at strengthening capacity of the Members in DRR;
- Mobilizing resources to carry out priority activities of the PTC related to the DRR Component;
- Monitoring and evaluating overall progress in the implementation of the DRR Component of the Coordinated Technical Plan;
- Recommending to the PTC priority areas, programmes and activities for cooperation in DRR research by experts of the Members;
- Promoting measures for more effective cooperation with other components of work of the Panel, including the development of the conceptual framework on multi-hazard early warning systems and public outreach programs; and,
- Reporting overall progress in the implementation of the DRR component of the CTP.

Membership

The WGDRR will consist of the following members:

- ✓ Mr. Adthaporn Singhwichai, Thailand; as Chairperson
- ✓ Mr. Captain Faisal, Oman; as Vice Chairperson
- ✓ Members' representatives

The PTC invites ESCAP and WMO to continue their involvement in the work of WGDRR. The PTC also requests the other concerned agencies to participate in the activities of WGDRR. The term of service on the WGDRR is 1 year subject to extension authorized by the PTC.

Operation modalities

In view of the limited financial resources of the PTC Trust Fund, the WGDRR is expected to perform its work through email and other means. The WG members shall meet if necessary.

Reporting requirements

The Chairperson of the WGDRR is required to submit an annual report on DRR activities with regards to the implementation of Coordinated Technical Plan through the PTC Secretariat to the PTC Chairperson and the PTC Members for their consideration under the framework of the PTC. This report will include recommendations related to priority activities to be undertaken in the coming years.

Appendix-IV

Recommendations of the Workshop

1. Meeting stressed upon the regular particpation of the representatives from some international organizations at the Panel Sessions and requested WMO to extend inviation to these agencies for sharing of knowledge among the Members.

2. PTC should pursue the participation of all WGs focal points in the next Panel Session. WMO requested Panel representatives to attend the next PTC Session on self supportive basis.

3. Although Oman is not included in the SSOP Project, Oman be also kept abreast of the outcomes of the Project .

4. Emergency response framework should be establised within the Panel region (to be discussed in the next Panel Session).

5. To raise the financial contribution to the Panel's Trust Funds (PTCTF), Members are requested to contribute more for enhancing the activities under various Working Groups of the Panel.

6. For widening the scope of the vision and activities of PTC, the meeting urged WMO to invite more countries lying along the rim of PTC region including Saudi Arabia, Iran, United Arab Emirates, and Yeman to become Member of PTC.

7. Collaboration with ESCAP/WMO Typhoon Committee should be enhanced to share the technology, experiences and knowledge to mitigate tropical cylcone related damages. To this end, experts from Typhoon Committee should be invited to the next PTC Session.

8. Sharing of cross boundary hydro-met data at Upstream to low Riparian among the PTC Members for mitigating the impending severe floodings.

9. Coupling of storm surge Model with Rainfall runoff and coastal inundation Model in Panel Member countries may be studied and implemented if seen appropriate.

10. Human Capacity building of operational Hydro-meteorologists in the field of Flood forecasting Modeling.

11. Capacity Building in software and Infrastructure development of the Flood forecasting system.

Appendix-V

Statement of PTC Secretariat Accounts

(2013- 2014)

Sr. No.	Opening Balance and Receipts	Amount in Pak. Rs.
1	Balance after 40th Session of PTC	180,100/-
	Total	**180,100/=**
	Expenditures	
1	Printing of 35th Issue of the Panel News	45,000/-
2	PTC Website Hosting Fee etc.	12,000/-
3	Services for PTC website design/updation support	10,000/-
4	Services for compilation work of Panel News Issue	17,500/-
5	Honorarium to Meteorologist-PTC Secretariat @ US$150/= per month (equivalent to Pak Rupees) (uptill July 2013)	87300/-
6	Purchase of Cooler Toner for Colour Laser Jet printer	Nil
	Total	8300
	Net Balance in hand	8300