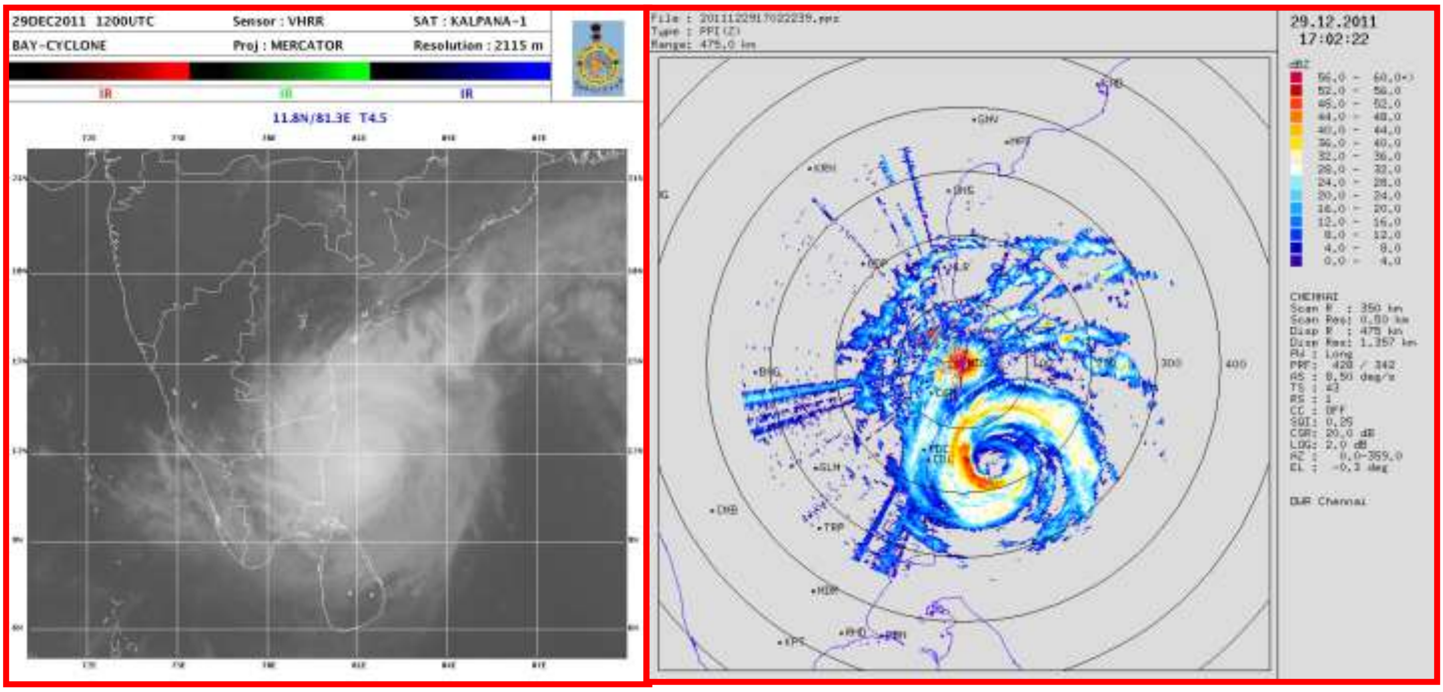
WMO/ESCAP
PANEL ON TROPICAL CYCLONES
ANNUAL REVIEW 2012



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

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

WMO

ESCAP

WMO/ESCAP

PANEL ON TROPICAL CYCLONES

ANNUAL REVIEW 2012

CONTENTS

PREFACE

First commenced in 1997, the publication of ***WMO/ESCAP Panel*** *- Annual Review* has entered **sixteenth** year of issue for the year 2012. 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, 2012 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 (2012 –13)

Chairman : Dr Somchai Baimoung (Thailand)
Vice-Chairman : Dr Thein Tun (Myanmar)
Chairman drafting committee: Mr S.H. Kariyawasam (Sri Lanka)

TECHNICAL SUPPORT UNIT (TSU)
ISLAMABAD, PAKISTAN

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

WMO SECRETARIAT FOR
TROPICAL CYCLONE PROGRAMME (TCP)

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

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

Mr. Yuichi Ono : Chief, Disaster Risk Reduction Section
Mr Clovis Freire : Economic Affairs Officer, Disaster Risk Reduction

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 2012 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 2012. Based on the real time and climatological data available with India Meteorological Department (IMD), India, special features of the 2012 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 2012-2013

CHAPTER-I

WMO/ESCAP PANEL ACTIVITIES IN 2012

1.1 METEOROLOGICAL ACTIVITIES

Activities of member countries on WMO/ESCAP Panel for the year 2012 were presented at the fortieth session of the WMO/ESCAP Panel on tropical cyclones held at Colombo, Sri Lanka from 25 February – 1 March 2013. 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

1.1.1.3 Forecast System

- WRF, JMA- NHM model, IIT-New Delhi Storm surge model, MRI model
- Installation of Diana by Met Norway

1.1.1.4 Outcomes of the program:

- Improved Forecast Services
- Now casting of severe weather events
- Increased accuracy of short and medium range forecast
- Multi hazard early warning
- Real Time Data Availability
- Spatial & Temporal Coverage
- Better Service Delivery

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 Guwahati	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 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

At present, CWIS at all airports is working satisfactorily. Performance of DIWEs has been more or less satisfactory during the year.
Integrated Automatic Aviation Meteorology System (IAAMS) are functional at Mumbai, New Delhi, Jaipur, Hyderabad, Bangalore, Chennai, Guwahati and Amritsar.

1.1.2.1.2 High Wind Speed Recorders (HWSRs)

HWSR system has been installed and operational at 13 coastal stations. These are Digha, Visakhapatnam, Chennai, Nellore, Machilipatnam, Karaikal, Puri, Balasore, Gopalpur, Paradip, Mumbai (Colaba), Veraval & Dwarka.
These are not functional at Puri, Balasore & Veraval. All HWSR stations are being equipped with GPRS modems so that the data in real time is available at website "imdaws.com".

1.1.2.1.3 AWS Network

Under the modernization Phase - I, a TDMA earth station along with 550 AWS has 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, 969 ARGs have been installed.

1.1.2.1.4 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.

1.1.2.1.5 Recent Achievements

1. Completion of installation of 550 AWS Project in February 2012.
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.

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

1.1.2.1.6.1 Projects under AOSN

I. Commissioning of TDMA type receiving Earth Station at IMD Pune
II. Commissioning of 50 Lightning Detection Sensors
III. Commissioning of 50 ship based Automatic Weather Stations
IV. Augmentation of Radiation Network.
V. Procurement of Digital Station Barometers (500Nos.).
VI. Procurement of spares for maintenance of Radiation network stations
VII. Up-gradation of the manufacturing facility for Surface Meteorological Instruments at IMD Work Shop- Procurement of Induction Furnace, Powder Coating machine and CNC Machine
VIII. Procurement and installation of Fire Alarm system in AWS Building

1.1.2.1.6.2` Projects under Weather Services – Aviation

1.1.2.1.6.2.1 Airport Meteorological Instruments (AMI)

I. Commissioning of Automatic Weather Observing System (AWOS) at -46 airports.
II. Commissioning of AWOS at 20 new airports.
III. Commissioning of Automatic Weather Observing System for safety of helicopter operations at 20 heliports.
IV. Procurement of spares for in house maintenance of AMIs, such as Current Weather Instrument System, ceilometers and Transmissometers.
V. Commissioning of 10 additional transmisometers for the airports

1.1.2.2 Upper Air observatories

1.1.2.2.1 RADAR Network

Originally India Meteorological Department was maintaining a network of 39 RADARs. Based on their usage, they are categorized as Storm Detection and Cyclone detection RADARs.

Cyclone Detection radars located along the east and west coast operate in S-band and storm detection radars located all over the country operate in X-band frequency range.

Optimum network requirements - 55 Doppler Weather Radars.

1.1.2.2.2 Cyclone Detection Radars (CDRs) :-

1.1.2.2.2.1 Present Status:

Prior to Mod. Phase-I – 5 Nos S-Band Doppler Weather Radars and under Mod. Phase-I & Ongoing - 12 S-Band (METSTAR), 2C-Band (Vaisala) & 2 S-Band(BEL).

1.	KOCHI	CDR Station	BEL
2.	BHUJ	CDR Station	BEL India
3.	KARAIKAL	CDR Station	S-Band
4.	PARADEEP	CDR Station	S-Band
5.	MUMBAI	Doppler Weather Radar	BEL
6.	CHENNAI	Doppler Weather Radar	Germany
7.	KOLKATA	Doppler Weather Radar	Germany
8.	MACHILIPATNAM	Doppler Weather Radar	Germany
9.	VISAKHAPATNAM	Doppler Weather Radar	Germany
10.	SHAR	Doppler Weather Radar	ISRO India
11.	HYDERABAD	Doppler Weather Radar	MetStar China
12.	LUCKNOW	Doppler Weather Radar	MetStar China
13.	MOHANBARI	Doppler Weather Radar	MetStar China
14.	NAGPUR	Doppler Weather Radar	MetStar China
15.	PALAM	Doppler Weather Radar	MetStar China
16.	PATIALA	Doppler Weather Radar	MetStar China
17.	PATNA	Doppler Weather Radar	MetStar China
18.	AGARTALA	Doppler Weather Radar	MetStar China
19.	HQ NEWDELHI	Doppler Weather Radar	VAISALA
20.	JAIPUR	Doppler Weather Radar	VAISALA

1.1.2.2.3 Procurement of 2 Nos. of DWRs from M/s BEL Bangalore

IMD is in the process of procuring two nos. of DWRs from M/s BEL, Bangalore under an ongoing scheme for replacement of existing radars at Bhuj and Kochi. The radar meant for Kochi has been installed at Mumbai due to some technical reasons. The RADAR is under installation at Bhuj.

1.1.2.2.4 Commissioning of 12 Nos. of DWRs:

In first Phase of modernization plan of IMD, 12 Nos DWRs procured from M/s Beijing Metstar, China are installed at Delhi (Palam), Hyderabad, Patna, Mohanbari, Patiala and Lucknow, and are yet to be installed at Bhopal, Goa, Paradip, and Karaikal.

1.1.2.2.5 Procurement of 2 C-band DWRs:-

IMD has procured 2 C-band dual polarized DWRs for installation in the IMD's radar network. These C-band DWR are installed at Delhi (HQ), Mausam Bhawan and at M.C Jaipur and commissioned.

1.1.2.2.6 Storm Detection Radars (SDRs):-

NAGPUR	Weather Radar	BEL
DELHI	Weather Radar	S-Band
JAISALMER	Weather Radar	S-Band
SRIGANGANAGAR	Weather Radar	S-Band
LUCKNOW	Weather Radar	X-Band BEL
MUMBAI	Weather Radar	X-Band BEL
CHENNAI	Weather Radar	X-Band EEC
GUWAHATI	Weather Radar	X-Band EEC
KOLKATA	Weather Radar	X-Band EEC
RANCHI	Weather Radar	X-Band EEC

1.1.2.2.7 Wind Finding Radars:-

KARAIKAL	Wind Finding Radar	BEL India
MACHILIPATNAM	Wind Finding Radar	BEL India
THIRUVANANTHAPURAM	Wind Finding Radar	BEL India
GOA	Wind Finding Radar	EEC

1.1.2.2.8 Weather cum Wind Finding Radars:-

CHENNAI	Weather & Wind Finding Radar	BEL
DELHI	Weather & Wind Finding Radar	BEL
HYDERABAD	Weather & Wind Finding Radar	BEL
PATIALA	Weather & Wind Finding Radar	BEL
AHMEDABAD	Weather & Wind Finding Radar	EEC
BANGALORE	Weather & Wind Finding Radar	EEC
BHUBANESWAR	Weather & Wind Finding Radar	EEC
MANGALORE	Weather & Wind Finding Radar	EEC
VISAKHAPATNAM	Weather & Wind Finding Radar	EEC

1.1.2.3.1 Status of Upper Air Instrument Network

At present, ascents with GPS Radiosonde are taken at Chennai, Srinagar & Hyderabad. IMD stations collocated with Indian Navy/IAF at 7 stations Nal, Aadampur, Kumbhigram, Arakkonam, Goa, Visakhapatnam & Kochi will transmit the observation taken from Indian Navy/IAF. Attempts are being made to start the manufacturing the Mark-IV radiosonde using solid state pressure sensor. Out of 39 RS/RW stations, priority “A” stations will take one ascent.

A scheme is proposed to improve the quality of observations at all 39 RS/RW stations under Modernization of IMD phase -1. To provide the data from high quality radiosonde, 25 RS/RW stations of the network will be operating with the GPS radiosondes procured through global tender.

- ❖ GPS based radio sounding system installed at Ahmedabad, Bhubaneswar, Bhopal, Kolkata and Nagpur.
- ❖ GPS radiosonde for Delhi has been obtained from IITM on loan basis
- ❖ Supply order placed for manufacturing of 4000 nos. of Indigenous GPS based radio sounding systems. Supply not yet received.
- ❖ Supply order placed for 8000 GPS sondes with 10 numbers of ground systems. The items will be received by end of February 2013.

The Global Climate Observing System (GCOS) Upper-Air Network (GUAN) is a subset of the global radiosonde network and comprises about 170 stations worldwide, to establish national commitments for the preservation of a minimum set of upper-air stations. At present, no Indian upper air station is part of GUAN and 6 RMCs namely New Delhi, Kolkata, Mumbai, Chennai, Guwahati & Nagpur are proposed to be part of GUAN.

The induction of Indigenous GPS radiosonde will be done in a phased manner. Indigenously developed radiosonde will be introduced at 14 stations in the first year for the extensive trial. Radiosonde will be manufactured in the workshop after procuring the required sensors package, GPS module, PCBs, Battery & housing. Radio receivers to decode the data from these radiosonde will be manufactured under MoU with M/s SAMEER or ISRO. Manufacturing facilities of IMD at Agra and New Delhi will be up graded as per ISO standards.

Even though, there is no replacement for the radiosonde measurement but various remote sensing instruments like wind profilers & Lidars have been introduced as alternatives to Pilot balloon observation in the global network to supplement high temporal resolution data suitable for NWP models. Another system named Microwave radiometer is also introduced to calculate a variety of surface and atmospheric parameters. These systems can operate unattended 24 hrs. and in nearly all weather conditions and also capable of providing data nearly in all weather conditions.

1.1.2.3.2. Meteorological Satellite

Met. Satellites of special relevance to TC analysis over North Indian Ocean are:

- INSAT and Kalpana
- Oceansat-II
- DMSP
- NOAA
- METEOSAT
- METOPs
- MODIS Payload from AQUA/TERRA.
- TRMM

All processed, VHRR/CCD images are analysed and advisories based on the imageries and derived products are provided to main forecasting centre of IMD. Normally

3-hourly satellite bulletins are prepared and sent on GTS for use of everyone. In case of severe weather, special satellite bulletins are issued.

During the occurrence of tropical cyclones, the cyclone centre, and intensity are determined using Dvorak Technique every hour and communicated to the main forecasting centres of IMD and are also disseminated to other Met. Offices.

Efforts are on to use Objective Dvorak Technique provided by SAC, ISRO in future cyclones.

1.1.2.3.2.1 Future plans:

1.1.2.3.2.1.1 INSAT-3D: INSAT-3D Satellite Scheduled to be launched in 2013.

Payloads

a. It has a 6-channel Imager almost similar to GOES satellites of USA.
b. It has a 19 –channel Sounder similar to GOES satellites.
c. It has a Data Relay Transponder (DRT) similar to Kalpana-1 and INSAT-3A.

INSAT-3D being an advanced satellite has better resolution and hence more accurate in monitoring weather and generating all other products and its vertical profile of temperature and humidity will make a great impact on weather forecasting by conventional and NWP methods and similarly on other applications.

It will be possible to detect night time fog more frequently and its hydro- estimator will be a better estimate of rainfall for flood monitoring etc.

1.1.2.3.2.1.2 Megha-Tropiques mission of ISRO: Polar orbiting:

It has the following payloads:

a) Microwave Analysis and Detection of Rain and Atmospheric Structures (MADRAS), with five channels of microwave for estimation of atmospheric water parameters in the equatorial belt.
b) SAPHIR microwave humidity sounder and radiometer of 6 channels for humidity profile.
c) SCARAB-broadband radiation measurement for measurement of Radiation fluxes.

Megha-tropique will give surface wind speed and convective rains over oceans and will be used in weather forecasting. Vertical profile derived from Radio occultation will be used in NWP models.

- Planning to determine Central Pressure, Maximum Sustained Wind of Tropical systems using Brightness Temperatures like other countries.
- Direct access of Meteosat-7 data & products.

1.1.2.4.1 Prediction Models in operational use during the year 2012

NWP Division of India Meteorological Department (IMD) operationally runs three regional models WRF (ARW), WRF (NMM) and Quasi-Lagrangian Model (QLM) for short-range prediction and one Global model (GFS T574/L64) for medium range prediction (7 days). The WRF-VAR model is run at the horizontal resolution of 27 km and 9 km with 38 Eta levels in the vertical and the integration is carried up to 72 hours over three domains covering the area between lat. 25^o S to 45^o N long 40^o E to 120^o E. Initial and boundary conditions are obtained from the IMD Global Forecast System (IMD GFS) at the resolution of 25 km. The boundary conditions are updated at every six hours interval. The QLM model (resolution 40 km) is used for cyclone track prediction in case of cyclone situation in the north Indian Ocean. IMD also makes use of NWP products prepared by some other operational NWP Centres like, ECMWF (European Centre for Medium Range Weather Forecasting), GFS (NCEP), JMA (Japan Meteorological Agency), UKMO etc. A multimodel ensemble (MME) for predicting the track of tropical cyclones for the Indian Seas is developed. The MME is developed applying multiple linear regression technique using the member models WRF, QLM, GFS (NCEP), ECMWF and JMA. NWP division also provides six hourly intensity forecasts and genesis potential inputs during cyclone conditions.

Recently, Hurricane WRF (HWRF) and TC Ensemble Forecast products are also added for improving cyclone forecast service of IMD.

1.1.2.4.1.1 Models in the experimental mode

1.1.2.4.1.1.1 Operational NWP Support for Cyclone Warning Service

Following Numerical Weather Prediction Models are used for monitoring and prediction of tropical cyclones over north Indian Ocean:

1.1.2.4.1.1.1.1 Global Models:

1. IMD GFS (T-574)
2. National Centre for Environmental Prediction (NCEP) GFS Model
3. European Centre for Medium-Range Weather Forecasts (ECMWF) Model
4. Japan Meteorological Agency (JMA) Model
5. Meteo France ARPEGE Model
6. UK Met Office (UKMO) Model

1.1.2.4.1.1.1.2 Regional models:

1. Quasi-Lagrangian Model (QLM)
2. Weather Research Forecast (WRF) IMD
3. Hurricane Weather Research & Forecast Model (HWRF)

1.1.2.4.1.1.1.3 Ensemble Systems:

1. Multi Model Ensemble Prediction Model (MME)
2. Single Model Ensemble Prediction System including:
    - Global Ensemble Forecast System Model (GEFS)

- European Centre for Medium-Range Weather Forecasts (ECMWF) Model
- UK Met Office (UKMO) Model
- Japan Meteorological Agency (JMA) Model
- MCH Canada

The following initiatives implemented at IMD during 2012

India Meteorological Department operationally runs three regional models WRF (ARW), WRF (NMM) and Quasi-Lagrangian Model (QLM) for short-range prediction and one Global model (T382L64) (current version T574) for medium range prediction (7 days). The WRF-VAR model is run at the horizontal resolution of 27 km and 9 km with 38 Eta levels in the vertical and the integration is carried up to 72 hours over three domains covering the area between lat. 25^{o} S to 45^{o} N long 40^{o} E to 120^{o} E. Initial and boundary conditions are obtained from the IMD Global Forecast System (IMD GFS) at the resolution of 35 km. The boundary conditions are updated at every six hours interval. The QLM model (resolution 40 km) is used for cyclone track prediction in case of cyclone situation in the north Indian Ocean. IMD also makes use of NWP products prepared by some other operational NWP Centres like, ECMWF (European Centre for Medium Range Weather Forecasting), GFS (NCEP), JMA (Japan Meteorological Agency), UKMO etc. A multimodal ensemble (MME) for predicting the track of tropical cyclones for the Indian Seas is developed. The MME is developed applying multiple linear regression technique using the member models WRF, QLM, GFS (NCEP), ECMWF and JMA. NWP division also provides six hourly intensity forecasts and genesis potential inputs during cyclone conditions. Cyclone track prediction skill of these models are summarized here in Tabular form in the verification section.

1.1.2.4.2 Hurricane WRF for Indian Seas

The basic version of the model HWRFV (3.2+) which was operational at EMC, NCEP was ported on IBM P-6/575 machine, IMD, New Delhi with nested domain of 27 km and 9 km horizontal resolution and 42 vertical levels with outer domain covering the area of 800x800 and inner domain 60x60 with centre of the system adjusted to the centre of the observed cyclonic storm.

The model has special features such as vortex initialization, coupled with Ocean model to take into account the changes in SST during the model integration, tracker and diagnostic software to provide the graphic and text information on track and intensity prediction for real-time operational requirement. HWRF model was tested to run the model in cycling mode at IMD, New Delhi. In this run only the atmospheric model (HWRF) was tested. The Ocean Model (POM-TC) and Ocean coupler requires the customization of Ocean Model for Indian Seas. IMD is expecting to implement the Ocean cupping in collaboration with INCOIS, Hyderabad. The model is presently under testing for experimental operational implementation. HWRF forecast of maximum wind, track, intensity of maximum wind and $P_{min.}$ during cyclonic storm NILAM are shown in Fig. 3.

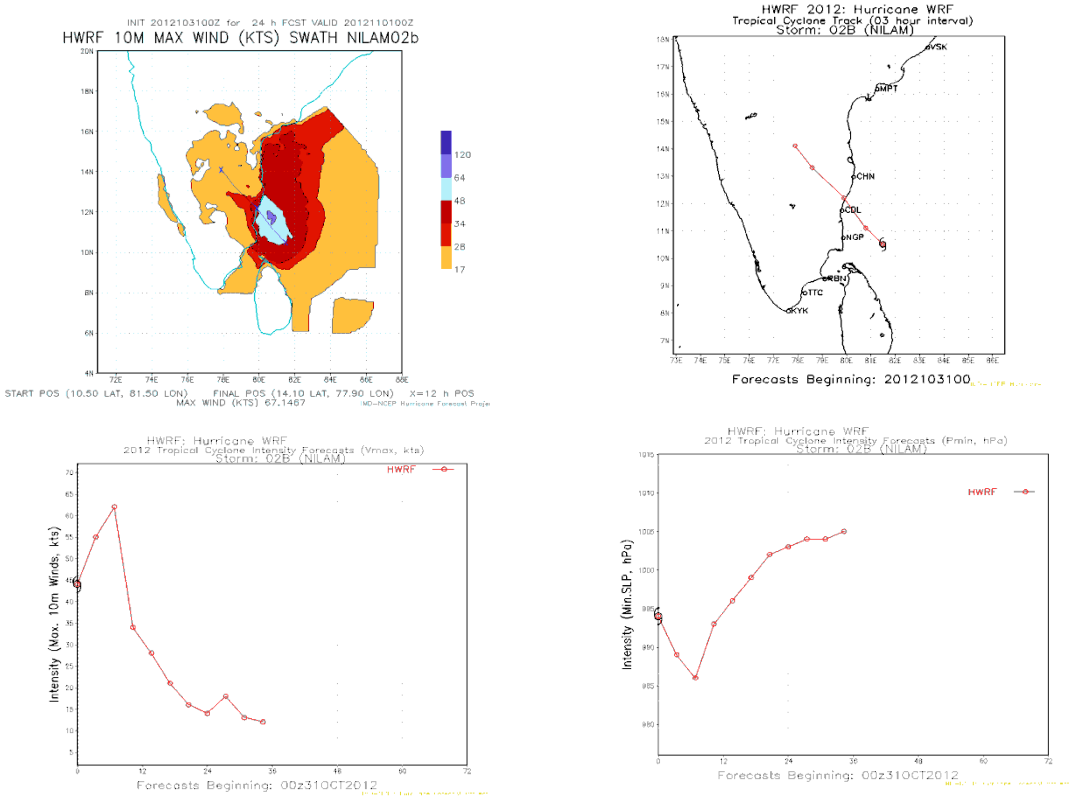
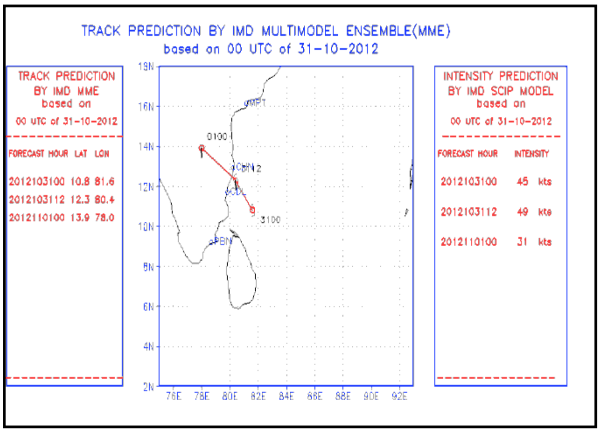


Fig.3 HWRF forecast of maximum wind, track, intensity of max. wind and $P_{min.}$

1.1.2.4.3 TC Ensemble Forecast for Indian Sea

As per the advice from WMO to provide a guidance of tropical cyclone forecasts in near real-time for the ESCAP/WMO members based on the TIGGE Cyclone XML (CXML) data, under the joint project of World Weather Research Program (WWRP) and Tropical Cyclone Program (TCP). TC homepage was developed by JMA and the same software was transferred to IMD to generate similar page for RSMC, New Delhi. The software was implemented at NWP Division, IMD, New Delhi and ensemble TC products from ECMWF, UKMO, NCEP and JMA will be provided experimentally during the post-monsoon cyclone season 2011 for ESCAP/WMO members of RSMC, New Delhi region. Products as per TIGGE ensemble run during CS NILAM based on 0000 UTC of 31st Oct. 2012 are shown in Fig.4.



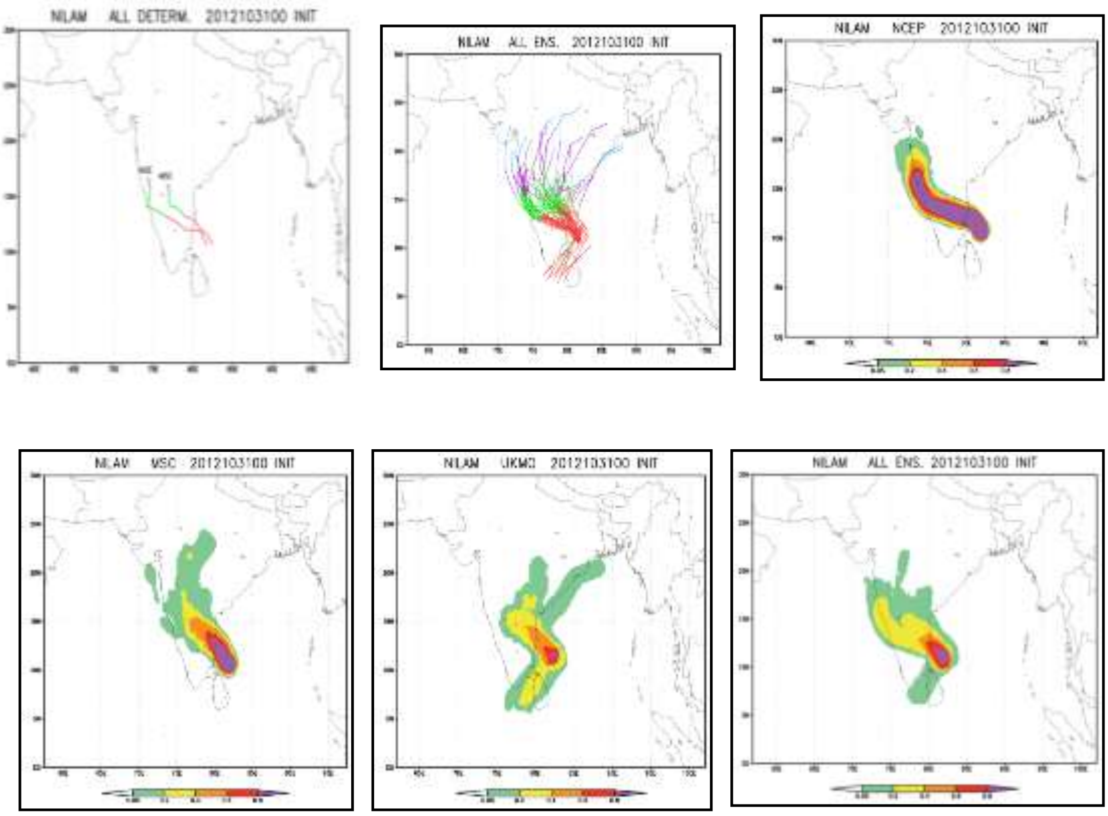


Fig.4 Deterministic and probabilistic track and strike probability during Cyclonic storm NILAM as per TIGGE ensemble run based on 0000 UTC of 31st Oct. 2012

1.1.2.4.4 Implementation of Global Forecast System (GFS)

Global Forecast System (GFS, based on NCEP) at T574L64 resolution has been implemented at NHAC, IMD HQ on IBM based High Power Computing Systems (HPCS). In horizontal, it resolves 574 waves (≈ 25 Km in the tropics) in spectral triangular truncation representation (T574). The model has 64 vertical levels (hybrid; sigma and pressure). This new higher resolution global forecast model and the corresponding assimilation system are adopted from NCEP, USA. The horizontal representation of model variables are in spectral form (spherical harmonic basis functions) with transformation to a Gaussian grid for calculation of nonlinear quantities and physics.

In the operational mode, the Global Data Assimilation (GDAS) cycle runs 4 times a day (00 UTC, 06 UTC, 12 UTC and 18 UTC). The assimilation system for GFS T574 is a global 3-dimensional variation technique, based on NCEP Grid Point Statistical Interpolation (GSI *3.0.0*; Kleist *et al 2009*) scheme, which is the next generation of Spectral Statistical Interpolation (SSI). The major changes incorporated in T574 GDAS compared to T382 GDAS are: use of variational quality control, flow dependent re-weighting of back ground statistics, use of new version and coefficient for community radiative transfer model, improved tropical cyclone relocation algorithm, changes in the land, snow and ice skill temperature and use of some new observations in the assimilation cycle. The data presently being pre-processed for Global Forecast System at IMD are Upper air sounding – TEMP, GPS & PILOT, Land surface – SYNOP, SYNOP MOBIL & AWS, Marine surface – SHIP, Drifting buoy – BUOY, Sub-surface buoy – BATHY, Aircraft observations - AIREP & AMDAR, Automated Aircraft Observation - BUFR (ACARS), Airport Weather Observations – METAR, Satellite winds – SATOB, High density satellite winds - BUFR (EUMETSAT & Japan), Wind profiler observations - BUFR (US/Europe), Surface pressure Analysis - PAOB (Australia), Radiance (AMSU-A, AMSU-B, HIRS-3 and HIRS-4, MSU, IASI, SSMI, AIRS, AMSRE, GOES, MHS, GPS Radio occultation, Rain Rate (SSMI and TRMM)

1.1.2.4.5 Meso-Scale Assimilation System (WRF-VAR)

The regional mesoscale analysis system WRF (ARW) was implemented on the HPCS at HQ of IMD, Delhi with its all components namely, pre-processing programs (WPS and REAL), data assimilation program (WRF-Var), boundary condition updating and forecasting model (WRF) and NCL for display. The pre-processed observational data from GTS and other sources prepared for the Global Forecast System in the BURF format (PREPBUFR of step 2 in GFS) is also used in case of WRF assimilation.

In the WRF-Var assimilation system, all conventional observations over a domain (200S to 450N; 400E to 1150E) which merely cover Regional Specialized Meteorological Centre (RSMC), Delhi region are considered to improve the first guess of GFS analysis. Assimilation is done with 27 km horizontal resolution and 38 vertical eta levels. The boundary conditions from GFS forecasts run at IMD are updated to get a consistency with improved mesoscale analysis. WRF model is then integrated for 75 hours with a nested configuration (27 km mother and 9 km child domain) with physics including cloud microphysics, cumulus, planetary boundary layer and surface layer parameterization. The post-processing programs ARW post and WPP are also installed on HPCS to generate graphical plots and grib2 out for MFI-SYNERGIE system respectively.

WRF at 3 km resolution was implemented for National Capital Region of Delhi Region. High resolution WRF has been in operational at other ten regional centres.

1.1.2.5.1 Telecommunication Network in IMD

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

1. India Meteorological Department has its National Meteorological Telecommunication Centre (NMTC) with an Automatic Message Switching computer System (AMSS) which is connected to WMO Centres 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 2012-2013 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) Data from airforce stations is being received and routed to national users.

(xii) 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.

(xiii) 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.

1.1.2.5.1.2 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.

1.1.2.5.1.3 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.

1.1.2.5.1.4 VSATs

A network of 26 V-SATs have been installed at selected seismological observatories, Cyclone Radar stations, Cyclone Warning Centres and Meteorological Centres 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.

1.1.2.5.1.5 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.

1.1.2.5.1.6 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).

1.1.2.5.1.7 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 centre 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 Centres (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.

1.1.2.5.1.8 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.

1.1.2.5.1.9 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.

Following are the services operational through this portal:

i. Procurement Monitoring System
ii. Personal Information System
iii. IT Inventory System
iv. File Tracking System
v. Leave Management
vi. Meteorological Photograph & Document Sharing System
vii. Abroad Visitor’s Information System
viii. IMD Directory Search System
ix. DGM’s engagement Monitoring System
x. Upper Air observatories Monitoring System
xi. Mausam Journal catalogue

xii. Salary and Miscellaneous payment's display
xiii. Progress Report Display and Upload
xiv. Forecasting facilities
xv. Fault Monitoring and Lodging System
xvi. Biometric Attendance Record Updation
xvii. Pensioner's Corner
xviii. PROMAN Ver 2.0- Project Monitoring System
xix. MIMS Ver 1.0- Met. Instruments Monitoring System
xx. DAKIA- Dak Inventory Application
xxi. IMD AWAS- Online Guest House Booking and Management System
xxii. APARNA Ver 1.0- Annual Performance Appraisal Report Notation & Administration.

In addition, using the portal provision is made to:

a. To publish seniority list, Office orders and other documents of interest to IMD employees.
b. Publish Mausam Catalogue for reference.
c. Download various forms for use by employees.

1.1.2.5.1.10 Annual Global Monitoring

Annual Global Monitoring during the period 1-15th October, 2012 and the result sent to WMO via Internet. The % of SYNOP was 97.72% and TEMP 40.60%.

Video Wall was commissioned in NWFC with three years comprehensive Warranty w.e.f 30-8-2010.

Video Conferencing Facility with H.Q.NWFC to 8- Forecasting offices at RMCs & Pune is established.

The Intra IMD Portal popularly called METNET was launched on 27th July, 2008, by the IT Unit functioning under the Information System and Service Division, India Meteorological Department as a first initiative to have coordinated approach to standardize data base and various in house e-governance related administrative with the following objectives:

- To implement e- governance concepts in IMD,
- To create a suitable platform for sharing of Administration information in IMD,
- To Co-Ordinate the IT efforts of various sub office of the Department,
- Bring efficiency and transparency in Office work,
- To reduce the delay in exchange information and making it available in proper format,
- Create an organizational setup which is tuned to use IT to optimize administrative and scientific.

1.1.2.5.2 Ongoing projects:

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

1.1.2.5.2.2 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 Observations

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. Total of 23 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. Across the country, Maldives has 7 rainfall stations which measure only accumulated rainfall for 24 hours and readings are collected at 0300UTC for national use only.

1.1.3.2 Upper Air Observations

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. With all of its features, DMDD helps forecasters to do more precise predictions. However, this system is facing signal loss therefore nothing has been received during 2012. 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. Another component of this system is the application software MICAPS (meteorological data analysing system) which enables to display satellite pictures, surface & upper air data and NWP products and overlay different products and analysis of various weather phenomena.

1.1.3.4 Doppler Weather Radar

Doppler Weather Radar received as part of Multi-hazard Early Warning System has been repaired in 2011. However, it needs further calibration of equipment by a professional and local technicians are unable to do the job. MMS have begun the process of hiring an expert to bring this system to normal.

1.1.3.5 Numerical Weather Prediction

The system which runs WRF model gives problems time to time as the hardware become old and it is impossible to upgrade them due to financial crisis. Maldives

Meteorological Service continues to use NWP output provided by RIMES, ECMWF, IMD and other web based NWP products.

1.1.3.6 NMC's Global Telecommunications System (GTS)

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 2012, Maldives received many complains from other countries and GCOS of not receiving our SYNOP, 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 2011–12 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.

1.1.4 Myanmar

1.1.4.1 Improvement/Upgrading of Meteorological Facilities

Multifunctional Satellite Image(MTSAT) ground receiving system and related computer facilities, JMA GSM GRIB data, soft wares, JMA storm surge model, one high accurate digital barometer, technical guidance methods were provided under the Japan International Cooperation Program's Improvement of Storm Forecasting Project (2010-2012). GTS Message Switching System is operating normal condition. Recently DMH Head Office Nay Pyi Taw and RTH New Delhi, RTH Bangkok were linked. Procedures are being undertaken to test transmission via new Japan Meteorological satellite. Upper Air Observation System is still single observation station and need to establish more observatories. (10) Location specific Meteorological information like EPSgram, provided by WMO and ECMWF, were utilized for daily weather forecast, and WMO/RAII City Weather Forecast from Hong Kong Meteorological Services provided Meteogram for (12) cities. Meteorological services of DMH were very supported by these tools, on job training to the daily weather forecast and severe weather analysing and forecasting. GFS GRIB2 data based WRF Model is operating once per day and (30) images are updated and posed on DMH Website daily for agriculture, general public, transportation, etc. The WRF Modelling system is the first NWP activities and to be carried out for Regional Climate Model in near future. Meanwhile, Norwegian government's technical assistance for the development program of weather forecasting including NWP based DIANA Model will be collaborated in March 2013.

1.1.5 Oman

1.1.5.1 Upper Air Observation

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

1.1.5.2 Surface Observation

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.

1.1.5.3 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.

1.1.5.4 Wave Measurements

One wave radar measurement station was installed offshore of Qalhat (Sur)- Oman liquid Gas Company- an other two wave measurement stations located offshore of Sohar Station and Mina Salalah Station and the collected data is inserted on the GTS every three hours. Seven tide gauges were installed at Diba, Sohar, Wudam, Quriyat, Sur, Alashkhara and Duqm.

1.1.5.5 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 dial-up telephone link (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 centres as New Delhi and Abu Dhabi.

A bilateral Internet Circuit, which was established between these centres and the Directorate General of Meteorology and Air Navigation (DGMAN) for the exchange of meteorological data, has proved to be very effective, useful and most stable.

Beside that this connection is used to receive the boundary data initiated from the German weather service to be used for the Omani model. This connection have in its structure different servers as ftp server which is used for serving different users with special meteorological data. All these servers are protected by a firewall.

1.1.5.6 Satellite reception

The Department installed Second Generation Satellite ground receiving station and the ground-receiving stations for intercepting High Resolution images from Polar Orbiting satellites

1.1.5.7 Data Visualization

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

1.1.5.8. Data Processing System

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

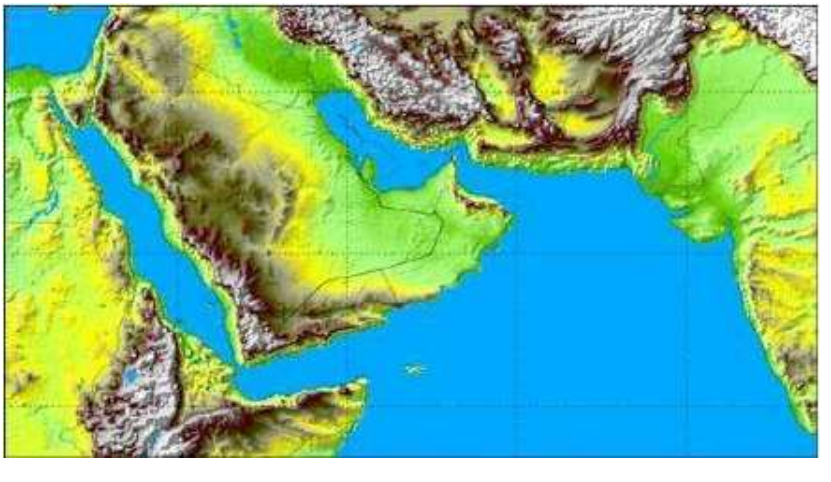
Current processing capabilities consist of a PC Cluster of 72 nodes with total of 144 processors. Quad-coreAMD Opteron 3.2 is used for each node. This make a total of 756 processing core. All nodes are connected via very fast Interconnection network using 144-port Infiniband switch with guarantees 3Gbps 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 for meso-α and meso-β. Main prognostic variables are: Surface pressure (ps), Temperature (T), Water vapour (qv) Cloud water (qc), Cloud ice (qi), Ozone (optional), Horizontal wind (u, v) and Several surface/soil parameters. More details are available on the model website (http://www.met.gov.om/hrm/index.php).

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 following figure shows the domain area.



B] Consortium for Small-scale Modeling COSMO is a non-Hydrostatic limited-area numerical weather prediction model for meso-α and meso-β. Main prognostic variables are: pressure perturbation (p‘), Temperature (T), specific humidity (qv) Cloud water (qc), Cloud ice (qi), Horizontal/virtical wind (u, v) and Several surface/soil parameters. More details are available on the model website (http://cosmo-model.cscs.ch **)**

DGMAN run a operational version of COSMO model . It runs on 7x7 km covers the same domain of ORM_14 and 2.8km resolution covering Oman. 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] Tsunami Model for the Gulf of Oman and India Ocean: Comit Model from IOC is used to develop some hypothetical experiments to simulate tsunami waves propagation and indentation**.**

1.1.5.9 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.

1.1.5.9.1 Verification Package

The Directorate General of Meteorology and Air Navigation (DGMAN) managed successfully to develop 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 in several countries such as UAE, Brazil, Jordan, Malaysia, Hungary, Vietnam, Iran, University of Berlin, Kenya and Madagascar. Panel Members may get a copy also if they request Oman's P.R.

1.1.5.10 Aeronautical Services

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

Other Important Achievements and Future Projects

- The Forecasting Centre runs now a weather studio to prepare TV general weather forecasts in Arabic and English.
- Installation of additional automatic weather stations (44 land stations currently).
- A network of Doppler weather radars to be installed starting from June 2013.
- Plan to run WRF numerical weather prediction model
- Update of the Met Website as well as introducing a smart phone application for weather.

1.1.6 Pakistan

1.1.6.1 Donation of Meteorological Instrumentation by CMA

During June 2012, China Meteorological Administration donated Met instruments to PMD under WMO VCP in order to further strengthen the meteorological observational network of PMD in the aftermath of devastating flooding in Pakistan during summer monsoon season 2010. The donation includes various meteorological instruments and the installation process is underway.

1.1.6.2 Upgradation of Weather Radar Network of PMD

During 2012, under JICA/Government of Japan project “Upgradation of weather Radars of Pakistan Meteorological Department” three PMD weather radars located at Islamabad, Rahim Yar Khan and Karachi were successfully upgraded. The project is also followed by a short training course for the engineering staff of PMD by the JICA experts.

1.1.6.3 Numerical Weather Prediction at PMD

Pakistan Meteorological Department (PMD) has been using High-resolution Regional Model (HRM) of DWD (the National Meteorological Service of Germany) as an operational model for Numerical Weather Prediction since 2007. The model output (prognostic charts) are also regularly uploaded at PMD’s website: www.pmd.gov.pk. Initially, the model was run with 28 Km resolution. Later, in March 2008, the model resolution was improved to 22 Km. In 2009, additional servers/hardware with processing power of 1.7 T-FLOPS was purchased to upgrade the computer system. Subsequently, the HRM has been operational with 11 km resolution since September 2010. The 7 km resolution was not successful with HRM for Pakistan due to complex topography of country and the limitations of the HRM (for being a hydrostatic model) in representing the full spectra of waves (e.g., trapped lee waves), which are connected to steep slopes. During 2012, the spatial coverage of HRM simulation has also been extended and now model is simulated using domain size 46°E to 96°E and 5°N to 50°N. A GTS link via ftp has also been established between China Meteorological Administration (CMA), and PMD Islamabad. NWP products of CMA's Global Spectral Model (GSM) in Grib1 format are being uploaded to our ftp server daily at 00:00, 06:00, 12:00, and 18:00 GMT. GSM has a horizontal resolution of TL639 (0.28125 deg) and is used for Short- and Medium-range forecast.

1.1.6.4 Interactive Voice Response (IVR) System Inaugurated at PMD

During 2012, Pakistan Meteorological Department (PMD) has been extending Interactive Voice Response (IVR) System facility under the Sustainable Land Management Program (SLMP). The IVR System provides the direct telephonic service to the public and stakeholders by dialing (051) 111-638-638 to get the weather related information.

The IVR System was inaugurated by Mr. Muhammad Javed Malik, Secretary, Ministry of National Disaster Management, at Meteorological Headquarter Office, Islamabad. The inaugural ceremony was also attended by Dr. Qamar-uz-Zaman Chaudhry, Advisor (Meteorology & Climate Affairs), Dr. Amjad Tahir Virk (NPC–SLMP), Dr. Shahina Tariq (COMSATS Institute of Information Technology), Mr Saleemullah Khan (UNDP), Mr. Irfan (WFP), Mr. Kazim Bukhari (Coordinator SLMP) and senior officials of PMD. The chief guest tested the IVR system during the introductory session and appreciated the new facility at PMD.

Establishment of Specialized Medium Range Forecasting Centre (SMRFC)

During September, 2012, Minutes of Discussion was signed between PMD and Japan International Cooperation Agency (JICA) for the project "Establishment of Specialized Medium Range Forecasting Centre (SMRFC) and Strengthening of Early Warning and Dissemination Network". According to the minutes, government of Japan through grant-in-Aid would provide State-of-the-Art technology related to the forecasting and early warning. The estimated cost of the project is around Pak Rs.1.75 Billion. After installation of the proposed equipment and machinery, PMD would be capable to issue weather forecasts and early warnings well in time.

1.1.7 Sri Lanka

1.1.7.1 Upper Air observations

Radiosonde observations were conducted three times a week at 1200 GMT with GPS sondes until May and then it started to do at 0600UTC considering utilization for weather day today forecasting. Pilot balloon observations were conducted at, Hambantota (43497) and Polonnaruwa(new station) at 0000,0600 and 1200 GMT and at Colombo at 0000GMT and at 0600 and 1200 GMT to supplement the radar wind observations (to fill the gaps of any failures of the equipments). From January, the Pilot balloon observations were resumed at Mannar (43413) where temporary suspended due to security reasons. At Puttalam (43424) where pilot observations were performed to fill the gap due to absence of the same at Mannar was terminated with resumption of the same at Mannar.

1.1.7.2 Surface observations

Data reception from 22 operational stations with the two stations commenced in 2009 namely, Polonnaruwa and Moneragala (No WMO number assigned yet) was very good. Observations taken and sent in plain language by Sri Lanka navy at Trincomalee (43418) are coded at NMC. Out of RBCN stations, silent climate TEMP data, Colombo (43466), due to non- availability of continuous data and nine RBSN stations are operational. Problems of equipments/sensors 35 Automatic Weather Systems have been mostly settled with the supplier. Another AWS was installed at Ampara at the beginning of the year. Eleven new rainfall stations were commenced in Anuradhapura district in the north central parts of Sri-Lanka.

1.1.7.3 Ships and Aircraft Reports

Ship observations are still not received at Colombo radio shore station. However, many are received through GTS. Reception of AIREPS at Airport Meteorological office remains poor as the data are downloaded through ADS (aircraft data surveillance) with other aeronautical data at the Domestic Airport at Ratmalana and as there is no proper mechanism to sort out the AIREPS.

1.1.7.4 Meteorological Satellite

The satellite imageries through internet were utilized throughout the year Under a bilateral agreement with KOICA, a project to install a receiving system of Communication, Ocean and Meteorological Satellites (COMS) at Colombo was installed and commissioned in May. The necessary training in hardware and software were also provided by KOICA. Chinese FENYUNGCast system was fully operational and was upgraded by CMACast in September

1.1.7.5 Improvement of facilities / Technical Advancement

Civil constructions with regard to Doppler Weather Radar were continued throughout the year. The location and ground condition of the site made it much difficult task for the completion although the site is very much appropriate for radar. Construction of new buildings for Jaffna Meteorological office was commenced. A block of land has been acquired for the construction of Trincomalee (43418) Meteorological office and construction of new buildings has been commenced.

An expert committee formed taking the leading role of Department of Meteorology to "investigate to minimize the damages due to lightning" continued its activities. Government of Sri-Lanka is planning to commence another International Airport at Mattala in Hambantota district in the south eastern part of Sri Lanka and hence new synoptic station and Meteorological Watch Office will be commenced at the airport premises to fulfill the aero meteorological requirements.

Links with RIMES was continued for Reducing Risks of Tsunami, Strom surges, Large Waves and other natural hazards in low elevation coastal zone. Under this program, to improve the forecasting capability of department activities on training and utilizing WRF model has commenced. Issuing of seasonal rainfall forecast under experimental basis was commenced.

1.1.8 Thailand

1.1.8.1 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	•

1.1.8.2 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.

1.1.8.3 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. Now it is in the process of verification.

1.1.8.4 Weather Forecasting Service

Thailand issues the routine day-to-day weather forecast and the tropical cyclone warning. For public awareness and advice, much more weather advisories are issued at frequent interval if cyclones form in areas of the Indian Ocean and the North Pacific Ocean. The bureau will then transmit weather products to public and related agencies by telephone, fax, e-mail, website, and mass media.

Based on analysing and forecasting tools, still the TMD uses primitive method, Dvorak technique and NWP products (EPS) in the growth of tropical cyclones. The accuracy of severe weather forecast and warning, and movement are related to technique and instrument. Depended on the internet, data were exchanged through GTS Circuit with various meteorological centres, such as the JMA and the JTWC. These exchanged data were proved very effective and useful to adjust more accuracy of the storm’s course and intensity.

1.1.8.5 Ocean wave and Storm Surge Forecasting

Marine Meteorological Centre under Thai Meteorological Department has been responsible for running Ocean wave and Storm surge model. In part of Storm Surge model, TMD has been using JMA Storm Surge Model, COHERENS and SMS model as operational in order to do warning people in the Gulf of Thailand and the Andaman Sea. The model products have shown the sea level changes or the maximum storm surge height map due to the influence of wind and low air pressure along the Gulf’s coast. You can visit our webpages as below:
http://www.marine.tmd.go.th/wam.html , http://www.oceansky.tmd.go.th/

1.1.8.6 Telecommunication

- Replacement of old analog with digital system improves the linkage of the GTS and the AFTN;
- Control systems of telecommunication networks increased the development of a national early warning system and enhanced the data-collection system of meteorological stations across the country;
- The GTS connected the TMD with the National Disaster Warning Centre (NDWC) for scattering DART BUOY, installed in the Indian Ocean, to the WMO's member countries. It also helped in-and-out data exchange improve in Table-Driven Code Form (TDCF). This project supported the TMD to be the RTH Bangkok WIS portal in Southeast Asia.

1.1.8.7 Awareness Activities

Public awareness was designed to educate students, teachers and public all about weather as seen successful projects, namely, "Meteorological Roaming" and "Training Teachers of Meteorology". Otherwise, we stressed on news distribution through public via media.

1.1.8.8 Information Access

The official website of the Thai Meteorological Department http://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. You can access marine meteorological information such as ocean wave forecast product, storm surge model products and so on at http://www.marine.tmd.go.th.

Activities of WMO

Regional Basic Synoptic Network (RBSN)

The representative of WMO reported status and monitoring results about the Integrated WWW Monitoring (IWM) that continued to provide information on the performance level of the observing and telecommunication systems. As per the average results of the IWM exercise carried out on a quarterly basis during the period July 2011 to April 2012, the availability of expected SYNOP reports on the Main Telecommunication Network (MTN) from a total of 298 surface stations (an increase of one station during the intersessional period) in the RBSN operated by Members of the WMO/ESCAP Panel on Tropical Cyclones is given in the table below. The average availability of SYNOP reports ranged from 62% to 98% during this period. The availability of SYNOP reports continued to be more than 70% for all countries, except for the Maldives, which nevertheless showed a very positive increase from 9% to 62% during this period. Overall, the total availability of reports increased from 86% in the previous year to 88% during this period.

The availability of expected TEMP reports on the MTN from a total of 53 upper-air stations (52 stations - 2010/2011) in the RBSN operated by Members of the WMO/ESCAP Panel on Tropical Cyclones according to the results of the IWM exercise carried out on a quarterly basis from July 2011 to April 2012 is also provided in the table below. The average availability of TEMP reports ranged from zero to 70% with decreased availability in most countries. As during the previous period, the availability of TEMP reports from Myanmar remains at zero along with Sri Lanka which included one new station during this period. Overall, with the reduction in the number of reports received from a majority of Panel Members the average percentage of the total number of TEMP reports received declined from 38% to 32% during this period.

It is pertinent to note that investigations into dissemination of especially upper-air data indicate that some countries perform observations at non standard times of observations (the four main standard times of observations for surface synoptic stations included in the RBSN are 00, 06, 12 and 18 UTC and for upper-air synoptic stations carrying out radiosonde and radio wind observations it is 00 and 12 UTC) resulting in the possible non inclusion of availability in the Integrated WWW Monitoring (IWM) results.

Marine and Ocean Meteorological Observations

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 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 Ocean Obs’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. All data are being made freely available to all Members in real-time. However, progress has been slowing down recently, and 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 (1292 global units in November 2012) although technical problems with regard to the drifter life-times and their drogues have been noted since 2011. Efforts are being made to increase robustness of the drifters, and the number of those reporting sea level pressure (585 global units in November 2012). Regions such as the North West Indian Ocean, the Mozambique Channel, the SouthWest 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 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. 3626 floats were operating worldwide in December 2012 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 still short of requirements in the far Southern Ocean. Regions such as the South China Sea, the East China Sea, the Mozambique Channel, the Gulf of Aden, and around Indonesia appear poorly covered. 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 real time 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. Currently 15% of active floats use high bandwidth two-ways telecommunication systems and this is projected to rapidly increase. Pilot deployments of bio-optical-geochemical sensors and ice-avoidance capabilities continue. Several groups are developing and field testing “deep floats”. The evolution of Argo to pursue new and additional missions is being discussed at various workshops and by the Argo Steering Team.

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 consists of a basin scale network of 46 deep ocean moorings that provide essential data to complement other existing satellite and in situ observations in the region. Plans for 2013 are to maintain 30 sites (i.e. 65% of the 46 target) and add 2 more sites. 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. 5.1.21 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. A new VOSClim class of vessel has recently been introduced in the VOS Scheme for 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 293 stations can be considered operational in May 2012, and there are focused efforts to address the remaining 25% of stations not currently on-line.

Panel members are invited to explore enhanced contributions of WMO Members in the region in support of the implementation of the buoy networks in the tropical Indian Ocean in particular (RAMA Array). Of particular interest is the provision of ship time to assist in the deployment and servicing of RAMA 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 (stroker@jcommops.org).

Aircraft-Based Observations

The WMO aircraft-based observing system, comprising the AMDAR observing system supplemented by aircraft observations derived from ICAO systems, now produces well over 300,000 upper air observations per day on the WMO GTS, with the AMDAR system contributing the vast majority and around 300,000 observations from 38 participating airlines and a global fleet of over 30000 aircraft. This critical 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 figure below shows a filtered coverage map, with vertical profile locations indicated in red and illustrates the limited coverage over Western Asia and the Bay of Bengal.

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 utilisation of AMDAR as a contribution to derivation of high quality upper air data and vertical profiles. CBS is also overseeing the production 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 would be expected to have a significant additional positive impact on tropical cyclone forecasting and monitoring skills and applications.

Surface-Based Remotely-Sensed observations

Of critical importance for severe weather and tropical cyclone monitoring and prediction are weather radar systems and the data and products derived from them. WMO and the Commission for Basic Systems (CBS) have overseen a recent 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 will make 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 nominate WMO radar metadata focal points to ensure that all weather radars are included and routinely maintained and updated in the WRD.

Planning has commenced for a Workshop in early 2013 on the Regional and Global Exchange of Weather Radar Data. It is expected that the outcomes from this workshop would provide clear guidance to enable Members to meet the requirements for the international exchange of Doppler radial winds and reflectivity data, which was a clear recommendation from the fourth WMO Workshop on the impact of various observing systems on Numerical Weather Predictions.

WMO Information System (WIS/GTS)

The WMO Global Telecommunications System (GTS) comprises a dedicated network of surface-based and satellite-based telecommunication links and centres operated by countries, interconnecting all NMHSs for the round-the-clock rapid and reliable collection and distribution of all meteorological and related data and forecasts. The GTS also provides for the exchange of weather, water and climate-related warnings, supporting the distribution of multi-hazard alerts and advisories and exchange of related information. The GTS is fully operational in the countries Members of the Panel on Tropical Cyclones, interconnecting all NMHSs. RTHs Bangkok and New Delhi are the lead GTS centres in the area.

The current GTS is evolving towards the WMO Information System (WIS) to provide new and more flexible functionality to support all NMHSs core activities. This includes ensuring the rapid exchange of warnings and information to support national Early Warning Systems. The WIS implementation plan is progressing well, with two parts being developed and implemented in parallel: Part A consisting of consolidation and further improvements of the GTS for time-critical and operation-critical data, including its extension to meet operational requirements of all WMO Programmes, and Part B, consisting of the extension of the information services through flexible data discovery, access and retrieval services to authorized users, as well as flexible timely delivery services. For the WIS-GTS real-time network structure, the concept of Area Meteorological Data Communication Networks (AMDCN) has been developed, in which each WIS Global Information System Centre (GISC) is responsible for ensuring that telecommunication links and data flow in its area of responsibility are coordinated appropriately. Also, the global DVB-S infrastructure of the Integrated Global Data Dissemination Service (IGDDS) is progressing well with the implementation of inter-regional data exchange mechanisms and user support services.

WIS has been operational from January 2012, with five GISCs (Beijing, Exeter, Offenbach, Tokyo and Toulouse) now offering services. More GISCs are planned, including one in New Delhi. These are supported by Data Collection or Production Centres. GISCs Beijing and Tokyo are offering an interim metadata management service that centres can use to manage their WIS Discovery Metadata until their principal GISC becomes operational. The Manual on WIS (WMO No. 1060) and amendments to include WIS in the Technical Regulations (WMO No. 49) have been published. These combined with a Guideline to WIS and guidelines for WMO Metadata for WIS (http://wis.wmo.int/page=WmoCoreMetadata) will allow all Members to begin to implement the new WIS functionality. It is expected that GISC New Delhi will take the leading role in ensuring Members of the Panel on Tropical Cyclones also implement and benefit from the new functionality of WIS.

The Common Alerting Protocol (CAP, ITU Recommendation X.1303) is a content standard designed for all-hazards and all-media public alerting. CAP is used in the disaster response community for delivering information about a large variety of events, and it is suitable for the dissemination of weather, climate and water related alerts and warnings. Thus CAP will now be supported in the virtual all hazards network within the WIS-GTS.

For Members to benefit fully from WIS, it is essential that NMHS implement plans to deploy WIS functionality in their programme plans and that committees such as the Panel on Tropical Cyclones work with the GISCs and WMO secretariat to ensure their programmes include WIS implementation as a priority activity over this WMO 16th financial period.

Space-Based Observing System (SBOS)

The space-based observing system includes constellations of operational satellites in geostationary or Low-Earth Orbit (LEO). Environmental Research and Development (R&D) satellites provide a useful complement to these operational observations when available in near-real time. Of particular importance for tropical cyclones are geostationary imagery for continuous monitoring, infra-red and microwave imagery from LEO satellites to derive sea surface temperature, microwave sounding from LEO satellites to derive total precipitable water, microwave imagery associated with active microwave sensors for precipitation rate (like TRMM and the future GPM), scatterometry (e.g. with Metop/ASCAT) to derive ocean surface wind fields, and radar altimetry (e.g. Jason-2) to derive sea state. An updated summary status of satellite missions contributing to the Global Observing system is available on: http://www.wmo.int/pages/prog/sat/satellitestatus.php.

Current constellations of geostationary meteorological satellites of primary relevance for the Asia-Pacific region include: MTSAT-2 operated by Japan at 145°E; COMS-1, operated by the Republic of Korea at 128.2°E; FY-2E and FY-2D, operated by China at 105°E and 86.5°E respectively; Kalpana and INSAT-3A operated by India. Further coverage is provided on the West by Meteosat-7, operated by EUMETSAT, and on the East by GOES- 15, operated by the United States. The constellation of operational meteorological satellites in polar-orbit include METOP-A of EUMETSAT; FY-3A and FY-3B of China; NOAA-18, NOAA-19 and Suomi-NPP of the USA; and Meteor-M1 of the Russian Federation. Additional satellites are in back-up position, or undergoing commissioning. Several satellites are planned for launch in 2013, including: FY-2G and

FY-3C by China, and INSAT-3D by India. The ocean surface altimetry satellites Jason-1 and JASON-2, a cooperation among Europe (EUMETSAT), France (CNES) and the USA (NASA and NOAA), are operated on a 66° inclination orbit with respect to the equatorial plane.

The new-generation geostationary satellites in preparation by China, Japan and the USA will represent a major breakthrough for tropical cyclone observations. Japan plans to launch in 2014 the Himawari-8 spacecraft carrying an enhanced imaging instrument capable of providing 16-channel full-disc imagery every 10 minutes, and more frequent images on limited areas. The USA plan to launch GOES-R by the end of 2015 with a similar instrument. China plans to launch in 2015 the FY-4A spacecraft carrying a 14-channel Visible and Infrared imager with 15-minute full-disc repeat cycle and, for the first time on a geostationary satellite, an interferometric infrared sounder. It is important to anticipate these new capabilities in developing new applications.

Among the R&D or other environmental missions that provide a valuable contribution to operational tropical cyclone activities, one should note in particular: NASA's Aqua and Terra missions; NASA-JAXA's TRMM (with precipitation radar, microwave imager and lightning mapper); China's HY-2A ocean monitoring satellite (with scatterometer, altimeter and microwave radiometer), ISRO's Oceansat-2 (with scatterometer, ocean colour monitor and radio-occultation) and CNES-ISRO's Megha-Tropiques (with microwave imager and sounder for precipitation estimation); and JAXA's GCOM-W1 missions (with microwave imager providing all-weather sea surface temperature measurements) launched in 2012. The ISRO-CNES SARAL (with an altimeter) is planned for launch in 2013. As concerns the Global Precipitation Measurement (GPM) programme, the launch of its core satellite is planned for 2014.

A detailed inventory of satellite and instrument characteristics is maintained in the "OSCAR" on-line database: http://www.wmo.int/oscar . It also contains gap analyses for the different components of the GOS. For example the planned availability of scatterometers, capable of providing ocean surface wind observations over the next 20 years is presented in: http://www.wmo-sat.info/oscar/observingmissions/view/12 and summarized in Table 1 for the next 10 years. (It is underlined that this information reflects the planned availability of certain instruments on orbit; the actual availability of the data furthermore depends on the actual status of instruments and spacecraft, on the operation of the ground segment and on the open access to the data.)

Data accessibility issues are reviewed in the context of the Integrated Global Dissemination Service (IGDDS) project. One objective of this project is to implement a quasiglobal coverage of WMO Regions by multipurpose telecommunications satellite-based broadcasting services using the Digital Video Broadcast (DVB) standard (See WIS/GTS below). In this regard, the CMACast dissemination system, operated by China, covers Asia and part of the south-western Pacific area with up to 70Mbps data rate to disseminate data and products from various FY-2 and other satellites, and NWP outputs. Other operators are disseminating data and products either through Direct Broadcast from the meteorological spacecraft, or via the Internat. Japan makes MTSAT-2 HRIT and LRIT data and JPEG satellite images available over the Internet. KMA disseminates COMS data by Direct Broadcast in HRIT and LRIT standard. India activates the Cyclone

Warning Dissemination System (CWDS), during the cyclone season, to disseminate selected data through the INSAT-3C communication satellite.

The Panel showed its appreciation to EUMETSAT for its support to the Members' observation of disturbances over the Indian Ocean. However, concerns were expressed by Oman and other Members about the life time of MeteoSat-7 which is supposed to end in 2016. Noting the importance of the coverage of MeteoSat-7 of the Indian Ocean for monitoring the cyclones, the Panel requested the WMO Secretariat to take actions to avoid the disruption of the satellite observation over the Indian Ocean.

The Panel also thanked India for its continued support to the PTC Member countries through provision of the satellite data over the Inidan Ocean. Meanwhile, It requested India to allow the PTC Members to access the real time operational satellite data from INSAT. The Panel was pleased to be informed by the Indian representative that the IMD would be ready to provide satellite imageries in real time basis if necessary arrangements for provision of such data were made in more details.

ICAO

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, the requirements for the establishment and implementation of quality management systems (QMS) and trends in the provision of meteorological service for international air navigation.

Proposed recommendations:

- TCAC New Delhi 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];
- TCAC New Delhi to participate, as resources allow and particularly during tropical cyclone season(s), in routine coordination sessions with the WAFCs, hosted by WAFC Washington four times per day using a web-based chat room facility;
- PTC Members to review the provisions contained in Amendment 75 to Annex 3/WMO Technical Regulations [C.3.1] pertaining to the establishment and implementation, as a Standard, of QMS for the meteorological information supplied to the users, which became applicable on 15 November 2012, noting that the QMS should provide users of the meteorological information supplied with the assurance that it complies with the stated requirements (such as forecaster competencies), and to provide any available updates through their respective Meteorological Authorities to

assist with ICAO's assessment of the regional implementation of QMS for aeronautical meteorological information supplied to the users; and

- To note near-term intentions 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.

ICAO thanked the members of PTC for their reports and noted with interest the information provided by Oman on the impact of a major dust storm that affected the State in March 2012, the planned installation of a Doppler weather radar network in Oman commencing in June 2013 and the planned upgrade to the Meteorology Website to include smart-phone application for access to METAR messages. The advance issue of warnings for the significant dust storm, which resulted in the closure of Oman International Airport, and the advancements in the provision of warnings that may arise form the Dust Storm Conference in Kuwait in 2012 may be seen as positive developments by ICAO. Similarly, the enhanced availability of meteorological information resulting from the developments in the radar network and the Meteorology Website, which would be useful for flight planning and safety, are likely also to be seen as positive developments by ICAO.

ICAO also noted with particular interest the continuing developments reported by Thailand of weather radar data on the TMD Website and progress towards a radar composite map. Along with the improvements to weather radar information reported by other members, ICAO would view such initiatives as positive developments, particularly in terms of the improvement to the availability of real-time meteorological information, which can enhance common situational awareness and is used for the purposes of flight planning and safety. Such benefits are noted by ICAO in addition to the enhanced tropical cyclone detection, monitoring and forecasting capabilities resulting from the development of improved weather radar networks and data.

UNESCO/IOC

Mr Tony Elliott (UNESCO/IOC) commented that there were about 70 sea level gauges in the Indian Ocean GLOSS network contributing sea level data in near real time via the Global Telecommunications Network. This data was invaluable for tsunami warning purposes and UNESCO/IOC is keen to increase the network size. He encouraged Panel Member countries to consider connecting as many of their sea level gauges as possible to the GLOSS network to enhance real time sea level availability in the region.

1.2 HYDROLOGICAL ACTIVITIES

1.2.1 Bangladesh

Bangladesh Meteorological Department (BMD) is providing the necessary technical and operational support, weather forecast, Rainfall data, Doppler Weather Radar observations to Flood Forecasting & Warning Centre of Bangladesh Water Development Board. Flood Meteorological unit of Bangladesh Meteorological Department (BMD) provides input to FF&WC of Bangladesh.

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 district wise, sub-divisionwise and statewise/seasonwise 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 for the four regions viz., North-West India, South Peninsula, Central India and North East India. During the Monsoon Season 2012 daily sub-division rainfall report were prepared and supplied to the Cabinet Secretary and other users. Distrctwise reports for last 5 years were put up on IMD Website and creation of sub-divisional rainfall maps was automated.

The seasonal statistics for the year 2012 is as follows:

- **Winter season** (Jan-Feb) 2012:- During Winter season the updated rainfall statistics is, the country as a whole received 4% less rainfall of LPA. Out of 36 sub-divisions 8 subdivisions recorded excess rainfall, 2 recorded normal rainfall, 12 recorded deficient rainfall 11 recorded scanty rainfall and 3 subdivision recorded nil rainfall.

- **Pre- monsoon** (March-May) 2012:- During Pre- monsoon the updated rainfall statistics is, the country as a whole received 31% less rainfall of LPA. Out of 36 sub-divisions 1 recorded excess rainfall, 5 recorded normal rainfall, 20 recorded deficient rainfall and remaining 10 sub-divisions recorded scanty rainfall.

- **SW monsoon** (June-Spt.) 2012:- During the monsoon season the real-time rainfall statistics for the country as a whole received was 8% less than the LPA. East & NE India, Southern peninsula, NW India and, Central India experienced rainfall of 89%,90%,93% and 96% of LPA respectively. Out of 36 sub-divisions 1 recorded excess rainfall, 22 recorded normal rainfall and remaining 13 sub-divisions recorded deficient rainfall.

NWP modeling for heavy rainfall forecast

The following modeling initiatives have been implemented at IMD during 2012.

1.2.2.1 Operational implementation of ARPS model

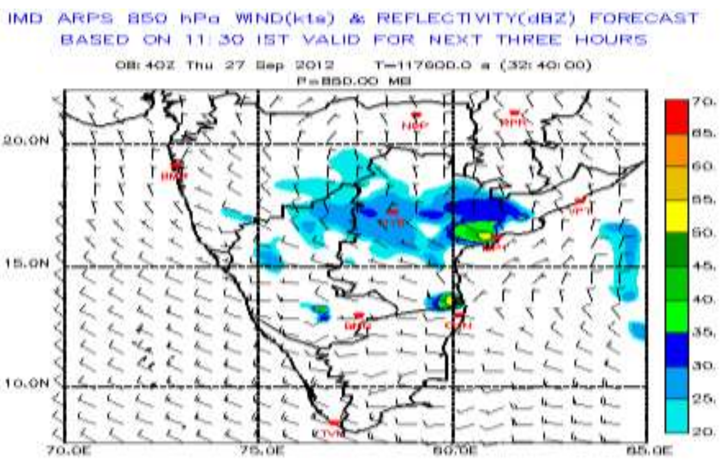


Fig.6 IMD ARPS 850 hPa Winds and reflectivity

Advance Regional Prediction System (ARPS) Model for North East Monsoon has been introduced in 2012. It is run using Initial and boundary condition from IMD Global Forecasting system (GFS). The radial velocity and reflectivity data of DWR are assimilated in ARPS Model through ADAS data assimilation package. The assimilation is performed as a sequence of intermittent cycles of 20 minutes. Reflectivity (dBZ) overlaid on wind field (knots) at 850 hPa (Fig.6), is plotted for next 3 hours updated at every hour round the clock Real time forecast from ARPS Model with Radar Data assimilation are available on http://www.imd.gov.in/section/nhac/dynamic/ARPS_NE_MON.htm.

1.2.2.2 Model based Quantitative Precipitation Forecast

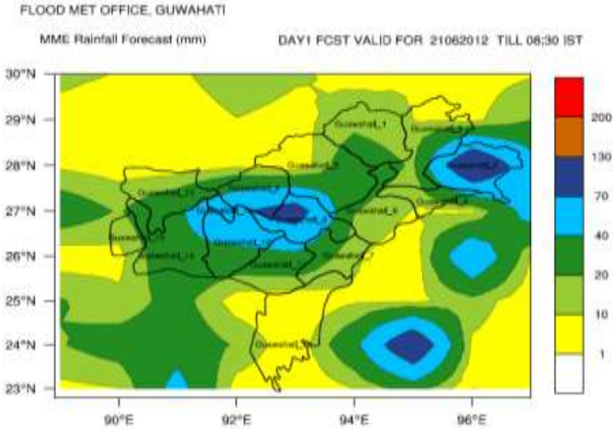


Fig.7 QPF Forecast using NWP models

Sub-basin wise Quantitative Precipitation Forecast (QPF) for day-1, day-2, day-3 using NWP model, operational 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 2012 for 71 flood prone river sub-basins. An example is shown in Fig.7.

MME for district wise heavy rainfall forecasting

Under Integrated Agromet Advisory Services (IAAS) scheme, district level weather forecast upto 5 days is being issued for seven weather parameters, viz., rainfall, wind speed and direction, maximum temperature, minimum temperature, relative humidity and cloud cover. In addition, weekly cumulative rainfall forecast is also provided. IMD, New Delhi generates these products based on a Multi Model Ensemble (MME) technique using forecast products available from number of models of India and other countries. These include T-799 model of European Centre for Medium Range Weather Forecasting (ECMWF), National Centre for Environmental Prediction (NCEP), USA and Japan Meteorological Agency (JMA), Japan and IMD and NCMRF models. The products are disseminated to Regional Meteorological Centres and Meteorological Centres of IMD located in different states. These offices undertake value addition to these products and communicate to 130 Agromet Field Units (AMFUs) located at State Agricultural Universities (SAUs), institutes of Indian Council of Agricultural Research (ICAR), IIT, etc.

During 12th Five Year Plan, IMD proposes to generate block level weather forecast for issuing block level Agromet advisories using NWP products. For this, pilot studies have been undertaken in collaboration with various organizations.

Flood Meteorological Service

Flood Meteorological Service of IMD provides the inputs to Central Water Commission through their 10 FMO established in different parts of India for operational flood forecasting. This unit is mainly engaged in developing Quantitative Precipitation

Forecast (QPF) model using different dynamical models for river basins during flood season.

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 36 projects have been completed and results communicated to the concerned project authority. The detailed project reports are being sent in respect of the projects completed on payment basis. The work of preparation of PMP Atlas for Krishna Basin has been initiated.

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 Myanmar

1.2.3.1 Occurrences of Floods in 2012

Department of Meteorology and Hydrology (DMH) is the responsible agency for flood forecasting and warning in the country. There are eight major rivers in Myanmar, which are Ayeyarwady, Chindwin, Sittoung, Thanlwin, Bago, Dokehtawady, Shwegyin and Ngawun rivers. DMH maintains 27 Hydrological Stations and 44 Hydro-meteorological stations and issues flood forecasts for 30 stations in Myanmar. During 2012, there were floods at downstream of Ayeyarwady river, upstream of Chindwin river, Thanlwin river, Sittoung river, Bago river, Shwegyin river and Ngawun river. These floods except Madauk of Sittoung River, Shwegyin of Shwegyin River and Hpa-an of Thanlwin river were normal flood, which the flood magnitude were about 2 to 4 feet and flood duration was about 2 to 9 days. In August, the big flood occurred at Madauk of Sittoung river and this flood was the second highest record during last 47 years and at Shwegyin of Shwegyin River was the third highest during last 48 years. Similarly, the flood occurred two times at Hpaan of Thanlwin in 2012 and the first flood wave exceeded the danger level by 4.5 feet and stayed about 22 days. Due to this flood inundated the wards of 1, 2, 3, 4, 5, 6, 7 and the neighbouring low land area. DMH has issued (23) flood warnings and (61) flood bulletins during 2012 flood season.

1.2.3.2 Hydrological services

Hydrological Division of DMH is responsible for issuing daily river forecast and flood forecast along 8 major rivers: Ayeyarwady, Chindwin, Sittaung, Thanlwin, Dokehtawady, Bago, Shwegyin and Ngawun. Whenever warnings are issued from River Forecasting Section (RFS) of D.M.H, the message is sent to the respective stations by telephone or Single Side Band (SSB) transceiver. As soon as head of the station receive the message of warning, he immediately inform the local authorities and other related departments in order to carry out the necessary action. At the same time the warnings are disseminated through the radio and television as well as through the Newspaper for general public.

RFS of D.M.H is using both simple and advanced techniques for issuing flood warning and bulletin to the users and public, and is also applying empirical models based on single and multiple regression analysis for forecasting peak flood level along Ayeyarwady and Chindwin rivers. The lead time for issuing flood warning is about one to two days for short range forecast and about five days for long range forecast, especially for deltaic area of Ayeyarwady. Flood usually occurs in each and every year at one river system or another. The occurrences of floods in Myanmar can be generally expressed as 6% in June, 23% in July, 49% in August, 14% in September and 8% in October. According to the previous 47 years' observation, severe flood years were noted as 1973, 1974, 1976, 1979, 1988, 1991, 1997, 2002, 2004 and 2007.

Regarding the training course for Hydrology, Initial Course of GIS (1 September to 1 November 2012), the hydrological Grade (I) course (10 December, 2012 to 9 January 2013) and grade (II) course (4 February to 7 March 2013) were held at Department of Meteorology and Hydrology in order to develop the knowledge of new generation of DMH and capacity development.

1.2.3.3 Discharge Measurement

In 2012, the new instrument for discharge measurement, which is River Surveyor, was purchased to measure the discharge. In order to provide runoff data, discharge and sediment discharge measurements are carried out every year at four sites in the selected three rivers by Hydrological Division, Upper Myanmar Division and Lower Myanmar Division. At the year 2012, measurements of discharge, sediment discharge and bed profile were implemented at Nyaung U and Myinmu for Ayeyarwady river, Mingin for Chindwin River and Bago for Bago river. Acid Deposition Monitoring As a national monitoring centre of EANET (Acid Deposition Monitoring Network in East Asia), DMH is responsible to monitor not only Wet deposition of rain water but also Dry deposition of air concentration in Yangon. The water quality Laboratory of DMH has been able to analyse not only the ion contents such as Cation NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} and Anion SO_4^{2-}, NO_3^-, Cl^- for dry deposition but also the ion contents such as Cation NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+} and Anion SO_4^{2-}, NO_3^-, Cl^- and measured pH and EC for wet deposition.

In November 2012, the three experts from Asia Centre for Air Pollution Research – ACAP(former ADORC) have visited to the laboratory of DMH and they implemented the activities in accordance with the objectives of the mission: to exchange views and information on the data quality on the acid deposition monitoring of EANET in Myanmar, to exchange views and information on the soil and vegetation monitoring in Myanmar as Future activities of EANET, to confirm the implementation of Filter Pack sampling and other, The Scientific Advisory Committee (SAC) and the Intergovernmental Meeting (IG) on the Acid Deposition Monitoring Network in East Asia (EANET) were held these section (SAC-2012) and (IG-2012) as co-host Country during the period of 20-28, November 2012 in Yangon, Myanmar, DMH, Laboratory summit the Annual Monitoring Data on Wet & Dry Deposition to the ACAP (Network Centre) in the end of June of year. And also, summit the Inter-laboratory Comparison Project-2012 on wet & dry deposition data to the ACAP (Network Centre) the end of February of year.

1.2.3.4 GIS application in Hydrology

GIS application in Department of Meteorology and Hydrology is initial stage at the present. The government has invested about 100 million Kyats for establishment of GIS application in DMH. In 2012, Flood Hazard Map for Homalin City was produced by the technical assistant of Geoinformatic Centre of Asia Institute of Technology and financial assistant by Japan Aerospace exploration Agency. During 2012, DMH has developed flood simulation by using IFAS for small catchments and ungauged catchments. DMH is also implementing geomorphological parameters of Myanmar river systems.

1.2.4 Oman

1.2.4.1 Water Resources Assessment and monitoring

The Ministry of Regional Municipalities and Water Resources is responsible for the hydrological measurements and the management of the water resources for the Sultanate of Oman .

The Ministry worked in establishing the hydrometric network in different regions of the Sultanate and developing and upgrading them with latest equipments. In this context, the total number of the monitoring points within the national network were 4681 monitoring stations at the end of 2012, which monitor the water sources such as rainfall, wadi and falaj flows and groundwater levels In addition to monitoring the changes in groundwater salinity and quality.

The hydrological data collected from these monitoring satiations used in the water studies conducted to manage and develop the water resources. It also coordinates in preparing the studies for planning and designing of recharge dams, roads and the general and private premises which can serve in the development of the country.

1.2.4.2 Measuring of Rainfall:

There are 362 rain gauges (277 Automatic and 85 of standard type). Eighty of these rainfall stations are fitted with telemetry using GSM modems. During the 2012 the maximum annual accumulated rainfall was 365 mm in Interior region. In North Oman recorded 298 mm in AL Batinah and 167 mm in Musndam while in the east (Sharqiyah) 144 mm, at the Capital (Muscat) was 176 mm. In 2012 the Monsoon was weak. Rainfall at in Dhofar region south of the country was less than 100 mm.

1.2.4.3 Telemetry Monitoring Stations:

The Ministry installed (52) stations operated by the telemetry system to end of 2011. In 2012 the number of Telemetry stations increased to 80 stations, that are rainfall and Wadi flows gauges.

1.2.4.4 Measuring of Wadi and Flood Flows:

There are 167 wadi gauge stations to measure wadi flow and to compute flood volumes. In addition to 25 stations to measure the peak height of the wadi flows. In year 2012 all wadi flow were in North Oman The highest recorded was (214Mm3) in Al Batinah region. The total flood volumes during 2012 was estimated (211 Mm3).

1.2.4.5 Groundwater level measurements:

The Ministry operates a network of 2107 groundwater wells measured for water levels. Analysis of data showed that as a result of decrease in rainfall and recharge there is a gradual decrease in water levels in most areas of the Sultanate, except Muscat and East regions where recharge as a result of Cyclone Phet is still in progress.

1.2.4.6 Gauging *Aflaj* and Springs Flow:

The Sultanate has (3017) active *falaj*, (524) of them are monitored in a monthly basis for gauging the rate of flow and water quality as well as (64) springs located in the mountain parts.

1.2.4.7 Dams:

In 2012 there are 3 big dams were constructing (AL Amrat Dam , Salalah protection dam and Wadi Naam at east region) and 5 other small dams in Al Buraimi in west of Oman .The total dams in Oman are 48 dams , are 36 recharge dams and 12 Flood protections dams. On the 36 recharge dams stations for measuring flow and sedimentation. A total of 34 Mm3 was retained by recharge dams during 2012.

1.2.4.8 Events:

The Ministry arranged 6 main water resources related workshops and Meetings during 2012 these were:

- Contract 2 Meeting for the International Hydrological Programme (IHP) and attended one conference for IHP in Paris.
- World Water Day Seminar, 20-22 March, 2012 at the Sultan Qaboos University.
- Contract 2 meeting for Arab G - Wadi UNESCO to establish Arab committee at Muscat Sultanate of Oman.
- Attended a Regional Workshop on Regional Climate Model (RCM) Applications and
- Analysis arranged by (ESCWA).

1.2.4.9 Achievements:

Several studies have been completed during the year including; dams construction, study of the increase groundwater level in some part of the country, study the water situation, drilling of exploration wells, Oman Salinity Strategy , Oman Water balance and Master plan.

1.2.4.10 Training:

During the year 2012 the Ministry arranged for both local and overseas training and workshops :

The training Porgramme	No. of Trainees
Monitoring , processing and analysis Data of Flood instruments	15
Study and account of Floods and its impacts Direct & indirect Method measurements	14
Wadi Hydrology	15
Analysis of Rainfall gauge Data	21

1.2.5 Pakistan

1.2.5.1 Monsoon Flood 2012

The rains from 1st July to 20th August 2012 were scanty and at one time, it looked as if dry conditions might prolong and the filling of water reservoirs might become skeptical with below normal seasonal rainfall. There were light to moderate rain showers mostly in north Pakistan during 2nd and 3rd week of July. The highest monthly rainfall of 263 mm was observed in Kotli (in Azad Kashmir). Potwar region in Punjab province (Chakwal, Jhelum, Rawalpindi and Attock) also received some rainfall. Chhor (in Sindh province) received only 23mm monthly rainfall, while rest of Sindh province remained almost dry and hot. The first plentiful rainfall was recorded during last decade of August and the tempo for this overdue monsoon gained momentum during first half of September.

During last 10 days of August 2012, monsoon became active when 3 to 4 spells of rains (some time isolated heavy) were observed in upper parts of the country. Due to these spells of rain, some stations like Islamabad, Murree, Jhelum, Lahore, Sargodha, Mianwali, Bahawalpur, Khanpur, Muzaffarabad, Kotli, Balakot, Gupis, Cherat, Dera Ismail Khan, Kakul, and Parachinar received above normal rainfall for the month. However, no significant rainfall observed in Balochistan (except Sibbi and Zhob) and Sindh provinces.

Monsoon systems were fairly deep enough to precipitate heavily and over Khanpur, Rahim Yar Khan (in Punjab province) and over Jacobabad and Rohri (in Sindh province) during 6th to 11th September 2012. Jacobabad and the neighboring districts observed the driving rains of more than 448 mm in just two days (from 10th to 11th September 2012). This proved to be a turnaround from dry to wet set up and it flip-flopped the nearly drought like situation to a flooding scenario. Large areas in the affected districts were inundated with consequential damages. The situation in

Jacobabad became further irksome because of the run-off / overflows from the high altitude, upper districts of Jafferabad and Nasirabad in Balochistan province.

In southern Pakistan, where the borders of Punjab, Balochistan, and Sindh Provinces meet, a network of levees and canals diverts water from the Indus River to thirsty agricultural fields. Water is usually scarce in this part of Pakistan, but heavy monsoon rains can overwhelm the country's irrigation infrastructure, as they did in the summer of 2010. Flood conditions returned in the summer of 2012. According to news reported nearly 100,000 residents were displaced in Balochistan Province alone.

Summary of Damage during Floods-2012 by NDMA

Serial	Province	Persons Died	Persons Injured	Persons Affected	House Damaged		Villages Affected	Area Affected (Acres)	Crop Affected (Acres)	Cattle Head Perished	Relief Camps	Persons in Relief Camps
					Partially	Fully						
1	KP	38	36	0	4,293	105	0	0	0	0	0	0
2	Punjab	60	272	887,345	16,440	9,116	1,512	1,490,827	473,998	898	40	5,064
3	GB	0	0	0	70	0	0	0	0	0	0	0
4	AJK	31	32	0	1,017	226	0	0	0	0	0	0
5	Islamabad	3	0	0	0	0	0	0	0	0	0	0
6	Sindh	239	2,449	3,166,023	137,477	221,654	13,221	274,556	245,459	1,826	467	344,423
7	Balochistan	59	123	707,422	7,666	4,333	753	0	402,535	6,927	0	0
	Total	430	2,912	4,760,790	166,963	235,434	15,486	1,765,383	1,121,992	9,651	507	349,487

1.2.5.2 UNESCO Project "Strategic Strengthening of Flood Warning and Management Capacity in Pakistan"

In the aftermath of 2010 Super Floods in Pakistan, UNESCO's Division of Water Sciences, UNESCO Paris Office has been implementing a project "Strategic Strengthening of Flood Forecasting and Flood Management of Pakistan" in order to upgrade early flood warning capabilities as well as capacity development of the country in hydrology with financial support by the JICA/Government of Japan. The project aims to address the following three inter-related focus areas:

- Strategic Augmenting of Flood Forecasting and Hazard Mapping
- Knowledge programs for sharing Trans boundary and Community data
- Capacity Development for Flood Forecasting and Hazard Mapping

The project is being benefited from the technical expertise of the International Centre for Water Hazard and Risk Management (ICHARM), Japan under the auspices of UNESCO Under this project, a flood forecasting and routing model is being developed. This model will cover the upper Tarbela and Kabul river catchment which is not available in the FEWS Model, currently being used at PMD's Flood Forecasting Division, Lahore. Under this project, ICHARM (international Centre for Water Hazard & risk management has developed an Integrated Flood Analysis System (IFAS) using data provided by satellites. The development of Indus-IFAS (i.e. IFAS for the Indus River system in Pakistan) is also part of the project. The project will benefit all flood affected areas by working closely with all relevant departments of the Government of Pakistan. The main beneficiaries of the project at national level include FFC, SUPARCO, NDMA and PMD. The targets achieved so far are as under:-

1) Holding of an international Workshop discussing and exploring different techniques for estimation of rainfall through satellite technology which was held in Lahore on 17th & 18th July 2012.
2) Sharing of Historical Rainfall, river flow data of different flood events.
3) Under this project two (02) PMD scientists have recently completed their MS in Hydrology and Flood related Disaster Management at International Centre for Water Hazard and Risk Management (ICHARM), Japan. While three (03) PMD scientists have been doing their Master in GIS/Remote Sensing at SUPARCO, Karachi.

1.2.5.3 Establishment of Regional Flood information System in the Hindu Khush Himalayan Region (HKH-HYCOS)

In wake of Super Floods 2010, the International Centre for Integrated Mountain Development (ICIMOD) based in Nepal", is implementing the project "Establishment of Regional Flood Information System in the Hindu Khush Himalayan Region (HKH-HYCOS)" in order to promote regional cooperation in flood risk reduction and to cope with future flood disaster in Pakistan with Federal Flood Commission (FFC) being the coordinating agency while WAPDA and PMD are main beneficiaries of the project. Under this project, two AWS (Automatic Weather Station) has been installed at Gupis and Kalam for sharing of Meteorological parameters among "ICIMOD" member countries. The first phase of the project is almost completed. Installation of six more Automatic Weather Stations at Lower Dir, Saidusharif, Kotli, Parachinar, Bannu and Chakwal will be taken up in the next phase of the project.

1.2.5.4 Finnish Meteorological Institute Assistance for Strengthening of Hydrometeorlogical Observational Network of PMD under WMO VCP

Finnish Meteorological Institute donated 10 Automatic Weather Stations to Pakistan Meteorological Department (PMD) under WMO VCP in November 2012, for further improving its flood monitoring / forecasting capabilities for effectively addressing the hydrometeorlogical disaster risk reduction challenges in Pakistan. The delivery of AWSs to PMD was the part of WMO special request's launched upon recommendation of WMO Expert Mission that visited Pakistan during November, 2010. The FMI also arranged two weeks AWS Factory installation/operation training for three PMD technicians in Finland during October, 2012.

1.2.6 Thailand

1.2.6.1 Enhancement of Facility

Water management in Thailand 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 Centre (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, 24 of 25 main river basins have 711 telemetric stations installed for water resources management and flood prevention and mitigation, RID have 2 projects to improvement of Flood Observation and Forecasting System by

1. Integrate the tele-metering system of 10 river basins

- Ping Basin
- Wang Basin
- Yom Basin
- Nan Basin
- Chao Phraya Basin
- Thachin Basin
- Sakaekrang Basin
- Pasak basin
- Prachinburi-Bangpakong Basin
- Maeklong Basin

The project will be completed on September 24, 2012

1.2.6.2 RID data Centre

Hydrological Data (rainfall, water level and flow) are sending every 15-minute with Automatic Real-time from the 23 river basins of telemetry systems (Thailand has 25 river basins) involved in natural rivers and steep-slope upstream watershed, the DWR has developed and installed the early warning systems with automatic flood-warning sirens in 458 of 2,370 villages in disaster areas throughout Thailand.

Last 2011, 7 of 37 existing telemetric systems were additionally installed with flood models of both hydrometeorology and hydrodynamic, such as MIKE11, MIKEGIS, INFOWORK and AIT River network.

The risk of floods are mitigated and reduced in three steps following.
.

- First, the total 711 telemetric systems installed in 24 of 25 river basins throughout Thailand monitor real-time hydrological data for flood forecasting;
- Second, the forecast was issued and transmitted to regional offices, local agencies and public through website, radio broadcasting or media;
- Last, after flood events, water drainage pumping begins to reduce high water level or inundation. The headquarters and regional offices then provide equipment for flood recovery, such as 1200 mobile pumps, 121 impeller pumps, 37 backhoes, 17 dredgers, 29 tractors 44 trucks, 295 water trucks and 6 boats.

1.2.6.3 Achievement

RID's staff attending training, workshop and conference both local and over sea have acquired more knowledge on technology relating flood forecasting and water resource management.

Activities of WMO

WMO Flood Forecasting Initiative

Notable progress had been made in the implementation of the Flood Forecasting Initiative including to establish an overarching Advisory Group for the Flood Forecasting Initiative (FFI-AG), as decided by Congress (Resolution 15 (Cg-XVI), aiming to ensure adequate monitoring, evaluation and guidance with respect to the implementation of the Strategy and Action Plan on the Flood Forecasting Initiative. 14 RA-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 had been 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 in November 2012. 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 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.

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.

Associated Programme on Flood Management (APFM)

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 Help Desk established under the programme since June 2009. National workshops on the development of flood management strategies were held in Thailand in March 2012 and Laos PDR in April 2012. 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.

WMO Quality Management Framework for Hydrology

The World Meteorological Organization (WMO) and the International Organization for Standardization (ISO) have agreed to increase their cooperation in the development of international standards related to meteorological and hydrological data, products and services. The Association agreed that the recognition of WMO as an international standardizing body for technical standards provided a valuable opportunity to further emphasize the role and benefits of applying the Quality Management Framework–Hydrology and providing Members with the necessary guidance on technical standards from data collection through to service delivery.

A draft publication: "*A Practical Guide for the Implementation of a Quality Management System for National Meteorological and Hydrological Services"* is available at 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 No. 0145), the Manual on Stream Gauging (WMO No. 1044), the Manual on Flood Forecasting and Warning (WMO No. 1072), the Guidelines for the Assessment of Uncertainty of Hydrometric Measurements, the Technical Report on Climate and Meteorological Information Requirements for Water Management (WMO No. 1094), the Technical Report on Water Quality Monitoring, and the Technical Report on Technical Material for Water Resources Assessment (WMO No. 1095). All these publications are available online at http://www.wmo.int/pages/prog/hwrp/index_en.php

Working Group on Hydrological Services

Participants noted that 14 RA-II agreed on the following theme areas for its Working Group Hydrological Services:

- Strengthening the capability of Members to assess their water resources: Water Resources Assessment, its Variability and Use;
- Improve accuracy and timeliness of forecasting floods of different cause and origin through enhanced cooperation between NMSs and NMHSs – within the context of the WMO Flood Forecasting Initiative;
- Hydrological Aspects of Drought, including Drought Monitoring, Assessment of Water scarcity and Deficits;
- Hydrological responses to climate variability and change and promotion of the use of climate information by water managers;
- Improved Accuracy of Hydrometric and Sediment Observations including Space based Technologies;
- Sediment disasters and mass movements.

Recommendations

Recognizing the importance of hydrological forecasting in connection to activities of the PTC it is recommended that the PTC:

- Establishes closer links with the RA-II WGH on the working level and with individual experts;
- Develops a Requirements Document for hydrological services in support of current and planned PTC activities;
- Makes use of services provided through CHy and the WMO Flood Forecasting Initiative in particular as well as proposals for new HYCOS components;
- Further provides suggestions for activities to be carried out in support of PTC needs in hydrology;
- Makes use of the services provided by the APFM in the area of Integrated Flood Management;

Following the successfully links made between the WG-Hydrology of the Typhoon Committee and the WMO RA-II Working Group Hydrology, PTC requests WMO to invite a member of the newly established WG Hydrology of the PTC to the next meeting of the RA-II Working Group Hydrology to foster linkages between the two working groups.

1.3 DISASTER PREVENTION AND PREPAREDNESS

1.3.1 Bangladesh

Bangladesh Meteorological Department (BMD) is the authoritative organization in the country for issuing advisories and warnings related to Meteorological, Hydrological, and earthquake information, Tropical Cyclones, Storm Surges and Coastal Inundation etc. All Government Organizations, Department of Disaster Management, NGO's, Public and Print Media receive advisories and warnings from Bangladesh Meteorological Department.

A Disaster Management Law has been enacted in Bangladesh from 2012 with a view to creating the legislative tool under which disaster risks and emergency management actions are being undertaken in Bangladesh and providing the legal basis under which activities and actions are identified, undertaken and managed.

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 Marine 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

The revised **stages of cyclone warning** (7 stages instead of the present 4 Stages of Warning) have been suggested by NDMA of Govt. of India headed by top officials of the government. The same is being deliberated further and with some modifications will be implemented from the ensuing cyclone season. It is also proposed to modify the format of Cyclone Warning bulletins to make it more comprehensive for the use of Disaster Managers. The possibility of automation in generating 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. which could be generated from a single bulletin format is being pursued by Cyclone Warning Division at New Delhi.

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. Orders are being placed shortly for 300 new CWDS (Cyclone Warning Dissemination Systems), which are modern and easy to maintain.

1.3.2.3 Disaster Management

1.3.2.3.1 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.

1.3.2.3.2 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.

1.3.2.3.3 Current Status

1. Meetings related to cyclone preparedness and disaster management conducted by the State Govt. departments are regularly attended by IMD officers to provide necessary briefings and inputs.
2. Frequent lectures on Disaster Preparedness and Mitigation are delivered to educate the State Govt. officials and NGOs.
3. Exhibits on Statistics on frequencies of landfalling Tropical Cyclones over the coastal belts of North Indian Ocean, Cyclone Warning procedures employed by IMD, Damages caused due to landfalling cyclones etc. are prepared every year with updated data and displayed in the meteorological exhibition conducted during the WMO Day and National Science Day.
4. Exhibits are also supplied to schools and other academic/ govt. institutions for display during scientific programmes. IMD officials also participate in such exhibitions.

1.3.2.4 On-going Projects

1.3.2.4.1 WMO-RIMES project on *Reducing risks of tsunami, storm surges, large waves and other natural hazards in low elevation coastal zones*

IMD works in collaboration with WMO and Regional Integrated Multi-hazard Early Warning System for Africa and Asia (RIMES) on an applied research project -‘***Reducing risks of tsunami, storm surges, large waves and other natural hazards in low***

elevation coastal zones' which is supported by United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). The project aims to reduce tsunami, storm surges, large waves and other hazard risks in low elevation coastal zones by strengthening institutional systems for end-to-end warning, and building institutional capacities for the application of warning information products in decision-making.

The project is being implemented initially in Bangladesh, India, Maldives, Myanmar, Sri Lanka and Thailand from May 2011 to April 2013. While in other project countries, the activities are at the national level, considering India's vastness and complexity, Tamil Nadu has been chosen as the representative state, and based on the experiences; the activities could be replicated in other parts of India.

The key aspect of this project is that it will assist in strengthening application of IMD products in Tamil Nadu and in obtaining feedback for further refining our products to meet user-specific information requirements from key sectors in Tamil Nadu such as agriculture, fisheries, animal husbandry and water resources.

CWRC, RMC, Chennai coordinates the project. A project working group meeting on '**Integrating IMD Forecast Information products into planning and programmes of climate sensitive sectors'** was convened on 21st February 2012 at Regional Meteorological Centre, Chennai. Tamil Nadu State Govt. officials from the departments of agriculture, fisheries, public works and disaster management participated in the meeting.

1.3.2.5 Supply of *Cyclone eAtlas-IMD* CD

1.3.2.5.1 ***Cyclone eAtlas – IMD***, a software for generation of tracks and statistics of cyclones and depressions over the North Indian Ocean was brought out by IMD during 2008. The database for the software is updated and sent to all buyers of the CD every year.

1.3.2.5.2 ***Web eAtlas:*** The web enable eAtlas of tracks and statistics of cyclonic disturbances since 1891 is made available on IMD Website(www.imd.gov.in) on Cyclone page.

1.3.2.6 Cyclone Hazard Prone Districts Map of India

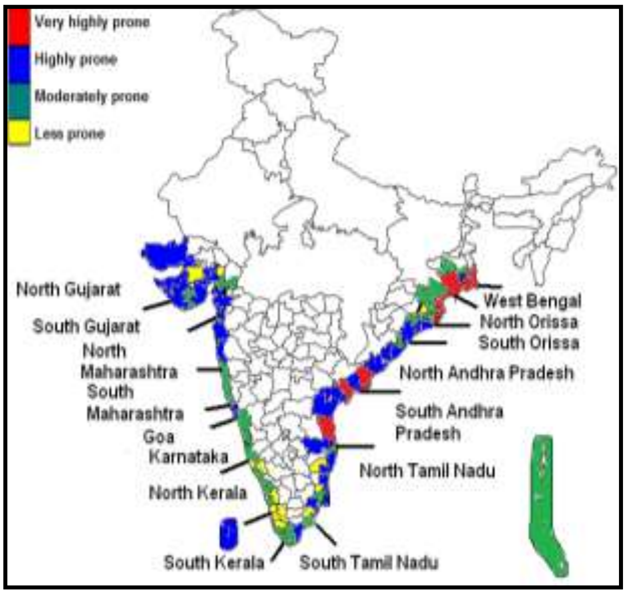


Fig. 5 Cyclone Hazard Prone Districts Map of India

As per the recommendations of the sub-committee constituted by National Disaster Management Authority (NDMA), the Cyclone Hazard Prone Districts Map of India has been prepared based on frequency of cyclones affecting the districts, frequency of severe cyclones affecting the districts, probable maximum precipitation over the districts, maximum wind strength over the districts due to the cyclone and probable maximum storm surge over the districts (Fig.5).

1.3.2.7 Experimental efforts are on for Cyclone Intensity and Track prediction based on WRF model.

Track and Intensity predictions were generated on real time basis (experimental) and validated in respect of the Cyclonic Storm ***Nilam*** over the Bay of Bengal during 28 October -01 November 2012.

1.3.2.8 Dr. S. Balachandran, Scientist-E, participated in the inaugural day proceedings of '**Climate Risk Management Farmers' Field School**' organised by the **Regional Integrated Multi-hazard Early Warning System, Thailand** and **Centre for Ecology and Research, Thanjavur** at the Tamil Nadu Rice Research Institute, Aduthurai on 3rd July 2012 and delivered a technical talk on the occasion.

1.3.3 Maldives

Maldives Meteorological Service is mandated 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.

1.3.3.1 Warnings and Advisories

During 2012 Cyclone Season, the severe weather was monitored locally through the 5 Met. Stations, 9 Automatic Weather Stations and SATELLITE image receiving system. Products of various numerical weather prediction (NWP) 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. MMS issued 42 WHITE Alerts, 7 YELLOW Alerts and 1 RED Alert during 2012 Cyclone Season. Apart from these, interviews, briefing to sea travellers, fisherman, national defense, police, NDMC and various media were conducted.

MMS in collaboration with RIMES convened a Monsoon Forum during 2012. This forum serves as a national platform for its dialogue process between forecast providers and users, with the following objectives:

1. Ensure that forecasts/ warning information products, including their uncertainties and limitations, are communicated to and understood by users.
2. Encourage the use of forecasts to mitigate risks in climate-sensitive sectors, including, but not limited to agriculture, water resources, disaster management, and health.
3. Receive user feedback for improving usability of forecast products.
4. Provide a platform for inter-agency coordination of policies, and sectoral plans and programs for dealing with potential impacts of hydro-meteorological hazards.
5. Provide a platform for long-term process of understanding risks posed/opportunities brought about by past, current, and future climate.

The first forum convened in Fuvahmulah proved as a success when the November 2012 flood event occurred there.

1.3.4 Myanmar

Myanmar, one of the disaster prone countries in the world, is a member of ASEAN Committee on Disaster Management (ACDM). Here, Relief and Resettlement Department (RRD) is a focal point of ACDM. Moreover, Myanmar is a signatory country to the ASEAN Agreement on Disaster Management and Emergency Response (AADMER), and also joined World Conference on Disaster Reduction (WCDR) in Kobe, Japan in January 2005. Therefore, Myanmar has to do follow up actions under Hyogo Framework for Action adopted by WCDR.

1.3.4.1 National Mechanism for Disaster Management in Myanmar

In Myanmar, the lead organization for Disaster Management is Myanmar Disaster Preparedness Agency (MDPA) which was reformed according to the Notification No.(23/2011) dated (20.4.2011) of the President Office of the Republic of the Union of Myanmar. In MDPA, the Union Minister for Social Welfare, Relief and Resettlement is taking as a Chairman, the deputy Ministers for Defence and for Home affairs are as Vice Chairmen, Deputy Minister for Social Welfare, Relief and Resettlement as Secretary and Director General for Relief and Resettlement as Joint-secretary, and it comprises of 8 members.

Under MDPA, there is Myanmar Disaster Preparedness Management Working Committee and (14) Sub-Committees. Myanmar National Search and Rescue Committee(MNSRC) was also constituted and in which Chairman is Union Minister for Home Affairs, Vice Chairmen are Union Minister for SWRR and for President office, Secretary is chief of Myanmar Police Force and Joint- Secretary is Head of Police Officers, and comprises of 20 members. Roles and Responsibilities for all these Agency, Committee and Sub-Committee have been already designed and ready to function.

Under the lead of National Disaster Preparedness Agency, Disaster Preparedness Committees have been organized at the State/ Region/ District/ Township level and up to Village Tract level. All of these Committees at different levels have to follow the designed functions of before/during and after disaster.

1.3.4.2 Functions of Relief and Resettlement Department for Disaster Risk Reduction

Relief and Resettlement Department have implemented with effort Disaster Risk Reduction activities such as Preparedness (Prevention), Response and Rehabilitation.

As part of Preparedness (Prevention), for the sake of effective public awareness, Relief and Resettlement Department has conducted Training of Trainers (TOT), Disaster Management Courses (DMC), Educative Talks in village level, and Workshops in collaboration with State and Regional Authorities, related Departments, UN, INGO and NGO. Moreover, with the intention of public widely know about natural disasters, RRD has produced and published pamphlets and posters into the community.

In order to rapidly provide relief items to the affected people in emergency situation, (8) kinds of relief items such as longyi for man, longyi for woman, blanket, pot, bowl, scraf, T shirt and Caborlit soap for (61500) households have been stand by stored at every RRD Ware houses in every State and Region. Moreover, RRD has provided shelters to the victims for their temporary living.

RRD has provided (50000) Kyats for per dead child (under 18 years), (100000) Kyats for per dead adult (18years and above), (50000) Kyats for per damaged house, (60000) Kyats for per damaged religious building. For the current nutrition of victims, RRD has provided (4.875) pounds of rice to per affected adult (12 years and above), (2.438) pounds of rice to per affected child (under 12 years). RRD had also provided a robe to each affected monk and nun.

Then, in collaboration with other related Departments, UN, INGO and NGO, RRD have implemented such rehabilitation activities as providing MEC zincs for building houses, infrastructure, livelihoods, constructing cyclone shelters, school cum shelters, hill locks, etc in the affected areas.

For Nation-wide awareness, on every October(13), Relief and Resettlement Department under Ministry of Social Welfare, Relief and Resettlement have annually celebrated International Day for Disaster Risk Reduction at Myanmar International Convention Centre, Nay Pyi Taw since 2010 in collaboration with UN, INGO and NGO.

For effective early warning system, Relief and Resettlement Department have collaborated with Meteorology and Hydrology Department, General Administration Department, other related Departments and Organizations to widely spread early warning and weather or disaster information into the community through fax and phone. Relief and Resettlement Department had also already drawn Flood Plans and published to every State and Region.

1.3.4.3 Achievement in Disaster Risk Management Policy and Practice

In collaboration with other related Departments, Organizations, Relief and Resettlement Department had already drawn Standing Order on Natural Disaster Management (2009), Disaster Management Law (2011), Hazard Profile, Institutional Arrangements for Disaster Management in Myanmar, Guideline for Township Disaster Management, and Myanmar Action Plan on Disaster Management (MAPDRR) has already endorsed and now the priorities of MAPDRR have been implementing. Moreover, Relief and Resettlement Department, Planning Department and Asian Disaster Preparedness Centre (ADPC) have been jointly organizing the National Training Course on Mainstreaming DRR into Development Planning.

1.3.4.4 Disasters happened in Myanmar and RRD's Functions during 2012

During 2012, (422) times of disaster had happened in Myanmar. So, there were (190890) affected persons, (127) dead persons, (121) injured persons, (486.58) Million (Kyat) for damage and loss. Relief and Resettlement Department had already provided (444.09) Million (Kyat) for all.

The most famous disasters in 2012 are Rakhine conflict, flood and Thabeik Kyin earthquake. Rakhine conflict happened two times. On (8.6.2012), the conflict firstly happened in Sittwe, Myaut U, Kyaut Taw, Minpya, Pauk Taw, Maung Taw, Yathae Taung, Buthi Taung, Yanbyae and Ponena Kyune. In this first time, there were (89) dead persons, (124) injured persons, (5338) damaged houses. So, Relief and Resettlement Department opened (19) relief camps in Rakhine. On (21.10.2012), the conflict secondly happened in Myaut U, Kyaut Taw, Minpya, Pauk Taw, Yathae Taung, Yanbyae, Kyaut Phyu and Myaybon. In this second time, there were (111) dead persons, (144) injured persons, and (5351) damaged houses. So, Relief and Resettlement Department opened (22) relief camps in Rakhine.

During 2012, July to September, Myanmar was extremely striken by flood especially in Kayin, Sagaing, Tanintharyi, Nay Pyi Taw, Bago, Mandalay, Mon, Yangon, Shan and Ayeyarwaddy. In this flood, there were (139319) affected persons and altogether (167.297) Million (Kyat) had already provided. Thabeik Kyin earthquake happened on (11.11.2012) with (6.8) Richter scale in Sagaing and Mandalay. In this earthquake, there were (18) dead persons, (116) injured persons, (2496) damaged houses, (1633) other damaged infrastructure. So, Relief and Resettlement Department had already provided (44.426) Million (Kyat). During 2012, for Capacity Generating of officers from related Departments who have participated in Disaster Management, Relief and Resettlement Department could have already conducted (7) times of Capacity Generating Trainings for Disaster Management in every State and Region such as Kayah, Kayin, Chin, Bago, Magway, Mon and Shan, and then also (46) times of duplicate trainings in every state and region, and (52) workshops. Moreover, Relief and Resettlement Department could have provided Disaster Management lecture at the trainings of Central Institute of Civil Services, and other trainings. GIS and Remote Sensing Trainings could also have been conducted in Nay Pyi Taw in collaboration with UN-SPIDER and ADPC. During 2012, altogether (89700) pamphlets and (13755) posters had already distributed in all these trainings, workshops, and also to the public.

In 2012, October (13), Relief and Resettlement Department under Ministry of Social Welfare, Relief and Resettlement could celebrate 3rd Commemoration of International Day for Disaster Risk Reduction at Myanmar International Convention Centre, Nay Pyi Taw. At this commemoration, Honorable Vice President, Dr. Sai Mauk Kham delivered speech and High representative of UN delivered remarks. Moreover, here, like former times, Public participated Tsunami Drill video for (10) minutes which were conducted in Tsunami prone areas such as Ayeyarwaddy Region have been shown, and the competitions of essay, article, poem, and cartoon for Disaster Management have also been held, and rewarded prizes to the winners.

1.3.4.5 Ways Forward

Relief and Resettlement Department has objectives to implement the following projects:

- to establish Disaster Management Training School in Hinthada township of Ayeyarwaddy Region
- to establish Emergency Operation Centre
- to construct (45) Cyclone Shelters in Ayeyarwaddy Region
- to build hill locks in Pharpone and Laputta Districts
- to implement assessment and research activities
- to implement community based Disaster Risk Reduction

1.3.4.6 Conclusion

Relief and Resettlement Department under Ministry of Social Welfare, Relief and Resettlement has been implementing its responsibilities with effort in line with its objectives in order to Myanmar be a resilience and sustainable development country in collaboration with related Departments, UN, INGO, NGO. Like the international countries, Disaster Management is priority for Myanmar. Therefore, as RRD is a focal point for Disaster Management in Myanmar, we have decided to successfully implement our future plans, to try to our country be safer from devastating disasters, to try to our World be peaceful and healthy one in collaboration with international countries around the world, UN, INGO and NGO.

1.3.5 Oman

As part of implementing its national disaster management program, Oman has carried out various activities during 2012 aiming at enhancing its national and regional DR capabilities. These activates can be divided into the following categories;

1.3.5.1 Establishing the national emergency preparedness and response system;

In 2011, Oman's national emergency response system was restructured with a new multihazard cluster function based approach /system. In 2012, efforts were directed toward continuing the organizational and institutional aspects of the system components (sectors, regional committees, and national emergency management centre). Activities included, identifying sectors organizational structure (Government agencies, NGOs, and the private sector) their representatives, and TOR. Coordination and communications activities were initiated toward developing strategic plans for each sector beside developing and exercising preparedness and response plans. In 2013, focus will be on developing integrated operational process by which different ERS components can work together in harmony toward achieving rapid and effective disaster response.

1.3.5.2 Enhancing governorates emergency response system:

Another critical aspect of ER system development in Oman was the enhancement of regional emergency management system with focus in the enhancement of community first response capabilities. Regional emergency management committees were restructured as per the national response system with clear identification of rules and responsibilities among stakeholders. Revised disaster preparedness and response plans are under development.

1.3.5.3 Adopting unified incident command system:

Realizing the importance of having a common incident command system among various responding sectors, Oman has started the development and implementation of a standard incident command system that aims at having a unified incident response structure and process among different levels of response/responders.

1.3.5.4 Training:

Toward enhancing human recourses capabilities, training program was carried out focusing on the following aspects:

- ✓ Incident command system training.
- ✓ Specialized sector /function programs (search and rescue, medical response, relief and shelter management, critical infrastructure continuity, etc.)
- ✓ Participation in regional and international meetings, exercises and training programs.

1.3.5.5 Risk Reduction activities

Various risk reduction activities were executed during 2012 including the following:

- ➢ Enhancing coordination and cooperation with the national multi hazard early warning centre project; especially with regard to public warning and information sharing.
- ➢ Education for risk reduction strategy: working with NOUNSICO in developing a national strategy that aims at enhancing DRR public awareness and education.
- ➢ Academic and scientific research: coordination with local universities and academic research centres were made toward allocating certain percentage of their annual research project toward DRR activities specially that pertaining to risk mapping, land use, etc.
- ➢ Community vulnerability assessment and mapping.

1.3.5.6 Emergency Information Management system:

Phase II of SOEMIS project was completed with the collection of spatial and statistical data of the whole country .in January 2013, phase III started aiming at developing an intelligent decision support system that will utilize data collected in risk redaction, response, and recovery activities.

1.3.5.7 National search and rescue team:

Oman Urban Search & Rescue Team was classified as international medium level S &R team as per INSARAG guidelines and methodology and now ready to be deployed to international search and rescue missions.

1.3.5.8 Public Warning and hazard Information:

One the most effective DRR activities (that was tested during various climate situation Oman experienced during 2012) was developing standard operating procedures among Metrology, Hydrology, Emergency Management Authorities, and media. Coordination with PA for Radio and Television and other media stakeholders was made to achieve effective public warning through the provision of life data in both in TV and radio stations. Data provided included weather forecast, raining activities, flash flooded areas, hazardous area, highways and main roads blocked. Sharing of such data with effective warning campaign proved to be extremely effective way of reducing losses in lives.

Another activity, was the coordination with telecommunication industry to send bulk warning messages to people (mobile numbers) that are nearby high risk zones (thus saving time and resources needed by directing warning activities toward affected populations only.

1.3.6 Pakistan

1.3.6.1 National Disaster Management Plan

NDMA of Pakistan with assistance by the Japanese government through JICA has prepared a National Disaster Management Plan for 2012-2022. It is a long term and holist policy document for disaster risk management at national level. The Plan has been developed in harmony with Hyogo Framework of Action (HFA) 2005-2015 as agreed in UN-WCDR (January, 2005). It contains all the aspects of disaster management policy, strategies and actions including:

- National Hazard and Vulnerability Assessment
- Human Resource Development
- Community Based Disaster Risk Management
- Multi-Hazard Early Warning System
- Disaster Management Operation by type of Disaster, such as earthquake, flood, drought, cyclone, tsunami, etc.
- Action Programs of Disaster Management for 10 Years

Multi-Hazard Early Warning System is one of the components of the National Disaster Management Plan and PMD is the main national focal organization for this component. Under this component, the existing four PMD radars of Japanese technology will be replaced by new radars and three more radars will also be established to cover the western parts of the country.

For efficient execution of the National Disaster Management Plan the activities have been allocated to four stages of the Disaster Cycle. The Plan has been organized as per following four stages of the Disaster Cycle:

- Non Disaster (These activities include disaster mitigation leading to prevention and risk reduction)
- Pre-Disaster (These activities include preparedness to face likely disasters, dissemination of early warnings)
- During Disaster (These activities include quick response, provision of relief, mobilization of search & rescue and
- Post-Disaster (These activities include recovery and rehabilitation programs in disaster affected areas)

1.3.6.2 National Monsoon Contingency Plan

NDMA of Pakistan prepared National Monsoon Contingency Plan July-September 2012. The plan has been developed keeping in view of the past experiences and lessons learnt, from extreme hydrometeorlogical disasters of unprecedented nature. The main objective of the contingency plan is to promote better preparedness with a view to reduce risks and to respond to any disaster situation in a most befitting manner.

During the development of plan, NDMA held a number of consultative meetings with all the provincial governments and relevant stakeholders in order to take stock of their respective hazards and risk assessment measures, identifying priority needs, effective deployment of available resources, preparation of their Contingency Plans for the worst case scenarios i.e. the possible combination of the Super Floods 2010 and 2011 heavy monsoon rains and floods.

1.3.6.3 Strengthening of Seismic Monitoring System under Pak-China Seismograph Network Project

PMD with support by the China Earthquake Network Centre (CENC)/ China Earthquake Administration (CEA) has been implementing a project “Pak-China Seismograph Network” for strengthening of seismic monitoring network in Pakistan. Under this project, ten (10) new broad-band seismic stations have been established and these new seismic stations have been integrated with the existing seismic network of PMD, making the total number of such stations twenty (20). The project aims at better monitoring of earthquakes and precise earthquake hazard assessment.

1.3.6.4 Cooperative Agreement signed between PMD & Agency for Technical Cooperation & Development (ACTED)

Pakistan Meteorological Department (PMD) and Agency for Technical Cooperation & Development (ACTED) signed a Framework on 31st August, 2012, for cooperation to develop and implement GIS-enabled Meteorological Information System. This would help end users for effective response and timely mitigation measures in case any natural hazard is likely to affect vulnerable communities. The GIS enabled web tools will ingest near real-time meteorological data and products and would help in vulnerability assessment of locations along with population density which is the critical information for effective response system.

The Framework was signed by Mr. Andrew Buchanan, Country Director ACTED and Mr. Arif Mahmood, Director General, PMD, Both the organizations agreed that ACTED and PMD technical teams will jointly develop this on-line information system within minimum time and a prototype system for end users will be available by the end of this year.

1.3.7 Sri Lanka

The Disaster Management Centre (DMC) is the coordinating body under the Ministry of Disaster Management. It involve in disseminating the warnings and advisories from the technical agencies to the grass root level, conducting public and awareness programmes and preparedness and planning activities for prevention of the disasters with the respective agencies. District disaster preparedness plans have been completed for 16 districts and 573 plans for Grama Niladhari (lowest level in the administration) divisional level plans were completed. 117 mock drills were also completed. Cyclone hazard mapping has been completed with technical support from Department of Meteorology and financial support from UNDP. In addition, Landslide hazard mapping, Drought Hazard Mapping, Flood Hazard Mapping also conducted. Structural measures for land slides are also conducted with National Building Research Organization. Dam Safety & Water Resources Planning project under the Ministry of Irrigation & Water Management is a major project to enhance the capacity of department of Irrigation with regard to Hydrological disaster and expected to be commencing soon. Local authorities in the disaster prone areas have been strengthen to face for the disaster by providing necessary equipment by the DMC. National safety day celebration was performed on 26th December in Badulla (landslide prone district) concentrating preparedness activities and public awareness.

In the event of a Natural or Manmade disaster, Emergency Operation Centre (EOC) coordinates rescue operations, distribution of resources and emergency relief supplies with the assistance of Armed Forces, Police, Red Cross, UN systems and other relevant stakeholders to ensure quick evacuation and efficient distribution of relief items. EOC presently functions with a skeleton staff and plans to improve the operations with the recruitment of additional staff. UNDP, UNICEF, UNCHR, WFP, UNESCAP, UNOCHA, Red Cross and IOM have been supporting Disaster Management Centre continuously in Disaster Emergency Response and relief distribution activities while National Disaster Relief Services Centre, under the ministry provides the relief for affected community.

DMC has all together 77 commissioned along the coast in addition to the telephone, cell broadcast and number of modes of communicating the warning and another 25 towers have been planned. Very successful and efficient evacuation process were introduced with utilizing the assistance of farces.

1.3.8 Thailand

1.3.8.1 Key Members on Work

Key agencies involved in disaster preparedness and protection includes the National Disaster Prevention and Mitigation Committee (NDPMC) and the Department of Disaster Prevention and Mitigation (DDPM).

Under the Ministry of Finance, the NDPMC determines the regulations of payment in mitigation and prevention activities of all related agencies regarding the national disaster prevention and mitigation plan.

The Department of Disaster Prevention and Mitigation (DDPM), under the Ministry of Interior, is a primary government agency in disaster management, responsible for imposing and implementing program policy, formulating operational guidelines and establishing criteria on disaster management. The DDPM requires promoting disaster prevention and preparedness, assisting disaster management with specialists, hardware, and software, and also assists in loss reduction of life and negative impact of all disasters. In addition, it organizes and conducts training activities related to all disaster management by collaboration with local and international organizations, such as ADRC, ADPC, JICA, GTZ, UNDP UNISDR, UNOCHA, UNEP, and so on.

The DDPM cooperated with United Nation International Strategy for Disaster Reduction (UNISDR) and Asian Disaster Preparedness Centre (ADPC) to formulate Strategic National Action Plan (SNAP) for Disaster Risk Reduction for Thailand and set up the working group composed of representatives from agencies concerned to draft SNAP. The draft plan is now submitting to the Cabinet for approval.

1.3.8.2 Framework of Early Warning System

An early warning system in Thailand is divided into 2 levels: national and local level.

In the national level, the disaster warnings and forecasts from related agencies will be spread to people through mass media. The DDPM will put them into the mechanism of the Ministry of Interior scattered to provinces, districts and local agencies.

In the local level, the low cost rain gauge simple to use and manual disaster siren have been installed in the flooded areas to observe and notify disaster forecasts and warnings. The villagers, as trainees, will learn how to measure, record and read daily rainfall amount. If the rainfall exceeds the predefined normal level, the village headmen will be notified to spread warnings through the broadcasting centres by the manual siren device.

1.3.8.3 Enhancement of Disaster Management

Several projects have launched for enhancing the efficiency in disaster management.

Community Based Disaster Risk Management (CBDRM)

For improving public safety in risk areas, the CBDRM increases public capacity in disaster management. The DDMP cooperated with local agencies and international agencies to generate public awareness, as seen at present, more than 60,000 people in risk communities have been trained on this approach. In this year, the DDPM focuses on 18 communities selected from overall country to be retrained for sustainable community on disaster prevention.

1.3.8.1 Disaster Warning

Flash flood and Mudslide Warning Program aims for enhancement of local capacity in risk assessment and early warning collaborated with the Department of Provincial Administration, the Department of Local Administration, Meteorological Department, National Park Wildlife and the Plant Conservation Department, and National Disaster Warning Centre. Mr Warning is the voluntary villager functioning as a vigilant, a fore warner and a coordinator, now, having 20,296 persons in flood prone areas.

1.3.8.2 Disaster Prevention and Mitigation Academy (DPMA)

As a national training centre, the DPMA has begun since 2004 to develop curricula and mobilize technologies for standard training with collaboration of national and international agencies. This is to increase in capacity of the persons in charge of disaster management. The curricula of 6 campuses consists the Fire Fighting, Building Collapse (Search and Rescue), Hazmat Emergency Management, Civil Defense Volunteer and Disaster Management.

1.3.8.3 Search and Rescue Team

The Project of “One Tambon (sub-district) One Search and Rescue Team (OTOS)” stresses on the establishment, training and long-term maintenance in sub-district communities. It cooperates with various agencies, such as, the Department of Local Administration, Health Insurance Office, the Office of Health Promotion and Support Fund, and Thai Red Cross.

The objectives are (1) to ensure safety, and the rapid, efficient search and rescue; (2) to increase effective search and rescue team at every place throughout the country; (3) to build up capacity and effective search and rescue team by technical training and drilling; and (4) to provide first aid treatment and rapid transfer to medical. Last year, 73,371 persons throughout the country were 85% complete involved in OTOS program.

1.3.8.4 Capacity-Building of Civil Defense Volunteer

Recruited from local residents aged over 18 years, the civil defense volunteers have been trained the 5-day course on Civil Defense Volunteer to assist disaster management with now 1,200,176 volunteers in the country.

This program aims to increase public capacity on disaster prevention including search and rescue activities. After the training, the volunteers will organize officially locating at their communities and assist the government in case of emergency.

UNESCO/IOC

Mr Tony Elliott (Intergovernmental Oceanographic Commission of 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 for the IOTWS and reported on the outcomes of the 9th Session of the ICG/IOTWS, held in Jakarta in November 2012. He acknowledged the participation of the PTC Secretary, Dr Qamar-uz-Zaman Chaudhry, and noted that his intervention had been recorded in the meeting report, which would be submitted to the IOC Assembly in July 2013. He informed the Panel that the ICG had assessed the performance of the three Regional Tsunami Service Providers (RTSPs), Australia, India and Indonesia, in the period 12 October 2011 to 28 October 2012 and found that the performance indicators set by the ICG had been achieved. The ICG had therefore requested the RTSPs to assume full operational responsibility for tsunami advisories in the Indian Ocean region from 31 March 2013. The ICG also requested the Interim Advisory Service operated by the Japan Meteorological Agency (JMA) and the Pacific Tsunami Warning Centre (PTWC) to cease providing advisories to the IO region as of 31 March 2013. Mr Elliott encouraged the Panel member states to inform the ICG/IOTWS Secretariat of any changes in their Tsunami Warning Focal Points (TWFP) to ensure that they continue to receive RTSP advisory messages.

Mr Elliott reminded the Panel of IOC UNESCO's global coordination role in the establishment and governance of regional tsunami warning systems and in this context called for closer cooperation and collaboration between the IOC and the five Tropical Cyclone Programme Regional Bodies. There had already been good cooperation in the northern Indian Ocean, southwest Pacific and the Caribbean regions and Mr Elliott suggested that this could be extended to other regions and broadened to potentially include joint training programmes in areas of common interest.

Mr Elliott thanked the Panel for inviting IOC UNESCO to attend this session and gave IOC UNESCO's assurance that it would continue to liaise and collaborate with the Panel in areas of mutual benefit.

The Panel was informed that the next IOTWS/ICG will be held in Bangladesh or Oman in 2014 or 2015. The Panel decided to send the PTC Secretary to the meeting to represent the Panel on Tropical Cyclones.

1.4 TRAINING

1.4.1 Bangladesh

- To build capacity in NWP, weather forecasters of Bangladesh Meteorological Department were trained in a project "Human capacity on operational weather analysis"- supported by JICA. A pc cluster has been installed in the Storm Warning Centre of BMD for training on NWP under JICA project. JMA-NHM model has been installed in the Storm Warning Centre (SWC) of BMD.
- A training program was held from 21-28 Nov. 2012 in Bangladesh Meteorological Department, Dhaka under the project "Institutional support and capacity building for mitigation of weather and climate hazards in Bangladesh". The project is supported by Norwegian Meteorological Institute. Diana was installed in the

National Weather Forecasting Centre of Bangladesh Meteorological Department (BMD). Meteorologist of Bangladesh Meteorological Department received hands on training on the use of Diana as a tool for weather forecasting conducted by the Operational Forecaster/Meteorologist of Norwegian Meteorological Institute. Climatologist of BMD also received a hands on training on the analysis of Climate data by using R- Software

1.4.2 India

1.4.2.1 International Level:

RSMC, New Delhi is regularly conducting training on operational Tropical Cyclone Forecasting since 2005 for the Panel member countries. In year 2012, three participants from Sri Lanka, Thailand and Maldives were given training during 20 February to 2 March, 2012.

1.4.2.2 National Level:

1.4.2.2.1 The training activities at RMTC Pune are as follows:

1.4.2.2.1.1 Current Status:

The following regular courses are running at Central Training Institute Pashan,Pune

- i) Advanced Meteorological Training Course in General Meteorology
- ii) Forecasters Training Course in General Meteorology
- iii) Intermediate Training Course in General Meteorology

In addition to these courses, the refresher courses on the thematic topics are also being conducted. During the year 2012, advance refreshers course on ‘Application of DWR products on NWP’ was conducted at CTI, Pune during 19 November -24 November 2012.

1.4.2.2.1.2 On going projects:

Under World Bank aided Hydrology Project Phase II**, t**he following regular courses are running:

- iv) Basic Hydromet Observer Course
- ii) Hydromet Supervisor’s Course
- iii) Senior Level refresher course

1.4.2.2.1.3 Future Plans:

a. 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.
b. To design and organise advanced refresher training course of 10 weeks duration for the forecasters of Rwanda Met. Agency.

c. To introduce e-learning in training programme.
d. To upgrade the infrastructure of training institute & Trainees Hostel.
e. To revise the syllabus /Course contents of the different training courses.

Annual Training Calendar for the Year 2012 – 2015 is given below:

Routine Courses in IMD				
S. No.	**Course Name**	**Duration**	**Date of commencement**	**Eligibility Criteria**
1.	Advanced Met Training Course	One year	Second Monday of September of every year	B.Sc.* (with Physics or Maths as main subject) /M.Sc./B.E./ B.Tech.
2.	Forecasting Training Course	Six months	Second Monday of March and September every year	B.Sc. (with Physics or Math as main subject) and after successful completion of Intermediate Met. Training course
3.	Intermediate course in General Meteorology (For Basic Met Training course trained personnel)	Three months	Four batches per year starting in February, May, August and November every year	B.Sc. (with Physics or Maths as main subject) after successful completion of Basic Met. Training course.
4	Integrated Basic Training Course	Six months	Ab-initio training	Fresh recruited Scientific Asst. with B.Sc.(Phy., Math) qualification
5	Lab Assist Modular Course	Two months	Second Monday of February, June and October every year	Departmental Met. Attendant who have passed SSC and working in same cadre for 5 years
6	Training Course for Radio Mech. / Mech. Asst/ Mech. Grade I	3 weeks	Twice in a year	Departmental candidates with I T I qualification

1.4.2.2.2 Training activities of Telecom Training Centre(TTC) during 2012

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:-

(i)	Elementary Training Course in Met. Information System (Level-I)	(Duration – 4 months)
(ii)	Intermediate Course in met. Information System (level- II)	(Duration- 4 months)
(iii)	Advanced course in Met. Information System (level- III)	(Duration- 6 months)
(iv)	Short term course for Mechanics/Radio-Mechanics	(Duration- 1 month)
(v)	Familiarisation Course in IT & Met. Telecommunication Technique	(duration- 1 month)
(vi)	Short term course in Fundamental of IT & PC applications	(Duration- One month afternoon only)

1.4.2.2.3 Courses under Hydrology Project Phase II

S.N.	Name of the Course	Frequency/year	Duration
1	Basic Hydromet Observer's Course for Observers	3 batches per year	19 days
2	Hydromet Supervisor Course for Asst/Section Engineers	2 batches per year	12 days
3	Senior Level Refresher Course for Executive Engineers	1 batches per year	5 days

Note: 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.

1.4.2.2.3.1 Future Plan:

1. The seminars/workshops will be conducted for the cyclone forecasters in India during March and September 2013 as pre-cyclone exercise.

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.
- Maldives is in need of financial and technical assistance in strengthening its observational network, especially upper air observation, Automatic Weather Station and Radar Meteorology.

1.4.4 Myanmar

Training programs were undertaken on seasonal and weather forecasting, Meteorological hazards early warning for developing countries, reinforcement of meteorological services, flood hazard map, operating management of earthquake, tsunami and eruption observation system, climate change adaptation, environment impact assessment, etc.

DMH has sent approximately 9 staff for foreign training and a number of staffs and officers for workshops and meetings during 2012.

At present, one staff is undertaking a long-term training of Master's Degree on "Tsunami Disaster Mitigation" with the support of JICA in Japan.

During the year, one staff officer from DMH works together with RIMES' staff as secondment on seismological field.

Training Workshop on WRF Model by ADPC Experts on 16-18 November 2012, held in Meteorological Division of DMH Myanmar. (7) Participants from Meteorological and Hydrological Divisions were conducted science of WRF Modelling with practical works.

A degree offering program in the field of Meteorology and Hydrology has been carried-out by DMH since 1996 in collaboration with Dagon and Yangon Universities.

Instructors from DMH have been conducted Disaster Management Course for Disaster Managers in collaboration with the Department of Relief and Resettlement and Airline Transport Pilot Licence Course (ATPL), Commercial Pilot Licence (CPL) Course and Air Traffic Control (ATC) in aviation meteorology for air force.

Training are held for DMH' staff on Meteorological Grade I, II, III Course, Hydrological Grade I,II Course and for Navy and Air Force as their request.

1.4.4.1 Other Activities and Development

Myanmar Department of Meteorology and Hydrology(DMH) successfully set up high computing facilities to achieve the WRF and RegCM Model with National Budget in March 2012 and this system was completely installed WRF Model by ADPC Experts during the Training Workshop on 16-18 November 2012, held in Meteorological Division of DMH Myanmar. (7) Participants from Meteorological and Hydrological Divisions were conducted science of WRF Modeling with practical works. Now, WRF Model is running with GFS data by DMH's Forecasters. The WRF output products are regularly launched at the DMH website (www.moezala.gov.mm) starting from 15-1-2013. The (3) day outlook WRF products such as minimum temperature, sea level pressure, surface wind, rainfall and upper level wind are updated once per day based on 0000UTC GFS Data. National Monsoon Forum jointly organized twice annually with regional partner agencies and stakeholders for climate outlook and disaster risk reduction.

1.4.5 Oman

Oman has successfully hosted a workshop on tropical cyclones with the participation of several PTC members. The Centre of Excellence in Oman also hosted the eight's 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 2012 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	10
Tropical Cyclone Workshop	Oman	10
Tsunami	Indonesia	2
Tsunami workshop	Oman	10
Dust Conference	Kuwait	3
Radar Meteorology	China	1
database systems CLDB	Slovakia	1
numerical weather forecasts	Germany	1
Production of weather graphics for TV	Egypt	1

1.4.6 Pakistan

1.4.6.1 Capacity Building of PMD: Training Abroad & Human Resource Development

For the capacity building of its officials, PMD has been sending potential scientists abroad for postgraduate studies and higher trainings (MS, PhD etc.) in meteorology, seismology and climate sciences since 2006 with support by the Government of Pakistan and cooperation by international organizations, research institutions and foreign universities. So far, nineteen (19) officers have joined back to PMD after completion of their higher studies from United Kingdom, Canada, Norway, China and Thailand.

During 2012, three (03) PMD scientists have proceeded abroad for undertaking PhD. (Meteorology) at the Nanjing University of Information Science and Technology (NUIST), China with partial financial support by the China Meteorological Administration and NUIST and the remaining support by the Government of Pakistan.

In addition, two (02) PMD scientists have been doing their PhD (Meteorology) since October, 2009 with scholarships by the Chinese Academy of Sciences covering around 70% of their expenditures. The remaining cost of their studies has been borne by the Government of Pakistan. They are expected to join PMD by the end of May 2013 after completion of their PhD. Furthermore, two (2) scientists have been doing their PhD studies at the Chinese Academy of Sciences, China and Sejong University, South Korea respectively on scholarships since 2011.

Besides this, one scientist has been doing his 3-years M.Sc. (Hydrology) at Russian State Hydrometeorlogical University, St. Petersburg, Russian Federation under WMO scholarship since October, 2011.

During 2012, one more scientist has proceeded abroad for Ph.D in Earth System and GeoInformation Science on PhD Fellowship Scheme (HKPFS) at the Chinese University of Hong Kong, China.

In addition, during 2012, two (02) scientists have proceeded abroad for their M.Sc. (Meteorology) at King Abdul Aziz University, Jeddah, Saudi Arabia on scholarship.

In 2012, four (04) scientists have completed their MS in Hydrology and Flood related Disaster Management at International Centre for Water Hazard and Risk Management (ICHARM), Japan. Two of these scientists completed their MS under the auspicious of JICA while the other two under the auspicious of UNESCO with Japanese support under a UNESCO project which aim to improve flood alters in Pakistan. One more scientist completed his JICA sponsored postgraduate studies in seismology from Japan during 2011-2012.

During 2012, around 58 fellowships were availed by PMD scientists for attending short-term trainings/ workshops/ seminars abroad. These fellowships have been offered mainly by WMO, ICIMOD, ICTP, UNESCO, CMA, KMA, JMA, JICA, Hong Kong Observatory etc. and the foreign governments including those of China, and Finland etc.

1.4.6.2 Training of Met. Personnel at IMG, Karachi

During 2012-2013, various regular and special courses on meteorology were also conducted at PMD's Institute of Meteorology & Geophysics (IMG), Karachi for Met. personnel of PMD as well as for participants from other relevant organizations including Met branch of Pakistan Air and Naval Forces. These courses include Initial and Preliminary Meteorology Courses (WMO BIP–MT), Basic Forecasting Course (WMO BIP–M) and others.

1.4.6.3 Training at COMSATS Institute of Information Technology, Islamabad

Around seven (07) officers of PMD have completed their MS (Meteorology) from Department of Meteorology, COMSATS Institute of Information Technology (CIIT), Islamabad during 2012-2013. PMD has also been providing teaching faculty support to CIIT.

1.4.6.4 Capacity Building of Neighbouring Countries by PMD

PMD under one of it development projects has been extending its training facilities to the NMHSs of the neighbouring developing and least developed countries for their capacity building through WMO Voluntary Cooperation Programme since 2008.

For this purpose, special Preliminary Meteorology Courses (WMO BIP-MT) were conducted in successive years from 2008 to 2010 at IMG, Karachi. The Government of Pakistan (through PMD) had been providing complete financial support (in lieu of travel and per diem) to the nominees of NMHSs from neighbouring countries for their participation in these courses. Under this project, PMD has planned to organize another such course during 2013.

1.4.7 Sri Lanka

The Department of Meteorology organized a WMO workshop on Quality Management Systems for Aviation Meteorological Services.

Two meteorologists are currently receiving post graduate training at University of Philippines under the fellowship of WMO and another one has returned after the completion of M.S. degree in meteorology at the University of Philippines.

The following short term training workshop/seminars organized/cosponsored by WMO were attended by the scientific staff of the department:

1. Training on Storm Surge Experts with IIT, Delhi 10-21 Dec 2012;
2. Competence Assessment of Aviation Forecasters and Observers -29/10-02/11 2012, Israel;
3. Tropical Cyclone forecasting attachment to RSMC, 20/02-02/03 /2012, India;
4. Tropical Cyclone analysis, 17/12-19/12 – 2012, Oman;
5. Technical Planning Workshop on Severe Weather Forecasting Demonstration Project (SWFDP) Development for the Bay of Bengal Region (RA ll – South Asia), 23/01- 27/01/2012, India;
6. International Training Workshop on use and Interpretation of NWP prediction model, 03-07/12/2012, India;
7. Ocean Observation and instrument calibration, 19-21/November, 2012, India;
8. SASCOF-3 meeting and Workshop on seasonal prediction of southwest monsoon rainfall, 16-20 April 2012, India;
9. SW Indian Ocean Climate Outlook Forum – SWIOCOF, 24/09 to 03/10/2012, LA reunion.

In addition, scientific and engineering staff members also participated for short period in training programmes arranged by JICA, KOICA, JMA, RIMES, ADPC and SMRC.

Two training workshops were conducted by the Department for Agro meteorology data collecting personals.

Two training workshop were also conducted for meteorological technicians under Continual Education and Training program. Two years duration training program for newly recruited trainee grade of Meteorological Technicians were completed in the year 2012.

1.4.8 Thailand

In 2012, Thai Meteorological Department has sent officers to training workshops on various topics to apply their knowledge in order to develop routine job. Details of the training are listed below.

- 2 TMD officers joined the Training on Radar Composite Map Technique, held in
- Tokyo, Japan, 18-23 November 2012;
- 1 TMD officer joined Climate Prediction Training Program 2012, held in Busan, Republic of Korea, 18-30 November 2012;
- 1 TMD officers joined International Training Workshop on "The Latest Development on the Use an Interpretation of Numerical Weather Prediction (NWP) Models", held in Hong Kong, China, 2-8 December 2012;
- 1 TMD officer joined ASEAN Training Course on Earthquake Monitoring, Tectonic Deformation, Seismic Zoning Methods and Tsunami Early Warning System, held in Jakarta & West Java, Indonesia, 17 November-1 December 2012;
- 1 TMD officer joined International Training Course for Weather Forecasters, held in Nanjing, China, 16-27 September 2012;
- 1 TMD officer joined the Ewha International School on Data Assimilation (EISDA 2012), held in Seoul, Republic of Korea, 21-24 August 2012;
- 2 TMD officers joined Climate Prediction and Application Training Program for Green Growth in Developing Countries 2012, held in Busan, Republic of Korea, 3-15 June 2012;
- 1 TMD officer joined Training on Natural Disaster Management, held in Nakhonpathom, Thailand, 28 May-15 June 2012;
- 2 TMD officers joined Training Program on Consultancy Needs and Services in Disaster Management in Thailand, held in Bangkok, Thailand, 19-20 March 2012;
- 1 TMD officer joins Training on Operational Tropical Cyclone Forecasting, held in New Delhi, India, 19 February-March 2012;
- 1 TMD officer joins International Training Course on McIDAS-V Software Application in Satellite Meteorology, held in Beijing, China, 11-21 June 2012;
- 2 TMD officers joined Capacity Building in Regional Numerical Weather Prediction Based on the COSMO Model, held in Langen, Germany, 16-27 July 2012;
- 1 TMD officer joined APEC Training Course on Quantitative Precipitation Estimation/Forecasting (QPE/QPF), held in Quezon City, Philippines, 27-30 March 2012;
- 1 TMD officer joined the 8th Post Graduate Course in Satellite Meteorology and Global Climate, held in Ahmedabad, India, August 2012 - 30 April 2013;

- 1 TMD officer joined Typhoon Committee Research Fellowship Scheme 2012, held in Seoul, Republic of Korea, 1 May-29 June 2012;
- 1 TMD officer joined Capacity Building on Acid Deposition and Impact Assessment Analysis, held in Tokyo, Japan, 5-16 March 2012;
- 1 TMD officer joined International Training Seminar on "Methods for Short-term Climate Prediction", held in Nanjing & Beijing, China, 26 March-7 April 2012;
- 1 TMD officer joined International Training Course on Weather Radar Operation and Data Utilization, held in Seoul, Republic of Korea, 4-17 March 2012.

Activities of WMO

The Panel noted that, at its 64th Session held in Geneva in June-July 2012, the Executive Council (EC) of WMO reconfirmed the status of the WMO Regional Training Centre (RTC) in India, and also recognized the National Water Academy (NWA) in Pune as a new component of the RTC in India.

The Panel also noted that, at the same session, the EC recognized the training facilities of the Meteorological, Climatological and Geophysical Agency (BMKG) and the Research Centre for Water Resources (RCWR) in Indonesia as two components of a new RTC in Indonesia to at least 31 December 2015 with possible extension for an additional four years.

The Panel noted the training events and workshops which were organized in 2012 for the benefit of its Members. Since its last session, the Panel had benefited from education and training activities of WMO through the provision of fellowships, attachments, relevant training courses, workshops, seminars, and the provision of advice and assistance to Members.

The Panel noted the forthcoming training events planned for 2013, and the Members were encouraged to make maximum benefit of the training seminars, workshops and courses to be organized or co-sponsored by WMO.

The Panel also noted that the Cooperative Program for Operational Meteorology, Education and Training (COMET) has produced new training resources. The Panel Members were encouraged to make maximum benefit of these available training resources in English (*https://www.meted.ucar.edu/training_detail.php?page=1&topic=8&language=1&orderBy=publishDateDesc*) and Spanish (*https://www.meted.ucar.edu/training_detail.php?page=1&topic=8&language=6&orderBy=pu blishDateDesc*) languages, especially the online Tropical Textbook – a comprehensive guide to understanding tropical weather.

The Panel was encouraged to consider reviewing and adapting the competency approach being used by Tropical Cyclone Centres outside of ESCAP (e.g. the Bureau of Meteorology in Australia) and then identifying regional and national training requirements based around the competencies.

The Panel noted that WMO has consolidated information on available annual fellowships opportunities which is available to members on ETRP Website: *http://www.wmo.int/pages/prog/dra/etrp/fellowships/fellowsintouch.php*.

The Panel also noted that the WMO Regional Training Centres (RTCs) and national training institutions offer training courses time-to-time and they are made available on ERTP Website: *http://192.91.247.60/etr/aspscripts/search_subject_n.asp*

The Panel underscored the contributions of WMO to human resources development of many NMHSs in least developed and developing countries through its short- and long term fellowships and expressed appreciation for the open and transparent way in which the selection process is being carried out. It noted that as the WMO fellowships would remain an important facility for capacity development, Members should be encouraged to raise resources themselves and also seek more partners to cooperate with WMO in augmenting the available resources for fellowships in specialized areas.

The Panel express its appreciation and gratitude to RSMC New Delhi and Indian Institute Technology for their continued support for developing capacity of the PTC Members in forecasting of tropical cyclones and storm surges, respectively.

TC Competencies

The Panel was informed by WMO Secretariat that Tropical Cyclone Competencies is part of overall WMO Competency Standards in response to implementation of WMO Quality Management System (QMS), and corresponding requirements of capacity developments of the Member countries. The Tropical Cyclone Competencies describes the essential skills and competencies necessary for a TC forecaster to acquire for his/her successful carrying out operational duties in tropical cyclone circumstances. It is a structural approach to systematic requirements of TC forecasting centres of the Member countries. The Panel appreciated the information on Tropical Cyclone Competencies, and requested the WMO Secretariat to duly inform the Panel of any progress and development in this important aspect.

1.5 RESEARCH

1.5.1 Bangladesh

Research studies have been carried out in the following topics by the members of the Department-

- ✓ Analysis of extreme rainfall events
- ✓ Analysis of Tropical cyclone "NILAM".
- ✓ Analysis of significant Nor'wester events.

1.5.2 India

1.5.2.1 Forecast Demonstration Project on landfalling cyclones over the Bay of Bengal

Cyclone Warning & Research Centre (CWRC) at Regional Meteorological Centre (RMC), Chennai is the Field Operational Centre (FOC) of the project and is involved in co-ordinating with the participating scientific organisations, IMD's coastal field stations and Sagar Kanya cruise regarding notification of Intense Observation Periods (IOP) by the National Operational Centre (NOC) functioning from IMD, New Delhi. IMD personnel are deputed on tour to some non-regular field stations to cover special observations. Daily and weekly reports on status of observations are sent to NOC regularly.

1.5.2.2 Forecast Demonstration Project (FDP) on Continental Tropical Convergence Zone (CTCZ)

The monsoon rainfall mainly depends on the activity of monsoon trough. The part of monsoon trough lying over the land region is called as CTCZ. The CTCZ is responsible for spatio-temporal variability of monsoon rainfall over India. So, for better understanding and prediction of characteristic features of CTCZ and associated rainfall, an FDP on CTCZ has been taken up since 2010 as a multi-institutional campaign. This year the programme was conducted during (1 July-30 Sep) in Monsoon season.

1.5.2.3 Forecasting System for Thunderstorm and Hailstorm

During 2012, the following initiatives have been implemented at IMD for forecast of thunderstorm and hail storm

1.5.2.3.1 Meso-scale model ARPS

The storm scale model ARPS (Advanced Regional Prediction System) was implemented for the Delhi and Kolkata region at the horizontal resolution of 9 km with the assimilation of Doppler Weather Radar observations.

1.5.2.3.2 Nowcasting and very short range forecasting systems (0-6 hours)

For nowcasting purposes, application software called "Warning Decision Support System Integrated Information (WDSS-II)", developed by National Severe Storm Lab, USA has been used in experimental mode. For mesoscale forecasting, radar data has been assimilated into the ARPS mesoscale model. With the ingesting of Indian DWR observations, the application software is capable of detecting and removing anomalous propagation echoes.

Apart from the above, Doppler Weather Radar (DWR) is very helpful in nowcasting of severe weather events like thunderstorm and hailstorm. DWR gives number of derived products (images) from the three base products viz. Reflectivity, Velocity and Spectrum Width products which can be readily used for nowcasting and more accurate monitoring and warnings for severe weather events like flash floods, thunderstorms, dust storms, heavy rainfall, Gale winds, hail etc. Timely warnings of these severe weather events can save more lives and minimize the damages to properties. Frequency of observations: Doppler Weather Radars which are installed & commissioned operating round the clock (24x7) at 10 minutes interval.

So far 550 AWS, 878 ARGs systems have been installed & commissioned at various sites. One TDMA type AWS data receiving station has been installed also under the project 550 AWS. The data recorded by these AWS proved to be very useful in issuing operational weather forecast in very short range.

1.5.2.3.3 Forecast Demonstration Project (FDP) on Severe Thunderstorm Observation and Regional Modeling (STORM)

The thunderstorm is a natural hazard for the country, especially over east and north east India. Many people die every year due to thunderstorm. In order to improve monitoring and prediction of these thunderstorms, an FDP on STORM has been taken up since 2007. Since 2011, the SAARC countries like Bangladesh, Nepal and Bhutan are also participating in this programme. The FDP on STORM was continued during 2012 and special observational and forecast demonstration campaign was conducted during 15 April- 31May 2012.

1.5.2.4 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:

1.5.2.4.1 Statistical prediction of seasonal Tropical Cyclone over the North Indian Ocean

An experimental outlook on the seasonal Tropical Cyclone activity over the North Indian Ocean for the period October-December 2012 was prepared on real-time basis (during September 2012) and validated at the end of the season. Efforts are on for improving the prediction model.

1.5.2.4.2 Project TCRAIN

A project on ‘Tropical Cyclone Rainfall Analysis for North Indian Ocean - TCRAIN’ was recently undertaken at CWRC, RMC Chennai and rainfall characteristics of 43 Tropical Cyclones that affected North Indian Ocean during the period 2000-2010 were determined using TRMM data. 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 has been 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. The products are displayed through menu-driven user interface and are proposed to be uploaded in the RMC Chennai website shortly.

1.5.2.5 On-going Projects

1.5.2.5.1 A brain storming session on Tropical Cyclone Research in India is proposed to be conducted by CWRC, RMC Chennai.

1.5.2.6 Future Plans

1. Cyclone Warning & Research Centre, functioning from the Regional Meteorological Centre, Chennai is proposed to be upgraded as **National Tropical Cyclone Research Centre**, during the next five years.

1.5.2.6.1 Papers published in Mausam

1. **Statistical Prediction of Seasonal Cyclonic Activity over North Indian Ocean** by **S. Balachandran and B. Geetha**
2. **Satellite Derived Sea Surface Temperature Variability in the Bay of Bengal** by **O. P. Singh.**
3. **Investigation of Features of May, 2001 Tropical Cyclone over the Arabian Sea through IRS-P4 and other Satellite Data** by **P. N. Mahajan, R. M. Khaladkar, S. G. Narkhedkar, Sathy Nair, Amita Prabhu And M. Mahakur**
4. **Rainfall Estimation of Landfalling Tropical Cyclones over Indian Coasts through Satellite Imagery** By **Charan Singh, Sunit Das, R. B.Verma, B. L. Verma And B. K. Bandyopadhyay.**
5. **Cyclones and Depressions over the North Indian Ocean During 2011 by Dr. Medha Khole, Sunitha Devi S. and M. V. Mande.**
6. **Doppler Weather Radar Analysis of Short Term Cyclonic Storm** by **D. Pradhan, U. K. De.**
7. **The Relationship between Geopotential Height and Movement & Landfall of Tropical Cyclone in the Bay of Bengal Region** By **G. K. Das, S. K. Midya, G. C. Debnath, S. N. Roy.**
8. **Outcomes and Challenges of Forecast Demonstration Project (FDP) on Landfalling Cyclones over the Bay of Bengal b**y **M. Mohapatra, D. R. Sikka, B. K. Bandyopadhyay And Ajit Tyagi.**
9. **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.**
10. **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.**

11. **Barotropic Energetics analysis of Tropical Cyclone Khai Muk** by **S. Balachandran.**
12. **Track, Intensity and few Dynamical Aspects of 'Aila' as Simulated by Operational NWP Model of The IAF** by **T. P. Srivastava and Anil Devrani.**
13. **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.**
14. **Studies On VIF Atmospherics during the Tropical Cyclone "Aila" and several Monsoon Period Thunderstorms over North-East India** by **Rakesh Roy, Anirban Guha, Barin Kumar De And Abhijit Choudhury.**
15. **Observational Aspects including Weather RADAR for Tropical Cyclone Monitoring** by **S. Raghavan.**
16. **Recent Advances in Observational Support from Space-Based Systems for Tropical Cyclones** by **R. C. Bhatia and A. K. Sharma.**
17. **Estimation of Intensity of Tropical Cyclone over Bay of Bengal using Microwave Imagery** by **T. N. Jha, M. Mohapatra and B. K. Bandyopadhyay.**
18. **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.**
19. **Impact Of Cyclone Bogusing And Regional Assimilation on Tropical Cyclone Track And Intensity Predictions** by **Manjusha Chourasia, R. G. Ashrit And John P. George.**
20. **Tropical Cyclone Genesis Potential Parameter (GPP) and its application over the North Indian Sea** by **S. D. Kotal And S. K. Bhattacharya.**
21. **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**
22. **Ocean Atmospheric Coupled Model to Estimate Energy and Path of Cyclone near the Coast** by **Ramkrishna Datta**.
23. **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.**

1.5.2.6.2 The following research papers have been communicated to journals for publication:

i. A paper entitled "Decadal variations in translational speeds of cyclonic disturbances over North Indian Ocean" by B. Geetha and S. Balachandran in Mausam.
ii. A paper entitled "Characterisation and Asymmetry analysis of Rainfall distribution associated with Tropical Cyclones over Bay of Bengal: *NISHA* (2008), *LAILA* (2010) and *JAL* (2010) by S. Balachandran and B. Geetha in Mausam.

iii. A paper entitled "Energetics of Super Cyclone 'Gonu' and Very Severe Cyclonic Storm 'Sidr' " by Sunitha Devi S, Somenath Dutta and K. Prasad in Mausam.

1.5.2.6.3 Workshop/Seminar/lectures organised in India

1. The second WMO International Conference on Indian Ocean Tropical and Cyclone Change (IOTCCC) was held at New Delhi during 14-17 February 2012. The conference was inaugurated by Hon'ble Vice Chairman Sh. M. Shashidhar Reddy on 14th February 2012 and Dr. Shailesh R. Nayak, Secretary, Ministry of Earth Sciences presided over the inaugural function. About 150 delegates including 32 foreign delegates participated in the conference. There were four plenary sessions, 14 parallel technical sessions, two panel discussions and a concluding session. There were invited talks by the eminent scientists in the field of cyclone and climate change impact on cyclones over the Indian Ocean in the plenary sessions and beginning of each parallel, technical sessions. The several recommendations have been adopted at the end of the conference for further action. During the inaugural function following two books were released:
2. Agricultural Meteorology Division, India Meteorological Department, Pune, World Meteorological Organisation, Geneva and SAARC Agriculture Centre, Bangladesh jointly organized the Consultation Meeting on "Operational Agrometeorological Services in SAARC and other countries in RA II region" at National Meteorological Training Institute, Pune from 20-21 April 2012. A number of high level dignitaries viz. Dr. A. K. Azad, Director, SAARC Agriculture Centre, Mr. Robert Stefanski, Chief Agricultural Meteorology Division, WMO, Geneva, Prof. R. R. Kelkar, Former DGM, AVM (Dr.) Ajit Tyagi, Former DGM, Dr. K. J. Ramesh, Sc.'G', DST, Dr. S. Sardesai, Sc.'G', NIC participated in the meeting. The objective of the meeting was to share the ideas and understanding of agromet advisories services among the agrometeorologist from SAARC and non-SAARC countries in the RA-II which will ultimate boost the agriculturist activities and also benefit both the group of countries
3. A 3 days capacity building training workshop on "Seasonal Prediction of Southwest Monsoon Rainfall" conducted at the India Meteorological Department Pune during 16-18 April, 2012. The training workshop was attended by representatives from 7 South Asian countries, namely, Bangladesh, Bhutan, India, Maldives, Myanmar, Nepal, and Sri Lanka. An expert from (SAARC Meteorological Research Centre, Dhaka Bangladesh), also participated. Experts from the IMD and the Indian Institute of Tropical Meteorology, Pune and international experts from UK Met. Office and Japan Meteorological Agency participated in the training workshop as resource persons.
4. Third meet of South Asian Climate Outlook Forum (SASCOF-3) was organized by IMD / IITM during 19-20 April which was attended by representatives from 7 South Asian countries, experts from IMD and IITM, Pune and international experts from UK Met Office, Japan Meteorological Agency and Korea Meteorological Administration. Representatives from the WMO and scientists

from C-DAC, Pune, and Centre for Mathematical Modelling and Computer Simulation, Bangalore, took active part in deliberations for finalizing the consensus outlook for the summer monsoon rainfall over South Asia. There were 42 participants from 9 countries. In addition, around 20 experts from the national agro- meteorological services of the SAARC nations and an expert from the WMO also joined the forum.

5. The Agromet Core course meant for university Professors, Readers, Scientists from various agricultural/ agrometeorological research organizations/ICAR institutions/ universities was conducted from 24th April to 14th May, 2012. Total 14 participants (Professors/Scientists) from various Agricultural Universities throughout the country joined the course. The course content included various aspects of Agricultural Meteorology including climate change impact on crops, crop simulation modeling, crop yield forecasting, and application of remote sensing in addition to operational Agromet Advisory Service.
6. On-the-job Training of Intermediate (Gen. Met.) Batch No. 226 has been imparted to trainees at RC Kolkata as per schedule of NMTI, Pune during 30 April to 5 May 2012.
7. A training programme was arranged by Hydromet division on mkRAIN software during 3-4th May, 2012 at training centre, New Delhi. The officers from RMCs, MCs, and FMOs attended the programme. Inaugural address was given by Dr. L. S. Rathore, DGM followed by training lectures given by officers from Hydromet Division. During the period a lecture on DRMS Rainfall Data Processing through mkRAIN software was arranged.
8. A training program on 'Vrishti', a Geographical Information System for river basin rainfall data processing was held by Hydromet division, New Delhi in three phases, during 30 May-1 June and 4-6 June at HQ, New Delhi and during 12-14 June 2012 at Kolkata. The trainee participants were from the Flood Met. Offices and also from RMCs/MCs.
9. Three weeks Agromet Observers' course meant for grass-root level observers, was conducted from 4 June 2012 to 22 June 2012. Eight participants from the vast network of various Agromet. and other observatories under different State Agricultural Universities/ICAR Institutions, State Department of Agriculture participated in the course.
10. Dr. Medha Khole, DDGM (WF), participated in 'Web Portal Review Meeting " on 11th and 16th of January 2012 at C-DAC, Pune.
11. Dr. Medha Khole, DDGM (WF), delivered a lecture on "Extreme Weather Phenomena" at NFAI Auditorium, Law College Road, Pune organized by Vishwa Scientific and National Film Archive of India in association with Vigyan Prasar, Govt. Of India on 20th - 22nd.
12. Dr. Medha Khole, DDGM (WF), delivered a lecture on "Services rendered by IMD: An Overview" at a seminar hosted by C-DAC on Interdisciplinary application of Weather and Climate-Computational perspective.
13. Shri P.H.R. Rao, A.M.II, Shri M. V. Mande, SA, Shri Jhonson Samuel and Shri V.B. Kadam, S.A. attended the Training Workshop cum National Seminar on

"Challenges Developments and Opportunities in Nowcasting" at New Delhi during 27^{th} – 29^{th} January 2012.

14. Mr. Michel Jarraud, Secretary General, World Meteorological Organization, Geneva, Switzerland visited IMD, Pune, on 21st. Dr. Medha Khole, DDGM (WF), participated in the meeting of Secretary General, World Meteorological Organization with IMD officers and made a presentation on 'Activities of O/o DDGM (WF)'. The Secretary General also visited Weather Central and INOSHAC and was briefed upon the operational activities of the section and utilization of SYNERGIE workstation in Weather Forecasting during his visit alongwith AVM Dr. Ajit Tyagi (Ex. DGM).
15. Members of the 25th Session of WMO EC Panel of experts on Education and Training visited Weather Section on 29th. They were briefed about activities of Weather Section and INOSHAC related to Training.
16. Dr. Medha Khole, Scientist E, DDGM(WF) delivered an invited lecture on the topic , "Early warning systems of IMD pertaining to Cyclones" at YASHADA, Pune on 8th at the Maharashtra State Government's one day Workshop on Monsoon Preparation and Hydro Meteorological Hazards.

1.5.2.6.4 Workshop/Seminar/lectures attended outside India

Dr. S. K. Roy Bhowmik Sc. 'F' was on deputation to SAARC Meteorological Research Centre, Dhaka to attend Meeting of the Focal Points on "Formulation of Inter-Governmental Monsoon Initiative Programme" held in SAARC Meteorological Research Centre, Dhaka, Bangladesh during 30 to 31 May 2012.

Shri R. K. Giri, Scientist 'D' visited Kathmandu, Nepal during 23 to 25 May, 2012 to attend the HCOS project 4^{th} regional steering committee meeting.

Shri N.K. Pangasa Scientist 'F' visited Cairo, Egypt during 29 to 31 May, 2012 to attend Seventeenth Meeting SADISOPGS (Satellite Distribution operator group system) organized by ICAO Montreal.

Dr. R. S. Dattatrayam, Scientist 'F' attended the annual meeting of the Executive Committee International Seismological Centre, U. K. held during $17\text{-}18^{th}$ June, 2012 at Thatcham, Berkshire, UK to discuss and review the working of ISC towards suggesting improvements in the preparation and exchange of seismological bulletin data.

Dr. R. S. Dattatrayam, Scientist-'F' (EREC), IMD visited Brisbane, Australia, as part of a 4-member delegation led by Secretary, MoES, for attending the 34^{th} meeting of the International Geological Congress (IGC), during 5-10 August, 2012.
Shri Suresh Ram, Scientist 'D' CAMD, New Delhi attended 16^{th} Meeting of Communication/Navigation/ Surveillance and Meteorology Sub-Group at Bangkok, Thailand from 23-27 July 2012.

Ms Latha Sridhar, S.A. participated in the "Targeted Training Activity on El Nino Southern Oscillation - Monsoon in the Current and Future Climate" at ICTP, Trieste, Italy from 30th July to 10th August, 2012 organised by International Centre for Theoretical Physics.

Mr. Hirendra Ashwin Kumar Singh, Director alongwith three other officials was on deputation for four weeks from 20th August to 14th September 2012 for technical training in Hardware and software of Automatic Message Switching System (AMSS) at Paris, France.

Dr. L. R. Meena, Scientist, 'F' attended 15th Session of WMO Commission for Basic System (CBS) held at Jakarta, Indonesia from 10 -15 September 2012.

Dr. L. S. Rathore, Director General of Meteorology attended and chaired the meeting of Governing Board of SMRC from 12-13 September, 2012 followed by the Selection Committee meeting on 14th September at Dhaka, Bangladesh.

Shri Virendra Singh, Director participated in the WMO EUMETSAT workshop on RGB Satellite products Standard Application and opportunities from 17-19 September 2012 in Germany.

Shri A. D. Tathe, Director attended 2nd Bilateral meeting with KMA, Korea from 20-21 September, 2012 as a member of Indian delegation.

Dr. Ashok Kumar Das, Scientist "C" attended training on 'Application of Remote Sensing and GIS in Hydrology' during 11-13th September, 2012 at NIH, Belgaum.

Dr. Shailesh Nayak, Secretary, MoES and Chairman Earth System Sciences Organisation, comprising of Dr. L. S. Rathore, DGM, Dr. Ajit Tyagi, and Shri A.S.Khati, Joint Secretary, MoES visited WMO Geneva, Switzerland during 29-31Oct., 2012 to participate in Extraordinary Session of WMO Congress

Dr. M. Mohapatra, Sc.-E, was on ex-India deputation to Muscat, Oman during 17-19 December, 2012 to participate in a case study workshop on Tropical cyclone Analysis and Forecasting organised by world Meteorological Organisation (WMO).

FUTURE PLANS

1.. The centre, viz., Cyclone Warning & Research Centre, functioning from the Regional Meteorological Centre, Chennai is also proposed to be upgraded as **National Tropical Cyclone Research Centre**, during the next five years.

1.5.3 Maldives

Maldives is hosting a Collaborative Climate Research in its Addu City – A scientific Project in the Indian Ocean to better understand Global Climate & Weather Systems – Endorsed by World Climate Research Programme.

The Madden-Julian Oscillation (MJO) is a 30 to 90 day tropical weather cycle that alternates between large, strong rain storms and relatively quiet periods, moving from the Indian Ocean eastward to the Pacific Ocean. The MJO not only plays an important role in local weather in the tropics, affecting regional monsoon rains, but also impacts weather and climate in other parts of the world. Improved understanding of this important event will help short- and long-term weather forecasting and climate predictions across the globe. Dynamics of the Madden-Julian Oscillation (DYNAMO) study is being conducted from October 2011 – March 2012,which is the most frequent time for the onset of the MJO.

DYNAMO will provide researchers with vital observations of the MJO, a poorly understood phenomenon, particularly during the initiation phase. The results will help researchers to more accurately forecast the weather and climate of the equatorial Indian Ocean and around the world. Large-scale weather events, such as the MJO, create pulses that have direct effects on regional weather patterns around the world. During the field campaign land, ocean and atmosphere based observations will simultaneously be taken by using various radars, balloon launches, research vessels and research airplanes.

1.5.4 Myanmar

Department of Meteorology and Hydrology organized “Research and Development Team (R and D Team)” with the purpose for building capacity of younger generation and enhancing research activities of DMH. A number of Research work and small projects related to tropical storms, Climate trend, Climate Change, drought events and other meteorological and hydrological hazards are carried out by scientists of DMH and they presented their research work at various conferences/ symposia / workshops at national and international levels during 2012. For example;

- Research studies on SW Monsoon and NE Monsoon have been carried out yearly with the emphasis on changing of onset/withdrawal phase, duration, intensity, monsoon rain, storm frequency and shiftment of their seasonal tracks, dry spell and wet spell, drought, extreme events etc.
- Research works on aspect of agro-meteorology and their practical applications (evapotranspiration, water balance etc.) to agricultural sectors of the nation, are carried out in co-operation with agriculturists
- Research works on many aspects of hydrology and their applications to important economic sectors of the nation are carried out in co-operation with the responsible personnel from other agencies concerned

- In 2005, DMH became a member of Acid Deposition Monitoring Network for East Asia (EANET). Since then, DMH had established a laboratory to monitor the air and water quality of Myanmar. During 2012, November, “The Scientific Advisory Committee (SAC) of Acid Deposition Monitoring Network in East Asia (EANET)” held its session in 2012 (SAC2012) and “The Intergovernmental Meeting on (EANET)” held its Fourteenth Session (IG14)”. At these sessions, regular monitoring works and research on acid rain and the findings are presented and discuss on the way forward.
- Myanmar enable to fulfil its commitments and obligations as required by Articles 4.1 and 12.1 of the Convention by preparing and reporting its Initial National Communication (INC) under the execution of National Commission for Environmental Affairs (NCEA).For this project, DMH has taken responsibilities for “Research and Systematic Observation” and “Vulnerability and Adaptation on Climate Change” sectors. It has now been approved by UNEP.
- Climate Change activities have been undertaken in DMH. At the currently, DMH is taking to implement the National Adaptation Programme of Action (NAPA) Project as an executing agency.
- With the support of WMO program and JICA, DMH has installed two storm surge models; IIT Storm Surge Model and JMA Storm Surge Model. A number of research activities are carrying out by using these two models as well as DMH’ empirical methods.
- In order to improve the disaster risk reduction in Myanmar, JICA had been provided short-term experts dispatch program starting from 2009 to 2012 on the Improvement of Tropical Storm Forecasting and Warning to DMH. After completion of Expert Dispatch program, DMH received its own capacity for more precise cyclone and storm surge forecasting and warning by using advanced technology and sophisticated equipments and research activities are promoted by the staff.
- DMH has run the Model for Assessment of Greenhouse gas Induced Climate Change/Scenario Generator (MAGICC/ SCENGEN) for climate scenarios of Myanmar for the year 2020, 2050 and 2100. Based on these climate scenarios, research activities have been done by the scientists with their concern.
- With the purpose of improvement of early warning system as well as research works, DMH successfully set up high computing facilities to achieve the WRF and RegCM Model with National Budget in March 2012 and this system now running by DMH forecasters.
- On WMO Day and DMH’s Diamond Jubilee Ceremony of 2012, Paper Reading Session was accompanied to strengthen research activities. At that session, about fifty numbers of research papers were presented on various meteorological, hydrological and seismological points of view.

1.5.4.1 Needs and Requirements for Research and Development

To enhance research activities technical/ financial/ expertise support will be necessary from various international/ regional organizations. Especially, the research programmes in DMH should also aim to maintain and develop international links that ensure collaboration with international research programmes and contribution to rapidly emerging new global technologies. The observational instruments must be replaced by automatic or computerized facilities to control quality of data and to provide quality information to regional/global climatic centre. The technology enhancement must be promoted by the usage of numerical models and data analysis. Workshop/ Forum must be performed frequently to raise awareness and response strategies and to deliver opportunities to researchers.

1.5.5 Pakistan

A number of Research work/small projects related to forecasting techniques, climate change, climate modeling, downscaling for seasonal and monthly prediction, verification of High resolution Regional Model (HRM), were also carried out by the scientists of PMD and they presented their research work at various conferences/ symposia / workshops at national and international levels during 2012.

1.5.5.1 Climate Change Scenario simulations performed at Pakistan Meteorological Department

Scientists at Research & Development Division of PMD has worked out future climate change scenario on finer temporal and spatial resolution using the IPCC recommended methodology and output of the Global Climate Model GCMs. The output of the GCMs is further downscaled by Regional Climate Model RegCM (Italy) version 4.1 and PRECIS (UK) version 1.9.3 using high speed computing system facility installed at PMD. Some basic information is given as under. Baseline : 1961-2000 Future dataset : 2001-2099 Spatial resolution : 50 km x 50 km and 25 km x 25 km Temporal resolution : Monthly annual and decadal

1.6.6 Sri Lanka

The following research studies were conducted by the Department during the year 2012:

1. Validation and verification studies on WRF;
2. Analysis of Rainfall Trend for the period of 1990-2010;
3. Analysis of trends in Temperature;
4. Development of display and decoding the synoptic observations;
5. Development of display system for AWS 10 minutes Data;
6. Effect of moon face on onset of Southwest Monsoon;
7. Studies on 3 day forecast by utilizing WRF model;
8. Tuning the WRF model by changing the Physics;

9. Decadal Rainfall Analysis (1951-2010);
10. Decadal Mean Temperature Analysis(1900-2010);
11. Calculation of Extra-terrestrial radiation pattern over Sri Lanka;
12. Identification of monsoon failures & extremes using SPI index (1951-2010);
13. Prediction of seasonal rainfall.

1.6.7 Thailand

The following research studies were conducted by Marine Meteorological Centre under Thai Meteorological Department during the year 2012:

- Wind-wave Characteristics Generated by Tropical Cyclone Activity in the Gulf of Thailand
- Virtual Wave: an Algorithm for Visualization of Ocean Wave Forecast in the Gulf of Thailand
- Understanding the Simple Model of Tsunami Propagation by SiTProS Model
- Decision Support System for Flash Flood Warning Management using Artificial Neural Network
- A Neural Network Model for Surface Air Temperature Estimation over the Eastern Part of Thailand in 2004
- Implementation of Neural Network for Spatial-Temporal Interpolation of Sea Surface Temperature in the Gulf of Thailand
- Wind-Wave and Tsunami Model in Thailand
- Analysis of Coastal Erosion by Using Wave Spectrum
- Forecasting Tropical Cyclone Movement by Neural Network
- Decision Support System for Prediction Air Temperature in Northern Part of Thailand by using Neural Network
- The Simulation of Wave model under North-East Monsoon along Coastline of Thailand
- Coupling of high-resolution meteorological and wave models over the Gulf of Thailand
- Affected by the northeast monsoon and the influence of the cyclone in the Indian Ocean induced Huge Wave along the eastern coastline of southern part of Thailand during December 25 - 28, 2011
- Alternative sites for HF Radar location along the shores of the Gulf of Thailand and the Andaman Sea

Activities of WMO

A training workshop for tropical cyclone forecasters in South East Asia was organized in 2012 by WMO's World Weather Research Programme (WWRP) in collaboration with the Tropical Cyclone Programme (TCP) under the 2010 Typhoon Landfall Forecast Demonstration Project (Shanghai, 12-14 Jun 2012). Fifty-two junior forecasters from 5 NMHSs in Southeast Asia were trained on new tropical cyclone forecasting techniques developed during the said FDP. The workshop report (CD format) was published in 2012.

The Expert Team on Climate Impacts on Tropical Cyclones held a meeting in New Delhi on 17 February 2012 to discuss future activities of the working group especially on the possible issuance of an updated statement on the climate impacts on tropical cyclones.

The 2nd International Conference on Indian Ocean Tropical Cyclones & Climate Change was successfully held in New Delhi from 14-17 Feb 2012. The conference was attended by 268 tropical cyclone forecasters & researchers (of the total 47 were graduate students & 65 early career scientists) from 15 Members of WMO. The Conference Proceedings including a list of recommendations on future research directions will be printed in 2013.

Another successful event held in 2012 was the International Conference on Opportunities and Challenges in Monsoon Prediction in a Changing Climate (Pune, 21-25 Feb 2012) which was attended by 350 monsoon forecasters and researchers (150 graduate students & early career scientists) from 21 Members of WMO and which also included some tropical cyclone experts.

During the two conferences above, the experts discussed the scientific basis of the projected increase of high-impact weather events (tropical cyclones and monsoons) and the complexities inherent in combating their hazardous impacts. Discussions during the conference resulted to a number of recommendations which will be forwarded to the writing teams working on IPCC’s Fifth Assessment Report (AR5) due in 2014.

Late in the year, the "2nd International Workshop on Unusual Behaviour of Tropical Cyclones" was held in Haikou, China from 5 to 9 November 2012. The Workshop was focused on improving the theoretical understanding and forecast capability of the rapid change phenomena in tropical cyclones and also stimulates future research work in this field. The workshop covered a range of topics (observations, prediction, research and field programs etc.) related to the unusual behaviour of tropical cyclones.

Also organized during the year was the Second Monsoon Heavy Rainfall Workshop (Petaling Jaya, Malaysia, 10 to 12 December 2012). Recent research results on the observation, modelling and prediction of heavy rainfall in the monsoon region (including heavy rainfall associated with tropical cyclone events) were presented and discussed during the workshop. It also provided training to heavy rainfall NMHS forecasters in the monsoon region. The oral session included invited lectures and selected contributed papers. A planning meeting for the proposed international field and modelling project, Southern China Monsoon Rainfall Experiment (SCMREX), was also held during the said Workshop.

Steps are being taken to organize a meeting of the Working Group on Tropical Meteorology Research tentatively in Macao, China from 26-27 October 2013. The working group will also hold in the same venue a meeting with another WWRP working group, the Joint Working Group on Forecast Verification Research. Discussions during the joint meeting will focus on projects and activities of common interest to the two working groups.

Also underway are preparations for the 5th WMO/CAS International Workshop on Monsoons (IWM-V) (tentative: Macao, China, 28-30 Oct 2013). The IWM series is a part of the WMO major quadrennial symposia and workshop series under the World Weather Research Programme (WWRP). It provides a forum for monsoon researchers and forecasters to discuss recent advances and current issues covering all time scales (meso, synoptic, intraseasonal, climate) that are relevant to the forecast of high-impact weather in the world's monsoon regions. The three previous workshops in the series were held in Bali (Feb 1997), New Delhi (Mar 20101), Hangzhou (Nov 2004) and Beijing (Oct 2008). One of the topics of the workshop will be on tropical cyclones and monsoons.

The 5th WWRP/WGTMR/MP Training Workshop on Monsoons will be held in conjunction with the IWM-V tentatively in Hong Kong, China on 1 November 2013. This one day workshop on operational monsoon research and forecast issues is a means to transfer new science and technology to National Meteorological and Hydrological Services in monsoon-affected regions.

Plans are to hold the eighth International Workshop on Tropical Cyclones (IWTCVIII) in the Republic of Korea in November 2014. The IWTC is one of WMO's major quadrennial workshop series organized by its World Weather Research Programme (WWRP) and Tropical Cyclone Programme (TCP). The quadrennial workshop is a special and unique gathering of tropical cyclone researchers and warning specialists from all regions affected by tropical cyclones, including those from Members belonging to the WMO TCP regional bodies. The main objectives of these workshops are 1) to examine current knowledge, forecasting and research trends on tropical cyclones from an integrated global perspective and 2) to report on these aspects and to offer recommendations for future forecasting studies and research with special regard to the varying needs of different regions.

Now online within the Indian Meteorological Department website is a webpage which provides the Tropical Cyclone THORPEX Interactive Grand Global Ensemble (TIGGE) Ensemble Forecast whenever a tropical cyclone is within the area of responsibility of TC RSMC New Delhi. The webpage was developed in association with WMO's North Western Pacific Tropical Cyclone Ensemble Forecast Project.

WWRP is pleased to announce that the first World Weather Open Science Conference will be held in Montreal, Canada from 17 to 23 August 2014. It will highlight recent advances in weather science and in the science practice of weather prediction. The Conference will also consider areas where a predictive capability is emerging, including a range of aspects of the natural environment, to provide predictions of importance in a range of different socio-economic sectors.

In 2012, the 64th Session of the WMO Executive Council (Geneva, 25 June to 3 July) approved the establishment of two The Observing System Research and Predictability Experiment (THORPEX) legacy projects. The first one is the 5-year Sub-seasonal to Seasonal Prediction (S2S) Joint Research Project (WWRP/THORPEX/WCRP) whose main goal is to improve forecast skill and understanding on the sub-seasonal to seasonal timescale, and promote its uptake by operational centres and exploitation by the applications community. Special attention will

be paid to the risk of extreme weather, including tropical cyclones, droughts, floods, heat waves and the waxing and waning of monsoon precipitation. The second project is the 10-year Polar Prediction Project (PPP) whose aim is to promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hourly to seasonal. The said project constitutes the hourly to seasonal research component of the WMO Global Integrated Polar Prediction System (GIPPS). More information about the two projects are available online at:
http://www.wmo.int/pages/prog/arep/wwrp/new/S2S_project_main_page.html
http://www.wmo.int/pages/prog/arep/wwrp/new/polar_prediction_research_project_main_page.html

Under development is a High-Impact Weather project which will serve as legacy to THORPEX emphasizing the improvement of high-impact weather predictions on the hours to-weeks timescales with a stronger focus on shorter time and space scales. The project will profit from the international experience gained in THORPEX. This proposed project will have links with the Polar Prediction and Sub-seasonal to Seasonal Projects mentioned above.

1.6 PUBLICATION

1.6.1 India

1.6.1.1 International Publication

1.6.1.1.1 Annual Review of Tropical Cyclones

The Annual Review for the year 2011 has been published by WMO. The Annual Review for the year 2012 is in progress and will be completed by the end of February and will be sent to Chief of PTC by the first week of March, 2013. Dr. M. Mohapatra will work as National Editor and Mr. B. K. Bandyopadhyay will work as Chief Editor for the Annual Review for the year 2013.

1.6.1.1.2 Tropical Cyclone Plan

The Tropical Cyclone Plan (TCP-21) edition 2012 has been completed and being published by WMO.

1.6.1.2 National Publications

1. The proceeding of two days conference on Bay of Bengal Tropical Cyclone Experiment (BoBTEX-2011) were published in special issue of journal **"Mausam"**
2. Vision Document of DDGM (UI) -Completed
3. Standard Operation Procedure (SOP) on Weather Forecasting and Warning has been published

4. Standard Operation Procedure (SOP) on Cyclone Warning in India has been completed and under publication
5. Radar Manual -Completed
6. Standard Operational Procedure (SOP) – Completed for Metstar DWR(Palam).
7. Radar Maintenance Manual (Gematronik) by DWR Chennai completed.

Details of the Cyclonic disturbance over north Indian Ocean during 2012

2. Details of the systems

2.1 Deep Depression over the Bay of Bengal (10–11 October 2012)

2.1.1 Under the influence of a cyclonic circulation over northwest and adjoining west central Bay of Bengal, a low pressure area formed over the same area on 7 October. It became well marked over northeast Bay of Bengal off Bangladesh coast on 10 morning. Moving northwards, it subsequently concentrated into a **Depression** at 1200 UTC of 10 and lay centred near Lat 21.0^o N/Long. 91.0^o E, about 350 kms southeast of Kolkata and into a **Deep Depression** at 1800 UTC and lay centred near Lat. 22.0° N / Long. 91.0° E. It moved northeastwards and crossed Bangla Desh coast near Hatia (Bangla Desh) between 0000 & 0100 UTC of 11 October and lay centred at 0300 UTC of 11 near Lat. 23.0° N / Long. 91.5° E, about 100 kms south of Agartala over Bangla Desh and adjoining areas of Tripura as **Depression**. It moved northeastwards and weakened into a well marked low pressure area over Mizoram & neighbourhood at 0600 UTC of 11 and further weakened into a low pressure area and lay over Manipur and neighbourhood at 1200 UTC. It became less marked on 12th.

2.1.2 Other features observed

The lowest Estimated Central pressure (ECP) was 1002 hPa from 1800 UTC of 10 to 0000 UTC of 11. The maximum estimated mean wind speed was 30 kts during the same period. The lowest observed pressure of 1002 hPa was reported by Chittagong at 0000 UTC of 11, when the system was to the west of Chittagong. Bangladesh reported sustained wind of 22 kts over Hatia, 25 kts over Sandip and 32 kts over Chittagong.

The system intensified into a deep depression before landfall, though it was lying very close to coast. The salient features of this deep depression are as follows.

(i) It formed from a remnant of low pressure system from the South China Sea which moved across Vietnam and Myanmar and emerged into the northeast and adjoining east central Bay of Bengal.

(ii) It was short lived with the life period of about 15 hrs.

(iii) It intensified into a deep depression before landfall, though it was lying very close to coast.

2.1.3 Weather and damage caused

System caused extensive damage in Bangladesh taking a toll of 43 human lives. Fairly widespread rainfall with isolated heavy falls occurred over Arunachal Pradesh, Assam & Meghalaya and Nagaland-Manipur-Mizoram-Tripura on 10 & 11. The significant amounts of rainfall (in cms, > 7 cm) are given below:

11 Oct. 2012:

Tripura

Belonia 9, Bagafa 7.

12 Oct. 2012

Mizoram

Lengpui 9. *Assam* – Matizuri 9, Kajalgaon (AWS) 7.

2.1.4 Satellite and RADAR observations

The system was tracked with the help of satellite (Kalpana–1) cloud imageries from 1200 UTC of 10 to 0600 UTC of 11. The maximum intensity of T No 2.0 was reported from 1500 UTC of 10 to 2000 UTC of 10.

The satellite imageries showed a developing low level circulation centre associated with increasing deep convection over the region. It was seen as a vortex with T 1.0 from 0300 to 0800 UTC 10. The T number of 1.5 was assigned at 0900 UTC and T 2.0 at 1500 UTC on the same day. The lowest Cloud Top Temperature (CTT) was about –80° C recorded during night of 10.

The system was also tracked by DWRs Khepupara, Cox's Bazar (Bangladesh) and Agartala. The DWR imageries from Agartala indicated that the wind speed was higher in the southern quadrant of the deep depression at the time of landfall. The radial wind of about 25–30 meter per second (48-58 kts) has been reported. It indicates that Agartala experienced 15–20 knots wind at the surface level during 0100–0300 UTC.

2.2 Cyclonic Storm (Murjan) over the Arabian Sea (22 – 26 October 2012)

2.2.1 A trough of low at mean sea level extended from southeast Arabian Sea to south Maharashtra coast on 20 and from Lakshadweep area to south Gujarat Region on 21. Under its influence, a low pressure area formed over southeast Arabian Sea and neighbourhood on 22. It lay as a well marked low pressure area over the same area in the evening of 22. It concentrated into a **Depression** and lay centred near Lat 11.0° N/Long. 66.5° E at 2100 UTC of 22. Moving westwards, it lay centred near Lat 11.0° N/Long. 65.0° E, 800 kms east of Amini Divi at 0300 UTC of 23 October and near Lat 11.5° N/Long. 64.0° E at 1200 UTC. It further moved westwards and intensified into a **Deep Depression** and lay over southwest and adjoining west central Arabian Sea centred near Lat. 11.5° N /Long. 63.5° E at 1500 UTC of 23. Moving slightly west-southwestwards, it lay over southwest and adjoining west central Arabian Sea and centred near Lat. 11.0° N /Long. 59.0° E at 0300 UTC of 24. Moving west–southwestwards, it further intensified into a **Cyclonic Storm (Murjan)** and lay centred near Lat. 10.5° N /Long. 56.5° E, about 1750 kms west-southwest of Amini Divi at 1200 UTC of 24 October. Then, it moved westwards and lay at 0300 UTC of 25 October near Lat. 10.5° N / Long. 53.5° E, about 2100 kms west–southwest of Amini Divi and near Lat. 9.5° N / Long. 51.5 ° E, about 2300 kms west–southwest of Amini Divi at 1200 UTC**.** It further moved westwards and crossed Somalia coast near Lat. 9.5° N / Long 50.8° E between 1700 & 1800 UTC and further weakened into a **Deep Depression** and lay centred near Lat. 9.5° N / Long. 50.5° E at 1800 UTC of 25. Moving further westwards, it weakened into a **Depression** and lay centred at 0000 UTC 26 October over Somalia near Lat. 9.5° N / Long. 49.5° E and lay centred at 0300 UTC of 26 October near Lat. 9.5° N / Long. 48.5° E. It further weakened into a low pressure area over Somalia and adjoining Ethiopia and became unimportant in the evening of 26 October.

2.2.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 998 hPa and estimated maximum sustained surface wind of 40 kts at 1800 UTC of 24. A ship with call sign 2FUB4 (13.5/56.6) reported wind 070°/35 kts at 1200 UTC of 24. There was no meteorological observation available from Somalia. The system generally moved in a westerly direction.

2.2.3 Weather and damage caused

As the system moved away from the Indian coast, no damage was reported due to this system. However, under its influence, widespread/fairly widespread rainfall with isolated heavy falls occurred over Lakshadweep area from 21 to 23, when the system lay as a low pressure area in its vicinity.

2.2.4 Satellite and RADAR observations

According to INSAT imagery, a vortex formed over southeast Arabian Sea with T1.0 and lay centred at 1200 UTC of 22 October near lat. 10.0^0N/ 68.0^0E. Wind shear was 10-20 Kt at 1200 UTC of 23rd indicating further intensification of the system. The system intensified further with intensity T2.0 at 1700 UTC of 23rd at centre 11.3N/63.3E. Moving in the westerly direction it intensified again into a cyclonic storm with intensity T 2.5 and centre 10.5N/56.5E.

System moved rapidly after 0900 UTC of 25th. With speed nearly 30 km/hr and crossed the coast at 1600 UTC of 25th October 2012 at 9.5N/50.6E.

The system was of shear pattern till 0600 UTC of 23rd. Then it changed into curved band pattern till landfall of the system.

The maximum intensity of the system according to Dvorak's classification was T 2.5 from 1200 of 24 to 1500 UTC of 25 October 2012.

2.3 Cyclonic Storm (Nilam) over the Bay of Bengal (28 October–01 November 2012)

2.3.1 A low pressure area over southeast Bay of Bengal and neighbourhood concentrated into a **Depression** over the same area and lay centred at 0600 UTC of 28 near Lat. 9.5° N/Long. 86.0° E, about 730 kms southeast of Chennai. Moving westwards, it lay centred at 1200 UTC of 28 over southwest Bay of Bengal near Lat. 9.5° N/Long. 85.0° E, about 650 kms southeast of Chennai. It continued to move westwards and intensified into a **Deep Depression** and lay centred at 0000 UTC of 29 over southwest Bay of Bengal near Lat. 9.5° N/Long. 84.0° E, about 550 kms southeast of Chennai. Continuing the westward movement, it lay centred at 0300 UTC over southwest Bay of Bengal near Lat. 9.5° N/Long. 83.5° E, about 530 kms southeast of Chennai and at 1200 UTC of 29 near Lat. 9.0° N/ Long. 82.5° E, about 500 kms south-southeast of Chennai. It further intensified into a **Cyclonic Storm (Nilam)** and lay centred at 0300 UTC of 30 over southwest Bay of Bengal near Lat. 9.0° N / Long. 82.0° E, about 500 kms south–southeast of Chennai. Further, it moved northwards and lay centred at 1200 UTC of 30 near Lat. 9.5° N/ Long. 82.0° E, about 450 kms south-southeast of Chennai. It moved north-westwards and lay centred at 0300 UTC of 31 over southwest Bay of Bengal near Lat. 11.0° N/Long. 81.0° E, about 260 kms south-southeast of Chennai. Moving north-north-westwards, it crossed north Tamil Nadu coast near Lat. 12.5° N / Long. 80.2° E, south of Chennai, near Mahabalipuram between 1030 and 1130 UTC of 31 and lay centred at 1200 UTC of 31 near Lat. 12.7° N/Long. 79.8° E, about 50 kms south–southwest of Chennai. It moved north-westwards and weakened into a **Deep Depression** over north Tamil Nadu and adjoining areas of Rayalaseema and interior Karnataka and lay centred at 1800 UTC of 31 October, near Lat. 13.0° N / Long. 78.5° E, about 180 kms west–northwest of Chennai. It further moved north-westwards and weakened into a **Depression** over Rayalaseema and adjoining areas of south interior

Karnataka and lay centred at 0000 UTC of 1 November 2012 near Lat. 13.0° N / Long. 77.5° E, about 75 kms, south of Anantpur and at 0300 UTC over south Interior Karnataka, near Lat. 13.5° N / Long. 77.0° E, close to Chitradurga. It remained practically stationary at 1200 UTC near Lat. 14.0° N/ Long. 77.0° E, near Chitradurga. Moving slightly northwards it lay centred at 1800 UTC of 1 November 2012 near Lat. 14.5° N/ Long. 77.0° E. It further weakened into a well marked low pressure area over Rayalaseema and neighbourhood in the morning of 2.

2.3.1 Other features observed

The lowest estimated central pressure (ECP) was 986 hPa *(post cyclone survey report)*. The lowest observed pressure was 987.8 hPa at 1040 UTC of 31 October at Kalpakkam (ISRO-AWS, located south of Chennai, (Post Cyclone Survey report)). The maximum estimated mean wind speed was 45 knots. Maximum sustained wind speed of 74 kmph (40 kts) has been reported over Chennai (NBK) at 1110 UTC of 31. The HWSR at Karaikal reported maximum wind speed of westerly/37 kts on 31st October.

The salient features of this storm are as follows.

(i) The cyclone followed a unique track with many rapid changes in direction of movement. It initially moved westwards, remained practically stationary for quite some time near Sri Lanka coast and then moved north–northwestwards till landfall. It moved west–northwestwards initially over land upto south interior Karnataka and then moved northwestwards and northwards. The remnant low pressure area moved northeastwards

(ii) It moved very fast on the day of landfall, i.e. 31st October 2012.

(iii) Over the land surface, the cloud mass was significantly sheared to the northeast of system centre during its dissipation stage leading to rainfall activity over entire Andhra Pradesh and adjoining Odisha.

(iv) Maximum rainfall occurred over southwest sector of the system centre and heavy to very heavy rainfall extended upto 300 km.

2.3.2 Weather and damage caused

Rainfall at most places with scattered heavy to very heavy rainfall occurred over north coastal Tamil Nadu. Rainfall at most places with isolated heavy to very heavy rainfall also occurred over north interior Tamil Nadu. Also, remnant of the system as a depression and subsequently as a low pressure area caused heavy to very heavy rainfall over Karnataka, Andhra Pradesh and Odisha. Six persons died in Andhra Pradesh. Two houses were fully damaged and 32 houses were severely damaged in Guntur district of Andhra Pradesh. Also, crops in 250 acres of Agricultural as well as 250 acres of Horticultural land were inundated due to heavy rains. Chief amounts of 24 hrs rainfall in cms (7 cm or more) ending at 0830 hrs IST of 01 November 2012 are given below.

31. 10. 2012

Tamil Nadu & Puducherry:

Vedaranniyam and Mahabalipuram 13 each, Trangambadi 10, Ennore AWS, Chennai (Nungambakkam), Nagapattinam, Kalpakkam and Tiruvarur 9 each, Madavaram AWS, Thiruthuraipoondi and Nannilam, Kelambakkam and Chennai Airport, Karaikal and Anna University 8 each, Tambaram, Sirkali and Mayiladuthurai, Kodavasal and Muthupet, Marakkanam and Vanur, Chengalpattu, Cholavaram, Puducherry 7 each.

Andhra Pradesh:
Srikalahasthi 11, Tirumalla 8, Chittoor 7.

01. 11. 2012
Tamil Nadu & Puducherry
Yercaud 24, Alangayam 20, Vandavasi 19, Tirukoilur 14, Vanur and Tindivanam 13 each, Gingee, Villupuram and Mylam AWS, Ambur and Tirupattur and Valangaiman 11 each, Sirkali, Kodavasal, Polur, Sethiathope and Tozhudur, Thali, Melalathur and Naduvattam 10 each, Parangipettai, Trangambadi and Kolli dam, Penucondapuram, Needamangalam and Arani 9 each, Chengam and Tiruvannamalai, Mayiladuthurai, Mannargudi, Kolachel, Chidambaram and Cuddalore, Pallipattu and Tirukattupalli 8 each, Aravakurichi, Barur, Hosur, Denkanikottai, Krishnagiri, Uthangarai and Pochampalli, Kattumannarkoil, Chidambaram AWS and Neyveli AWS, Thanjavur, Thiruvidaimaruthur, Kumbakonam, Madukkur, Vallam, Aduthurai AWS and Grand Anaicut, Sankarapuram, Nannilam and Thiruthuraipoondi, Vaniaymbadi, Puducherry, Pappireddipatti and Dharmapuri, Thuvakudi and Pullambadi, Eraniel and Kothagiri 7 each
Andhra Pradesh:
Vinjamur 16, Tirumalla and Ongole 15 each, Darsi 14, Addanki, Darsi and Kaveli 13 each, Rapur, Bhimunipatnam and Podili 12 each, Venkatagirikota, Kaveli (a) and Venkatagiri Town 11 each, Udayagiri and Avanigadda 10 each, Rajampet and Chittoor 9 each, Thambalapalli and Arogyavaram, Madakasira, Atmakur, Gudur and Nellore 8 each, Srikalahasthi, Punganur and Puttur, Amarapuram, Penukonda and Kadiri, Seetharampuram and Kakinada 7 each,
Karnataka:
Bagepalli 14, Koratagere 11, Kolar, Rayalpadu, GKVK, Hoskote 10 each, Srinivaspura, Doddaballapura, Nayakanahatti, CN Halli, Madhugiri, Thondebhavi, Gudibande 9 each, MM Hills, Mulbagal, Bangarpet, Bengaluru City, Bengaluru HAL AP, Nelamangala, Hiriyur, Kibbanahalli, Kunigal, Bargur, Chintamani, Gowribidanur 8 each, Panchanahalli, Kadur, Arasikere, Bandipura, Maddur, Malur, TG Halli, Devanahalli, 6 Jagalur, Hosanagara, Chitradurga, Gubbi, Sira, Sidlaghatta, Magadi, Channapatna, Kanakapura, Ramanagara 7 each.
02.11. 2012
Andhra Pradesh
Sattenapalle, Salur 14 each, Vijawada 13, Prathipadu, Nandigama, Nuzivid 11 each, Atchampeta, Bobbili, Koderu, Gudivada 10 each, Vizianagaram, Vuyyur, Gajapathinagaram, Addanki, Darsi, S. Kota, Tuni 9 each, Tuni, Kakinada, Ongole, Tiruvur, Chintapalle, Palasa, Bapatla, Araku, Tanuku, Avanigadda, Cheepurupalle 8 each, Guntur, Kaikalur, Bapatla, Mancherail, Podili, Yelamanchili, Tenali, Eluru 7 each.
2.3.3 Satellite and RADAR observations
The system was monitored mainly with satellite supported by meteorological buoys, coastal and island observations. It was also monitored by Doppler Weather RADAR (DWR), Chennai and CDR Karaikal.

The maximum intensity of the system according to Dvorak's classification was T 3.0 from 0000 to 1100 UTC of 31 Oct. The system was of curved band pattern till 1800 UTC of 30th October then it changed into CDO pattern. It further intensified (T3.0) at 0000UTC of 31st and continued to move in the same direction to cross the north Tamil Nadu coast around 1200 UTC of 31 October 2012 near12.5E/80.0E.

DWR Chennai monitored the system from the night of 29 October, when the cyclonic storm was about 500 km southeast of Chennai. Prominent features of Eye could not be seen persistently. RADAR-echoes in some parts of spiral bands were stronger than the eye-wall echoes on many occasions. Maximum observed reflectivity was around 55 dBZ. The wind field was less symmetric to the eye. Maximum velocity of about 30 mps observed in the cyclone field was associated with the spiral band.

Coastal surface observations were recorded on hourly basis, the half hourly INSAT/ Kalpana imageries and every 10 minutes DWR imageries and products were used for monitoring of cyclonic storm.

CDR Karaikal monitored the system from 27th Oct. No overlays were fitted for fixing centre of the cyclone. Observations were not recorded from 0000 UTC of 31 due to technical problem.

2.3.4 Performance of RADAR/Telecommunications Channels

DWR Chennai: The DWR performance during the cyclone surveillance period had been very good with optimum power output, sensitivity and stability without any trouble except during the period from 0615 to 0710 UTC – Radome door inter lock switch opened due to strong wind.

Performance of all telecommunication facilities viz., VPN connectivity, broadband internet connectivity, telephone, and tele-fax was good.

CDR Karaikal: RADAR worked satisfactorily during the storm period 26th to 30th Oct. The performance of all communication systems and standby generator was good.

2.4 Deep Depression over the Bay of Bengal (17–19 November 2012)

2.4.1 The well marked low pressure area over east central and adjoining southeast and west central Bay of Bengal concentrated into a **Depression** over the same area and lay over east central Bay of Bengal at 0600 UTC of 17, centred near Lat. 15.5° N/Long. 90.0° E. It moved slightly northwestwards and intensified further into a **Deep Depression** over the same region at 0900 UTC and lay centred near Lat. 15.5° N / Long. 89.5° E and near Lat. 16.0° N / Long. 89.0° E at 1200 UTC of 17, about 1000 kms east-northeast of Chennai. It remained practically stationary and lay centred at 0300 UTC of 18 near Lat. 16.0° N/Long. 88.5° E, about 950 kms east-northeast of Chennai. Moving westwards, it lay centred at 1200 UTC of 18 over west central Bay of Bengal near Lat. 16.0° N/Long. 87.5° E, about 800 kms east northeast of Chennai. It moved southwest wards and weakened into a **Depression** and lay centred at 0000 UTC of 19 near Lat. 15.5° N / Long. 87.0° E, about 750 kms east–northeast of Chennai and near Lat. 15.0° N / Long. 86.5° E, about 700 kms east–northeast of Chennai at 0300 UTC. It moved slightly westwards and lay centred at 1200 UTC of 19 near Lat. 15.0° N/Long. 86.0° E, about 650 kms east–northeast of Chennai. It further weakened into a well marked low pressure area over the west central Bay of Bengal at 1500 UTC of 19.

2.4.2 Other features observed

It formed from the remnant of low pressure system of south China Sea, which emerged into Bay of Bengal across Thailand. The lowest Estimated Central Pressure (ECP) was 1002 hPa from 1200 UTC of 17 to 1800 UTC of 18. The maximum estimated mean wind speed was 30 knots during the same period. The Maximum Sustained Wind (MSW) was reported as 31 knots by Buoy (23093, 16.5/88.0) at 0900 UTC of 18. The lowest central pressure of 1002.3 hPa was reported by the same Buoy at the same period.

The salient features of this storm are as follows:

1. The system moved westwards initially and then west-southwestwards under the influence of the middle tropospheric steering ridge.
2. The system weakened over the sea due to entrainment of cold and dry air from Indian main land in middle tropospheric levels and gradual increase in the vertical wind shear resulting in the northeastward shearing of convection from the low level circulation centre.
3. There existed a well defined low level circulation centre with banding features though the convection was significantly sheared to northeast under the influence of high wind shear on 18th and 19th November.

2.4.3 Weather and damage caused

There was no damage due to the deep depression, as it weakened over the sea.

Heavy rainfall occurred over Andhra Pradesh, Puducherry and Tamil Nadu due the remnant low pressure area of this depression. The chief amount of 24 hrs cumulative rainfall in cms (5 cm or more) ending at 0300 UTC of date are given below:

22 November 2012

Tamil Nadu & Puducherry

Sathanur Dam-10, Padalur-6, Sankarapuram-5,

23 November 2012

Coastal Andhra Pradesh

Tada-7

Rayalaseema

Tirupati (AP)-14, Perumallapalli and Puttur-7 each, Tirupati and Rajampet-6 each, Pakala-5,

Tamil Nadu & Puducherry: Pallipattu-6

24 November 2012

Tamil Nadu & Puducherry

Chengalpattu-14, Watrap and Tuticorin-10 each, Usilampatti, Bodinaickanur, Virudachalam-7 each, Coonoor-6, Viralimalai, Maduranthagam, Kothagiri, Ulundurpet, Vellore, Sirkali and Keeranur-5 each,

25 November 2012

Tamil Nadu & Puducherry

Manimutharu-14, Thenkasi-12, Shencottah and Maniyachi-6 each, Illuppur-5.

2.4.4 Satellite and RADAR observations

The maximum intensity of the system according to Dvorak's classification was T 2.0 from 0900 of 17 Nov. to 0800 UTC of 18th Nov. The cyclogenesis technique based on Oceansat-2 winds of 15 November showed that the system will develop into a cyclone.

The system was away from DWR Chennai range all through its life period.

2.5 Deep Depression over the Arabian Sea (22–25 December 2012)

2.5.1 The trough of low at mean sea level over southwest Bay of Bengal off Sri-Lanka coast lay over Maldives area and adjoining southeast Arabian Sea on 20 and over southeast Arabian Sea and neighbourhood on 21. It organized into a low pressure area and lay over southeast and adjoining southwest Arabian Sea on 22 morning. It rapidly concentrated into a **Depression** and lay centreed at 0600 UTC of 22 over central parts of south Arabian Sea near Lat. 9.0° N and Long. 64.0° E. It moved westwards and lay over southwest Arabian Sea near Lat. 9.0° N and Long. 62.5° E at 1200 UTC of 22. Further moving westwards, it intensified into a **Deep Depression** and lay over southwest Arabian Sea near Lat 9.0° N and Long. 60.5° E, about 1400 kms west-southwest of Amini Divi (Lakshadweep) at 0000 UTC of 23 and near Lat 9.0° N and Long. 60.0° E, about 1450 kms west-southwest of Amini Divi (Lakshadweep) at 0300 UTC. Moving west-southwestwards, it lay centreed at 1200 UTC of 23 near Lat 8.5° N and Long. 57.0° E about 1700 kms west-southwest of Amini Divi (Lakshadweep). Then, it moved westwards and lay centreed at 0300 UTC of 24 near Lat 8.0° N and Long. 54.0° E. Further, it moved west-southwestwards and weakened into a **Depression** and lay centred near Lat 7.0° N and Long. 52.0° E at 1200 UTC of 24 and near Lat 6.5° N and Long. 50.0° E at 0000 UTC of 25. Further moving west-southwestwards, it weakened into a well marked low pressure area over southwest Arabian Sea off Somalia coast on 25 morning and subsequently became unimportant.

2.5.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 1002 hPa from 0000 UTC of 23 to 1100 UTC of 24. The maximum estimated mean wind speed was 30 knots. The Maximum Sustained Wind (MSW) was reported as 23 knots by ships A8KX4 at 0600 UTC of 22 and by A8ZE4 at 1200 UTC of 24. The lowest central pressure of 1007.2 hPa was reported by the ship 2FUB2 (0.4/58.7), Buoy 23494 (8.4/73.0) and Amini Divi at 1200 UTC of 22.

2.5.3 Weather and damage caused

No damage was reported due to this system.

2.5.4 Satellite and RADAR observations

The maximum intensity of the system according to Dvorak's classification was T 2.0 from 0000 of 23rd Dec. to 1200 UTC of 24th Dec. The cyclogenesis technique based on Oceansat-2 winds did not show any sign of formation of cyclone.

1.7. REVIEW OF THE TROPICAL CYCLONE OPERATIONAL PLAN

The Panel reviewed and updated the List of Important Addresses and Telephone Numbers Connected with Tropical Cyclone Warning in the Panel Countries which was re-established in 2012 by Mr. B. K. Bandayopadhyay, rapporteur of Tropical Cyclone

Operational Plan (TCOP) with the support of the PTC Secretariat and in response to the recommendation of the Panel made at the 39th session in Myanmar.

The Panel also requested Mr Bandayopadhyay to update other sections of the TCOP to produce its 2013 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 2013.

The Panel noted 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. In view of better preparedness in those vulnerable countries, the Panel requested the WMO Secretariat to elucidate the best communication means for the advisories from the RSMC.

1.8. PTC SECRETARIAT

The Panel expressed its congratulation to Mr Arif Mahmood who has been designated as the new Secretary to the PTC, and Mr. Imran Akram of PMD as the new Meteorologist of PTC Secretariat, since 1 January 2013. It also appreciated the services being rendered by them.

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 (**Appendix II**). Keeping in view some savings, PTC Secretariat requested the Panel for provision of US$ 4,000 for its expenses during the year 2013-2014.

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 2012, including the WMO Voluntary Cooperation Programme (VCP), Trust Fund arrangements, Emergency Assistance Fund scheme and Technical Cooperation among Developing Countries (TCDC) activities, and expressed its appreciation to WMO, ESCAP and collaborating partners for providing assistance to Members of the Panel.

The Panel noted that, in 2012, Maldives made a cash contribution to the Voluntary Cooperation Fund (VCP(F)). An expert mission for training on MTSAT data utilization and feasibility investigations for the future projects of the Bangladesh Meteorological Department took place in January 2012. Two VCP projects were implemented in Pakistan for the restoration of Automatic Weather Stations (AWSs) and meteorological observation stations damaged by the severe flooding in July-August 2010.

The Panel was informed that, within the Trust Fund project "Installation of a Doppler radar system in Sri Lanka", two factory training courses, Factory Acceptance Tests, a Coordination Meeting were conducted at the premises of the supplier of the radar. The installation of the radar and relevant training are scheduled for the first half of 2013.

The first national Sub-Project of the Coastal Inundation Forecasting Demonstration Project (CIFDP) in Bangladesh (CIFDP-B) was supported by USAID-OFDA as part of a 7 million USD multi-regional and multi-annual DRR programme. The CIFDP progress is building collaborative arrangements for CIFDP-B implementation with the Panel on Tropical Cyclones, the regional Severe Weather Forecasting Demonstration Project (SWFDP) and Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES).

The Panel took note of the presentation made by the Secretary of Typhoon Committee, Mr Olavo Rasquinho, on the status 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, in which he reported the efforts that are being done for organizing the first workshop on Standard Operating Procedures, which will be held in Bangkok, tentatively on 8 and 9 May 2013.

The Committee was informed that experts from organizations and institutions involved in projects under the same Trust Fund, such as the Asia-Pacific Broadcasting Union (ABU), the Asian Disaster Preparedness Centre (ADPC), the Regional Integrated Multi- Hazard Early Warning System for Africa and Asia (RIMES) and other organizations, namely the Asian Disaster Reduction Centre (ADRC) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO have been invited to share their experience on Early Warning System with the participants of the workshop on SSOP.

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.

Noting the recent extension of its activities through the establishment of WGM, WGH and WGDRR, the Panel fully recognized the necessity of some actions to take to increase the revenue of the Trust Fund. While it recognized that PTCTF is based on the voluntary contributions, the Panel was of the view that the current amount of 2,000 USD of the Members' annual contribution is not sufficient to carry out the Panel's annual operating plans to attain the objectives of the Coordinated Technical Plan.

After due consideration, the Panel decided to request the WMO Secretariat to arrange an official letter addressed to the governments of the Panel Member countries requesting to increase their annual contributions to PTCTF from the current 2,000 to 3,000 USD. Considering that such a letter would be sensitive to the governments, the

Panel asked the WMO Secretariat to circulate a draft of the letter through the Members prior to the transmission.

The Panel also considered the increase of its membership not only for PTCTF but also 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.

The Panel endorsed the use of the Trust Fund for 2013 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)
⑥ Support for organizing a PTC Integrated Workshop (US$45,000)

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:

- Alternative sites for HF Radar location along the shores of the Gulf of Thailand and the Andaman Sea

  - Dr. Wattana Kanbua (Thailand)
- Operational progress and challenges in TC monitoring, forecast and warning in China

  - Mr Chuanhai Qian (China)
- Ocean Observations for Cyclone Studies

  - Mr. B. K. Bandyopadhyay (IMD)
- A Brief Introduction to SCMREX -- a WMO RDP

  - Dr Yihong Duan (China)
- Decision Support System for Flood Warning System By using Artificial Neural Network in Thailand

  - Dr. Wattana Kanbua (Thailand)

- Regional features associated with failure of the southwest monsoon rainfall in Sri Lanka- 2012

- Mr Sunil Kariyawasam (Sri Lanka)

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- FIRST SESSION

The Panel noted with appreciation that the Typhoon Committee proposed to hold a joint session with PTC in 2014. The Panel basically agreed to the proposal. The representative of Bangladesh proposed to host the 41st session of PTC in Bangladesh in 2014 subject to its government's approval. The dates of the 41st session will be determined based on the consultation between Bangladesh, WMO, ESCAP, Chairman of the Panel and Secretary of PTC. In this regard, the possible joint session with the 46th session of ESCAP/WMO Typhoon Committee should be taken into consideration.

1.12. ADOPTION OF THE REPORT

The report of the fortieth session was adopted at 11:00 hours on Friday, 1st March 2013.

1.13. CLOSURE OF THE SESSION

The Panel expressed its sincere appreciation to the Government of Sri Lanka, the host country, for providing the excellent facilities, the venue, other arrangements and its warm hospitality. The Panel also expressed its deep appreciation to Mr Sunil H Kariyawasam, Chairperson of the Panel, Mr Worapat Tiewthanom Vice-chairperson of the Panel as well as Mr Ali Shareef, 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 Sunil H Kariyawasam for their hard work in organizing the session, assistance provided to the participants and producing a session report.

The fortieth session of the Panel was concluded at 12:00 hours on Friday, 1st March 2013.

CHAPTER–II

(A) CYCLONIC ACTIVITIES OVER NORTH INDIAN OCEAN DURING 2012

The north Indian Ocean and adjoining land surface witnessed the formation of five cyclonic disturbances during the year, 2012. Out of five disturbances three formed over the Bay of Bengal and two over the Arabian Sea. Out of the three cyclonic disturbances over the Bay of Bengal, one intensified up to the stage of cyclonic storm, NILAM, two up to the stage of deep depression. Out of two cyclonic disturbances formed over the Arabian Sea, one intensified up to the stage of cyclonic storm, MURJAN and one up to the stage of deep depression. Tracks of the cyclonic disturbances formed over the north Indian Ocean during the period are shown in Fig 2.1.

The salient features of the cyclonic disturbances during 2012 were as follows:

- The number of total cyclonic disturbances (depression and above) during the year was significantly below normal, as only five cyclonic disturbances formed during 2012 against the normal of 13. Similarly only two cyclones formed during the year against the normal of about 5.
- Both the cyclones made landfall .While cyclonic storm 'MURJAN' made landfall over Somalia, the cyclonic storm, 'NILAM' made landfall over Tamilnadu and Puducherry coast.
- The track of the cyclonic storm, 'NILAM' was rare in nature as it initially moved westwards, came closer to Sri Lanka coast and remained stationary for about a day and then moved north-northwestwards to cross Tamilnadu coast.
- There were no cyclonic disturbances formed over the north Indian Ocean and adjoining land surface during monsoon season (June-Sep.) against the normal of 7 cyclonic disturbances. There were no cyclonic disturbances over the north Indian Ocean during the pre-monsoon season (March-May), 2012 also.

(a) Cyclonic Storm, "MURJAN" over the Arabian Sea (23-26 October, 2012.)

The cyclonic storm, Murjan formed over the south Arabian Sea in association with an active inter tropical convergence zone during last week of October 2012. It was the first cyclone over the north Indian Ocean during this year. Moving west southwestwards, it crossed Somalia coast between 1700 and 1800 UTC of 25th October near lat. 9.8^{0}N and 50.8^{0}E. The salient features of this cyclone are given below.

(i) It was the first cyclonic storm to hit Somalia after 1994. A severe cyclonic storm crossed Somalia coast on 19th November 1994 near lat. 8.0^{0}N.

(ii) The cyclonic storm, Murjan caused heavy rainfall and strong wind over Somalia and Ethiopia.

(iii) Though predicted by most of the NWP models to gradually weaken before landfall, it maintained its cyclonic storm intensity till landfall.

(b) Cyclonic Storm, 'NILAM' over the Bay of Bengal (28 October- 1 November)

A cyclonic storm, NILAM crossed Tamilnadu coast near Mahabalipuram (south of Chennai) in the evening of 31st October 2012 with a sustained maximum wind speed of 70-80 knots. The salient features of this storm are as follows.

(i) It followed a unique track with many rapid changes in direction of movement. It initially moved westwards, remained practically stationary for quite some time near Sri Lanka coast and then moved north-northwestwards till landfall. It moved west-northwestwards initially over land up to south interior Karnataka and then moved northwest and northwards. The remnant low pressure area moved northeastwards

(ii) It moved very fast on the day of landfall, i.e. 31^{st} October 2012.

(iii) Over the land surface, the cloud mass was significantly sheared to the northeast of system centre during its dissipation stage leading to heavy rainfall activity over entire Andhra Pradesh and adjoining Odisha

(iv) Maximum rainfall occurred over southwest sector of the system centre at the time of landfall and heavy to very heavy rainfall extended up to 300 km.

The statistics of the cyclonic disturbances formed during 2012 are given in Table 2.1.

Table 2.1: Cyclonic disturbances formed over north Indian Ocean and adjoining land areas during 2012

1.	Deep Depression over Bay of Bengal, 10-11 October 2012
2.	Cyclonic storm 'MURJAN' over Arabian Sea, 23-26 October 2012
3.	Cyclonic storm 'NILAM' over Bay of Bengal, 28 October- 1 November 2012
4.	Deep Depression over Bay of Bengal, 17-19 November 2012
5	Deep Depression over Arabian Sea, 22-25 December 2012

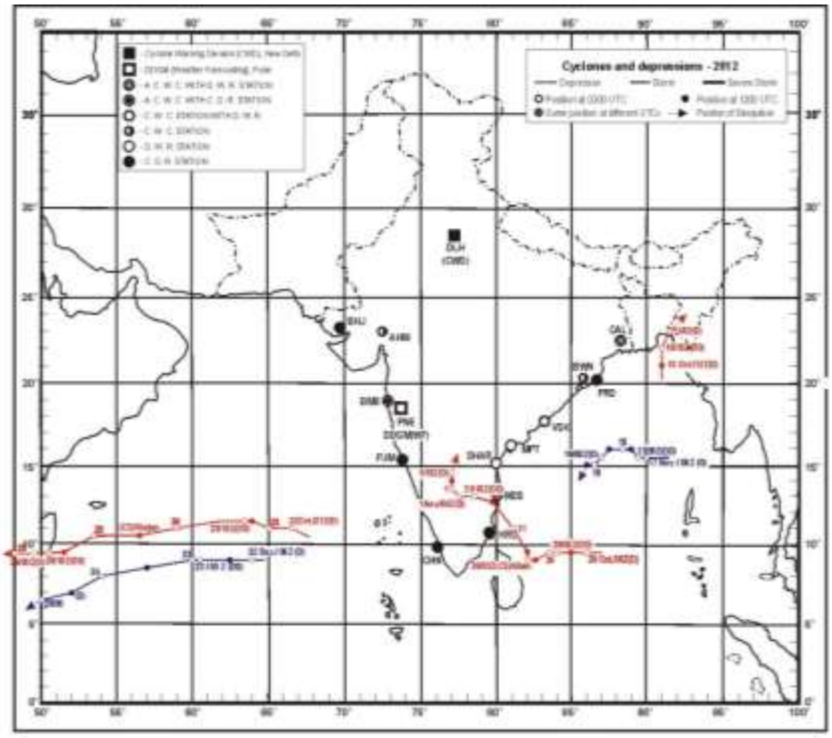


Fig. 2.1 Tracks of the cyclonic disturbances formed over the north Indian Ocean during the year, 2012

(B) Description of cyclonic storms during 2012

2.1. Cyclonic Storm 'MURJAN' over Arabian Sea (23-26 October, 2012)

2.1.1 Introduction

The cyclonic storm, Murjan formed over the south Arabian Sea in association with an active inter tropical convergence zone during last week of October 2012. It was the first cyclone over the north Indian Ocean during this year. Moving west-southwestwards, it crossed Somalia coast between 1700 and 1800 UTC of 25th October near lat. 9.8^{0}N and long. 50.8^{0}E. The salient features of this cyclone are given below.

(i) It was the first cyclonic storm to hit Somalia after 1994. A severe cyclonic storm crossed Somalia coast on 19th November 1994 near lat. 8.0^{0}N.

(ii) The cyclonic storm, Murjan caused heavy rainfall and strong wind over Somalia and Ethiopia.

(iii) Though predicted by most of the numerical weather prediction (NWP) models to gradually weaken before landfall, it maintained its cyclonic storm intensity till landfall.

2.1.2 Monitoring and prediction

The cyclonic storm was mainly monitored by satellite. The half hourly INSAT/ Kalpana imageries and products were used for monitoring of cyclonic storm. Various NWP and dynamical-statistical models including IMD's global and meso-scale models were utilized to predict the track and intensity of the storm. Recently installed Tropical Cyclone Module in the digitized forecasting system of IMD was utilized for analysis and comparison of various NWP models and decision making process.

The brief history of the genesis, intensification and movement of this storm are discussed below.

2.1.3 Genesis

Under the influence of an active inter-tropical convergence zone, a low pressure area formed over the south Bay of Bengal on 18th October 2012. It moved westwards across Sri Lanka and Palk straight and emerged into southeast Arabian Sea, near Lakshadweep area on 21st October. It continued to move westwards and intensified into a depression over southeast and adjoining southwest and central Arabian Sea near lat. 11.0^{0}N and long. 65.0^{0}E, about 800 km west of Amini Divi at 0300 UTC of 23rd October, 2012.

During the genesis phase, the Madden Julian Oscillation index lay in phase 2 with amplitude greater than one. The phase 2 is favourable for genesis and intensification of the cyclonic disturbances over the Arabian Sea. The sea surface temperature (SST) over the southeast Arabian Sea and adjoining areas was 29-30 degree C. The Ocean heat content (OHC) was 80-100 KJ/cm^2 over the area. The lower level convergence and relative vorticity as well as upper level divergence increased from 22nd to 23rd October. The upper tropospheric ridge lay along 15^{0}N and hence provided the upper level divergence for intensification. The vertical wind shear between 200 and 850 hPa levels was moderate (10-20 knots) around the system centre on 22nd and 23rd October.

2.1.4 Intensification and movement

As the depression lay to the south of the upper tropospheric ridge and the steering winds at middle and upper tropospheric levels were east-southeasterly, the system initially moved west- northwestwards and intensified into a deep depression at 1500 UTC of 23rd October under the favourable conditions as mentioned in previous section.

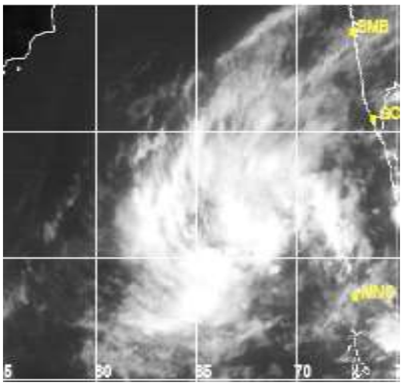
Thereafter, the convection increased in the southwest sector with increase in low level relative vorticity in this sector and the steering ridge to the north weakened leading to west-southwestward movement. However, the low to moderate wind shear continued to prevail over the region. Under these circumstances, the deep depression moved west-southwestwards and intensified into a cyclonic storm, 'MURJAN' at 1200 UTC of 24th October. It then continued to move west-southwestwards and crossed Somalia coast near lat. 9.5^0 N between 1700 and 1800 hrs. UTC of 25th October, 2012. Though the Ocean Heat Content was less over the southwest Arabian Sea (50-80 KJ/cm^2) and further less near Somalia coast (less than 50 KJ/cm^2) as well as SST (26-28^{0}C), the system could maintain its intensity of cyclonic storm till landfall, basically due to low to moderate vertical wind shear.

Table 2.1.1 Best track positions and other parameters of the Cyclone 'MURJAN' over the Arabian Sea during 23-26 October, 2012

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
23-10-2012	0300	11.0/65.0	1.5	1004	25	3	D
	1200	11.5/64.0	1.5	1003	25	3	D
	1500	11.5/63.5	2.0	1002	30	4	DD
24-10-2012	0300	11.0/59.0	2.0	1002	30	5	DD
	1200	10.5/56.5	2.5	1000	35	6	CS
	1800	10.5/55.5	2.5	1000	40	8	CS
25-10-2012	0000	10.5/54.0	2.5	1000	35	6	CS
	0600	10.0/53.0	2.5	1000	35	6	CS
	1200	9.5/51.5	2.5	1000	35	6	CS
	The system crossed Somalia coast near 9.5^{0}N and 50.8^{0}E between 1700-1800 UTC						
	1800	9.5/50.5	-	1001	30	4	DD
26-10-2012	0000	9.5/49.5	-	1002	25	3	D
	0300	9.5/48.5	-	1002	25	3	D
	1200	Weakened into a well marked low pressure area over Somalia and neighbourhood					

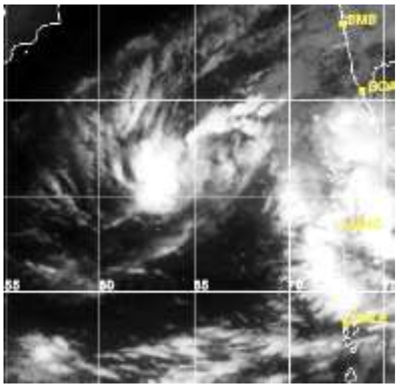
After the landfall, due to land interaction, it weakened into a deep depression over coastal Somalia at 1800 UTC of 25th October. It further weakened into a depression over Somalia in the morning of 26th October while moving west-southwest wards. It further weakened into a well marked low pressure area over Somalia and neighbourhood in the evening of 26th October, 2012. The track of the system is shown in Fig. 2.2. The best track parameters are shown in Table 2.1.1.

Formation of Vortex



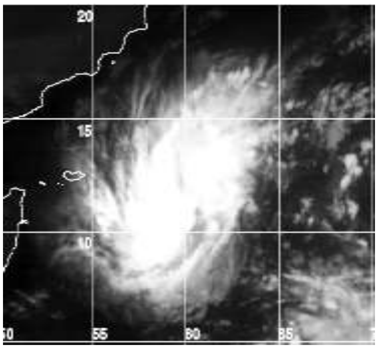
1200 UTC, 22.11.2012

Intensification of the system (T1.5)



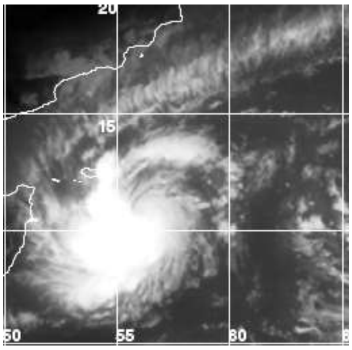
2100 UTC, 22.10.2012

Further intensification (T2.0)



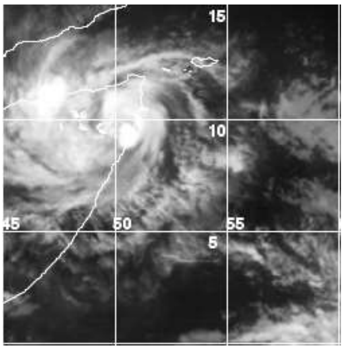
1700 UTC, 23.10.2012

Intensification into cyclonic storm (T2.5)



1200 UTC, 24.10.2012

Landfall



1600 UTC, 25.10.2012

Fig. 2.1.1. Typical satellite imagery of cyclone, Murjan at different stages of its evolution and landfall.

2.1.5 Satellite observations

According to satellite observations, a low level circulation developed over Tamilnadu and neighbourhood on 19th October at 0600UTC. It moved westward and intensified into a vortex with intensity T1.0 and centreed near 10.0^0N/68.0^0E on 22nd

October at 1200 UTC. It moved in west-northwestwards and intensified with intensity T1.5 at 2100 UTC of 22nd. The centre of the system at this time was located near 10.8^{0}N/66.5^{0}E. The system intensified further with intensity T2.0 at 1700 UTC of 23rd with centre at 11.3^{0}N/63.3^{0}E. and into a cyclonic storm with intensity T2.5 with centre at 10.5^{0}N/56.5^{0}E. The system was of shear pattern till 0600UTC UTC of 23rd. Then it changed into curved band pattern till landfall of the system. The typical satellite imagery of cyclone, Murjan at various stages are shown in Fig. 2.1.1.

Satellite based position and intensity are shown in Table 2.1.2.

Table 2.1.2 Position & Intensity of cyclone, Murjan according to satellite observations of IMD

DATE	TIME(UTC)	LAT(^{0}N)	LONG (^{0}E)	INTENSITY T No.	CTT (^{0}C)
21.10.12	0000	-	-	LLC	-
22.10.12	1200	10.0	68.0	1.0	-73
	1500	10.5	67.5	1.0	-76
	1700	10.8	67.5	1.0	-76
	2100	10.8	66.5	1.5	-71
23.10.12	0000	10.8	66.0	1.5	-62
	0300	11.2	65.0	1.5	-65
	0600	11.2	65.0	1.5	-76
	0900	11.3	64.5	1.5	-84
	1200	11.3	64.0	1.5	-80
	1500	11.3	63.5	1.5	-80
	1700	11.3	63.3	2.0	-84
	2100	11.3	62.5	2.0	-76
24.10.12	0000	11.3	62.0	2.0	-69
	0600	10.5	58.0	2.0	-79
	0900	10.5	57.4	2.0	-81
	1200	10.5	56.5	2.5	-78
	1500	10.5	56.0	2.5	-75
	1700	10.5	55.4	2.5	-77
	2100	10.5	54.2	2.5	-68
25.10.12	0000	10.5	53.8	2.5	-75
	0300	10.5	53.5	2.5	-79
	0600	10.1	52.9	2.5	-77
	0900	9.7	52.7	2.5	-75
	1200	9.5	51.6	2.5	-72
	1500	9.5	51.0	2.5	-69
	1600	9.5	50.6	Overland	-69

2.1.6 Realised Weather

As estimated by satellite imagery and products, the sustained maximum wind of 65-75 kmph prevailed along and off Somalia coast at the time of landfall. There was no meteorological observation available from Somalia.

There were reports of large scale flooding in Bosaso city in Somalia. The storm brought strong winds and heavy but beneficial rains within the areas of Bari region (Bossasso, Ishkushban and Bandar Beyla) according to Somalia Water and Land Information Management, as reported in the media.

2.1.7 NWP Guidance

The genesis, track and intensity of the cyclone, Murjan was reasonably captured by most of the models. The NWP model analyses of pressure and wind at 850, 500 and 200 hPa levels based on 0000 UTC of 23-26 October 2012 for ECMWF, UKMO and IMD GFS models are shown in Fig. 2.1.2- 2.1.4.

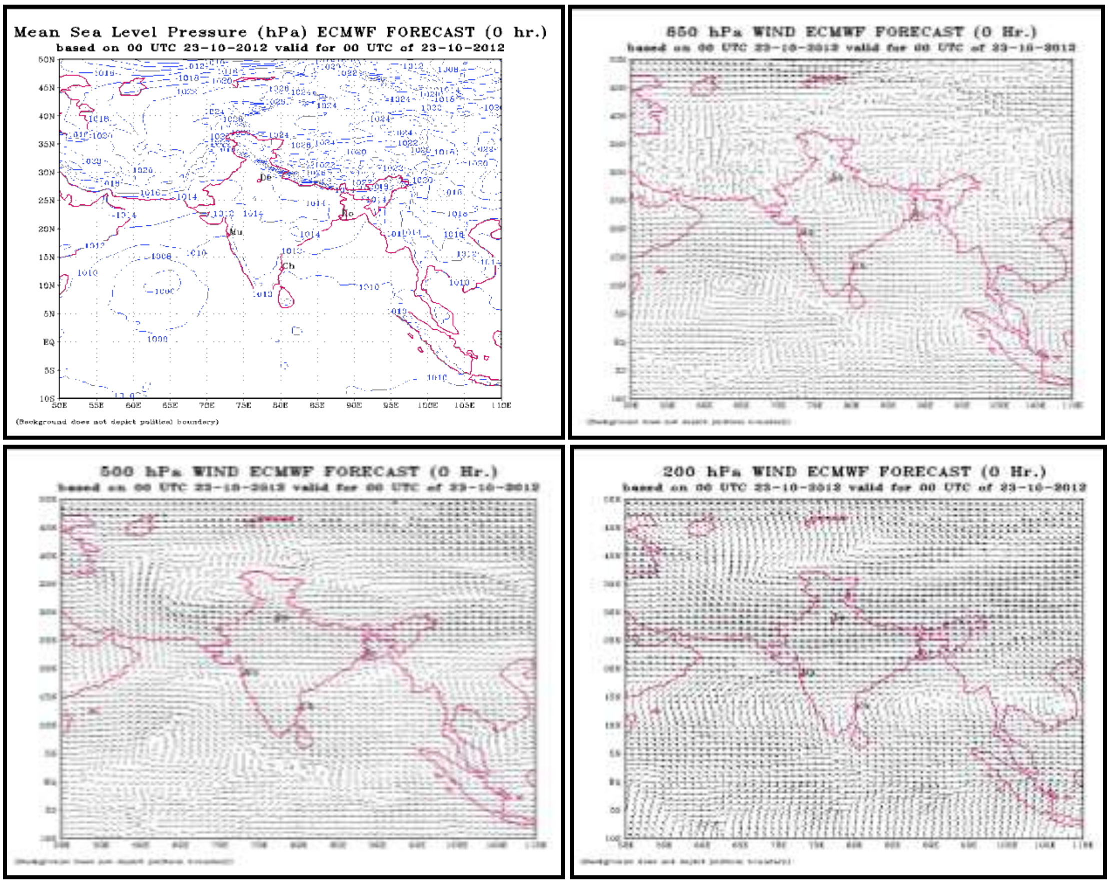


Fig. 2.1.2 (a) ECMWF analysis of MSLP and winds at 850, 500 and 200 hPa levels based on 0000 UTC of 23rd October, 2012

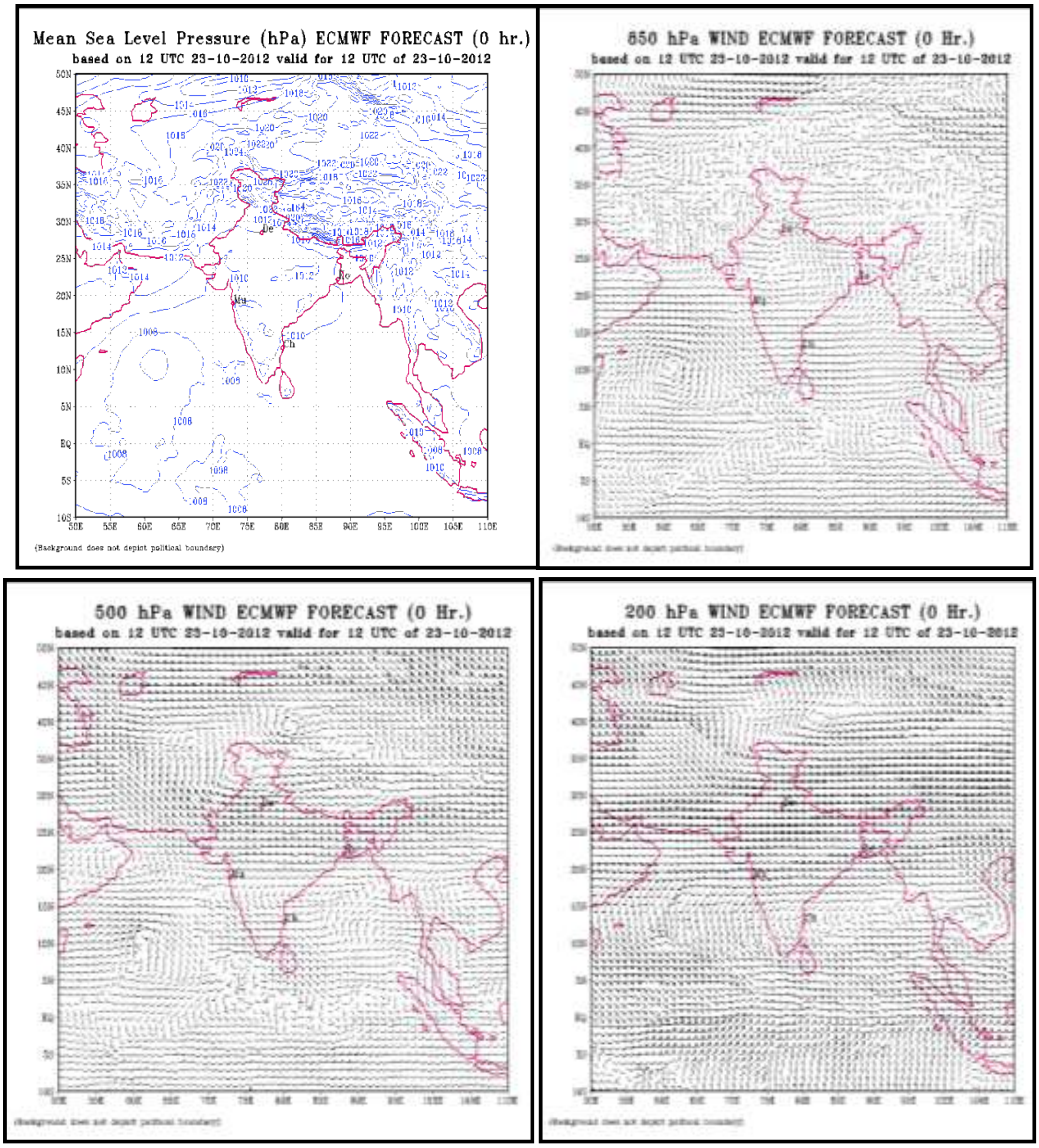


Fig. 2.1.2(b) ECMWF analysis of MSLP and winds at 850, 500 and 200 hPa levels based on 1200 UTC of 23rd October, 2012

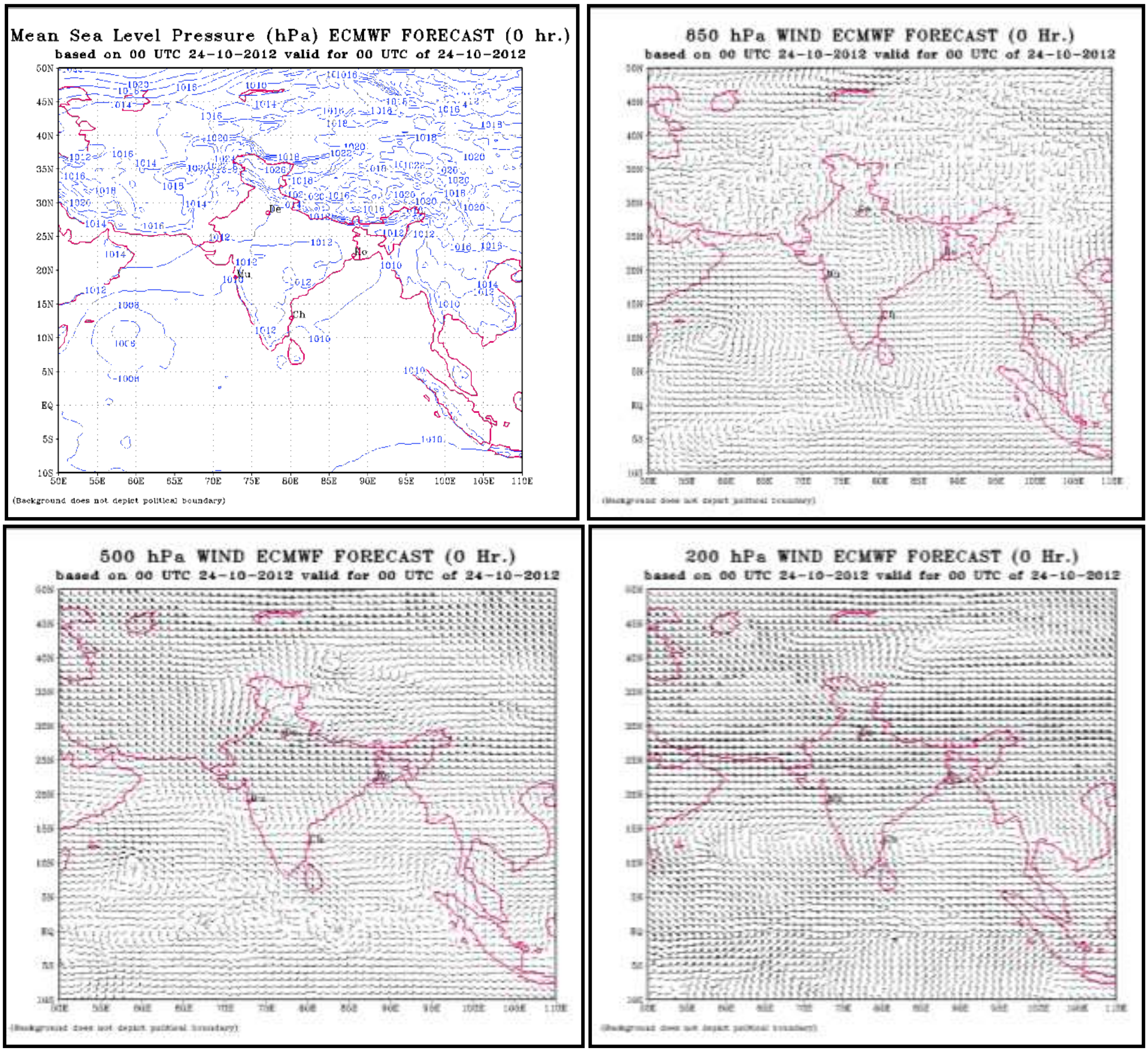


Fig. 2.1.2(c) ECMWF analysis of MSLP and winds at 850, 500 and 200 hPa levels based on 0000 UTC of 24th October, 2012

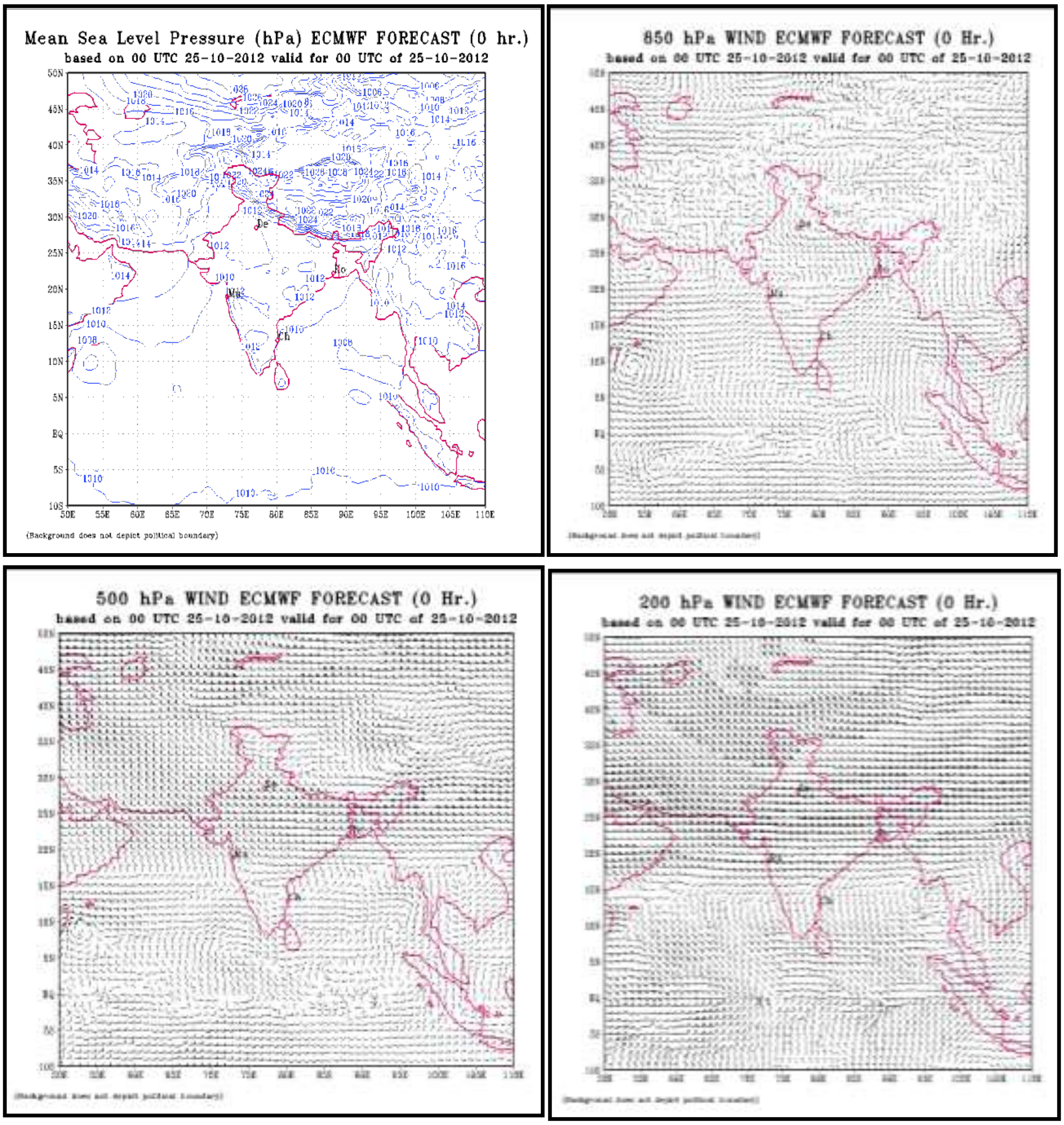


Fig. 2.1.2(e) ECMWF analysis of MSLP and winds at 850, 500 and 200 hPa levels based on 0000 UTC of 25th October, 2012

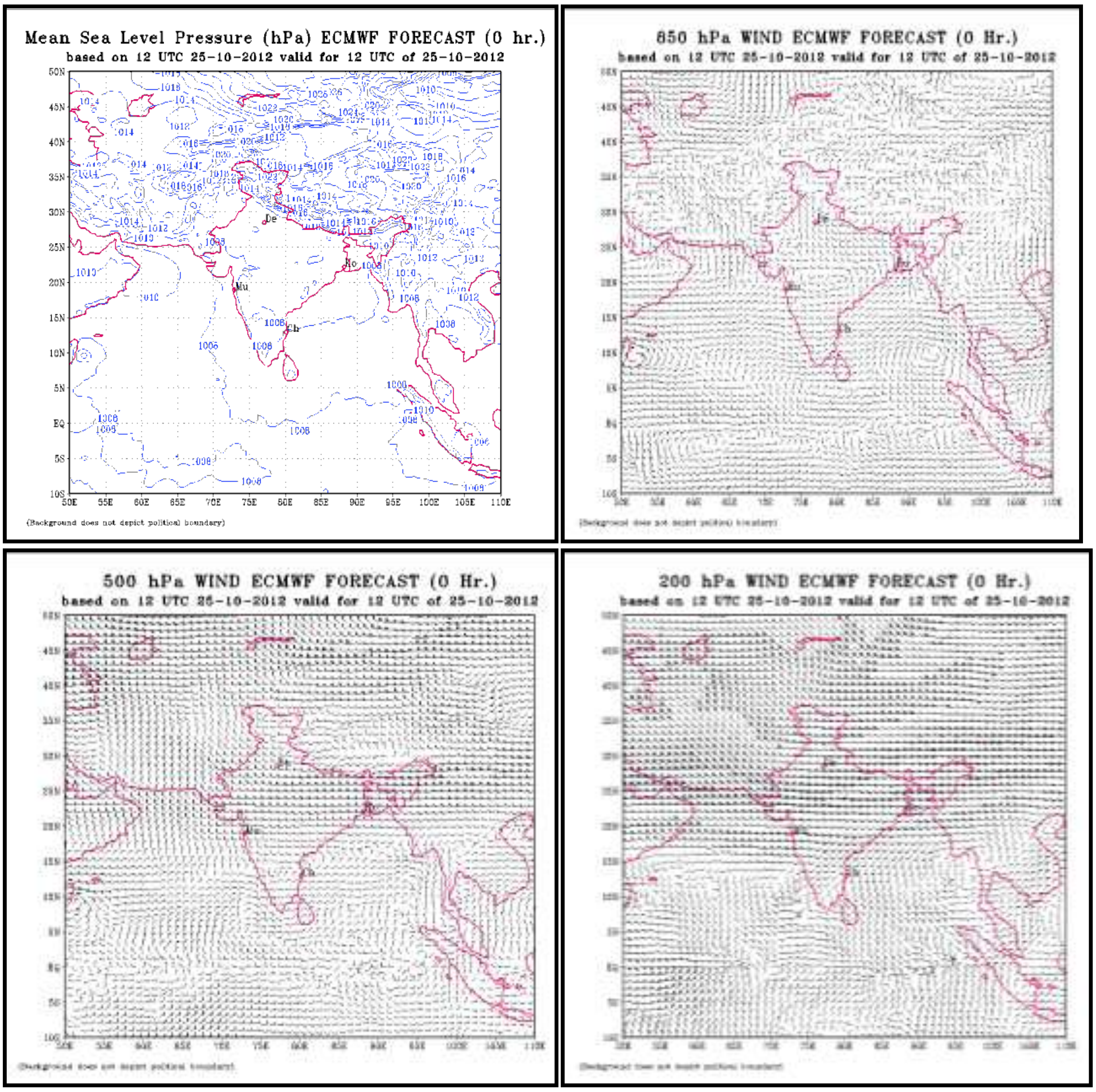


Fig. 2.1.2(f) ECMWF analysis of MSLP and winds at 850, 500 and 200 hPa levels based on 1200 UTC of 25th October, 2012

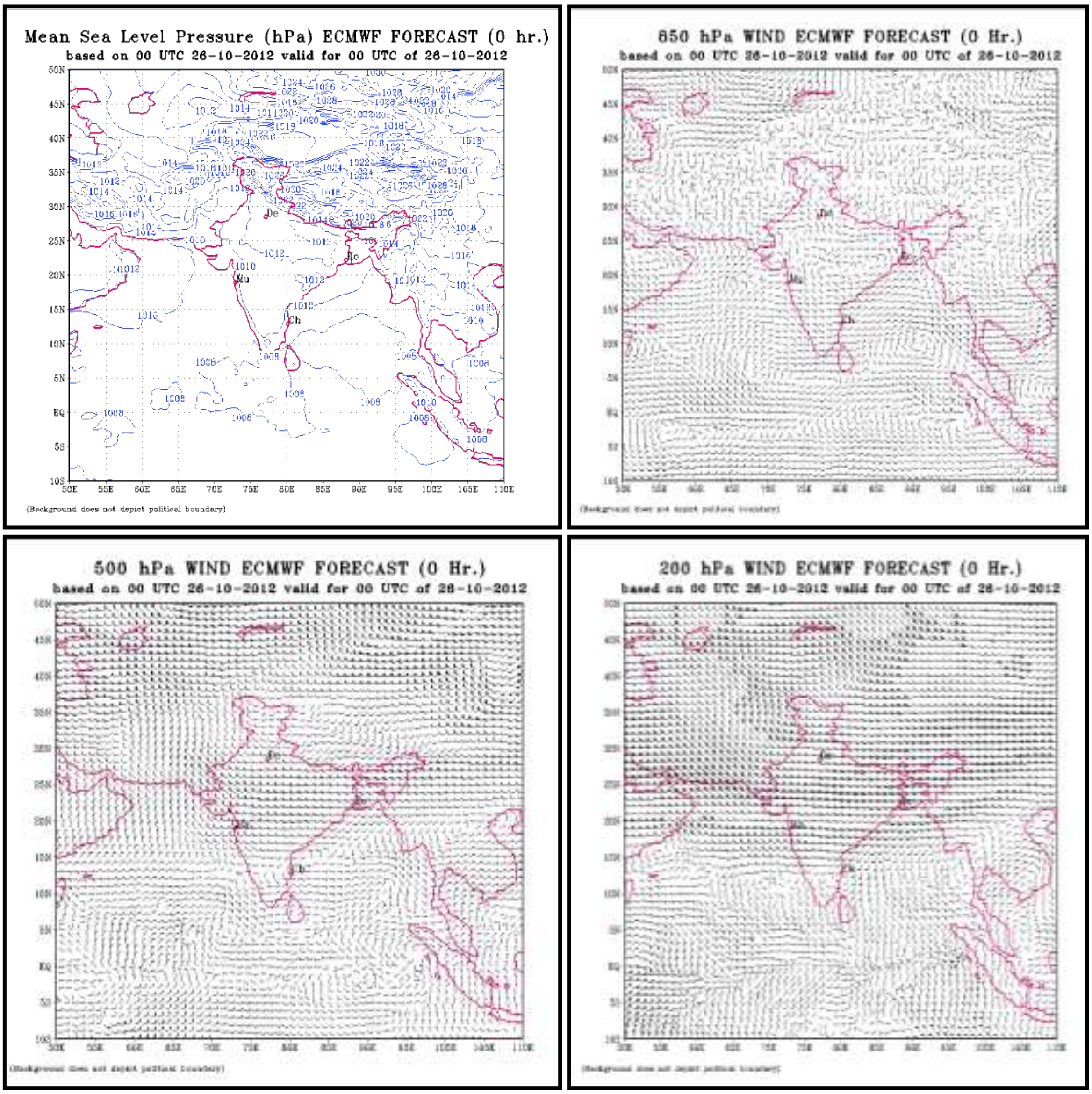


Fig. 2.1.2(g) ECMWF analysis OF MSLP and winds at 850, 500 and 200 hPa levels based on 0000 UTC of 26th October, 2012

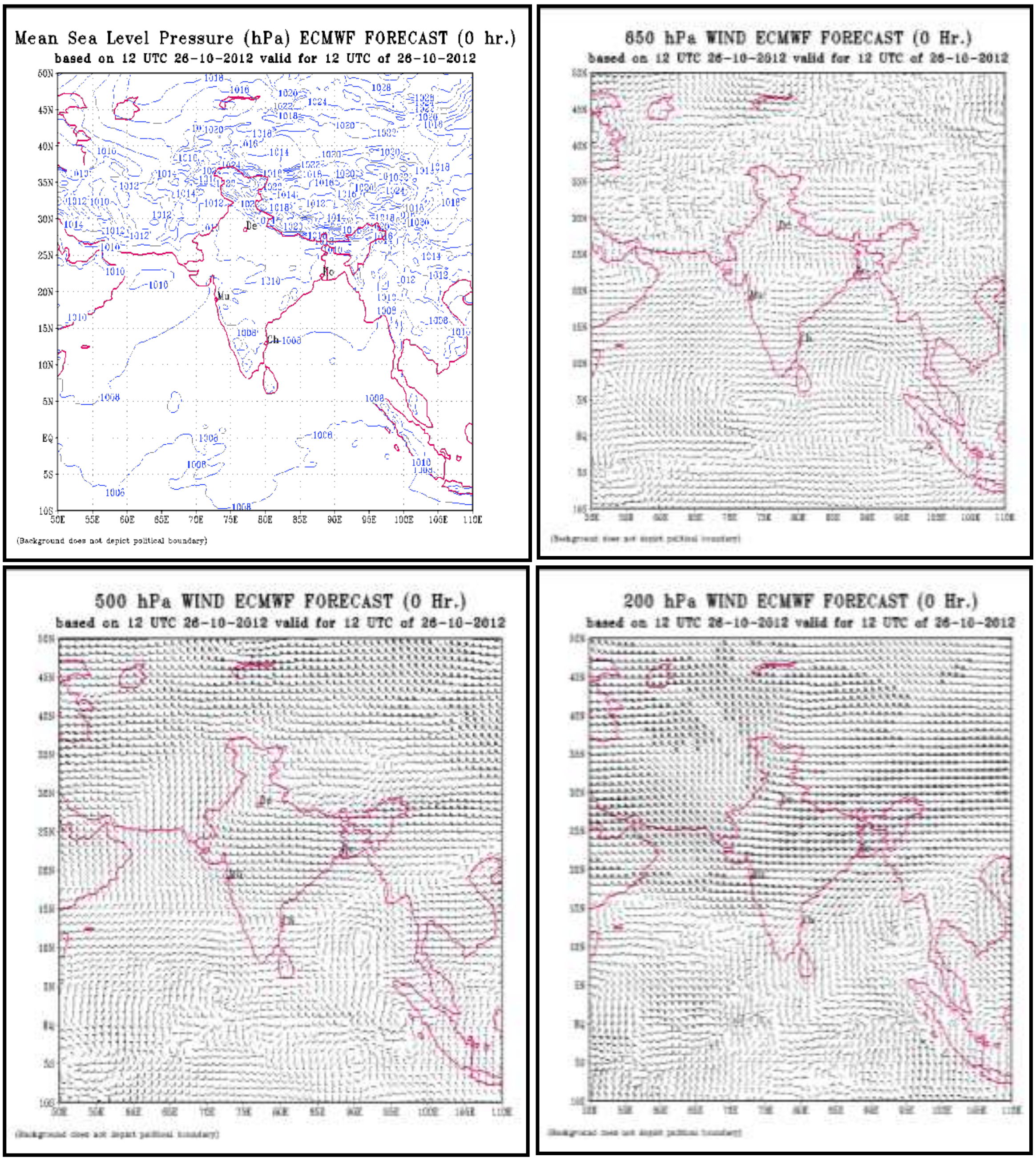


Fig. 2.1.2(h). ECMWF analysis of MSLP and Winds at 850, 500 and 200 hPa levels based on 1200 UTC of 26th October, 2012

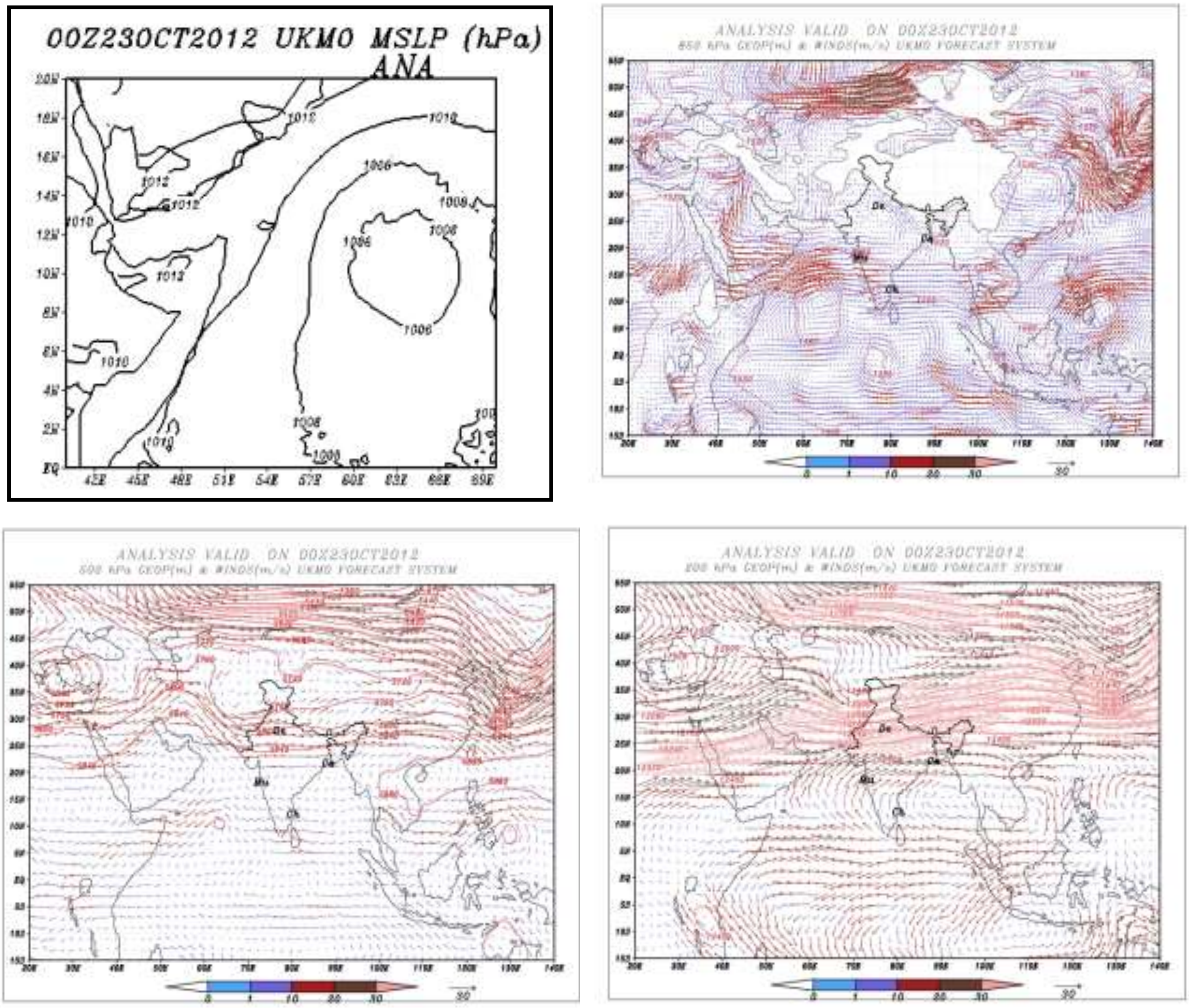


Fig. 2.1.3(a) UKMO analysis MSLP and wind at 850,500 & 200 hPa based on 0000 UTC of 23 October, 2012

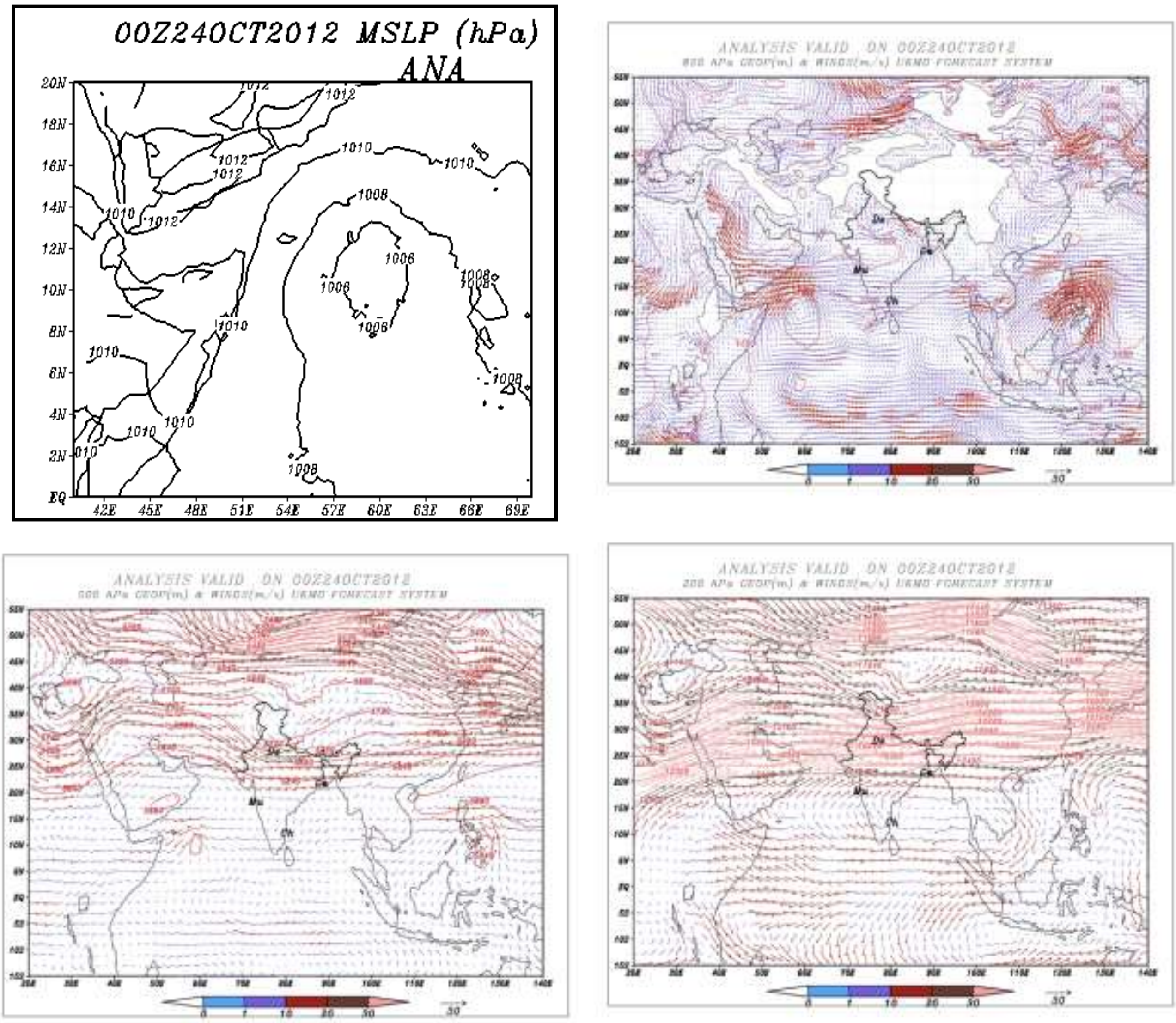


Fig. 2.1.3(b) UKMO analysis of MSLP and wind at 850, 500 & 200 hPa levels based on 0000 UTC of 24 October, 2012

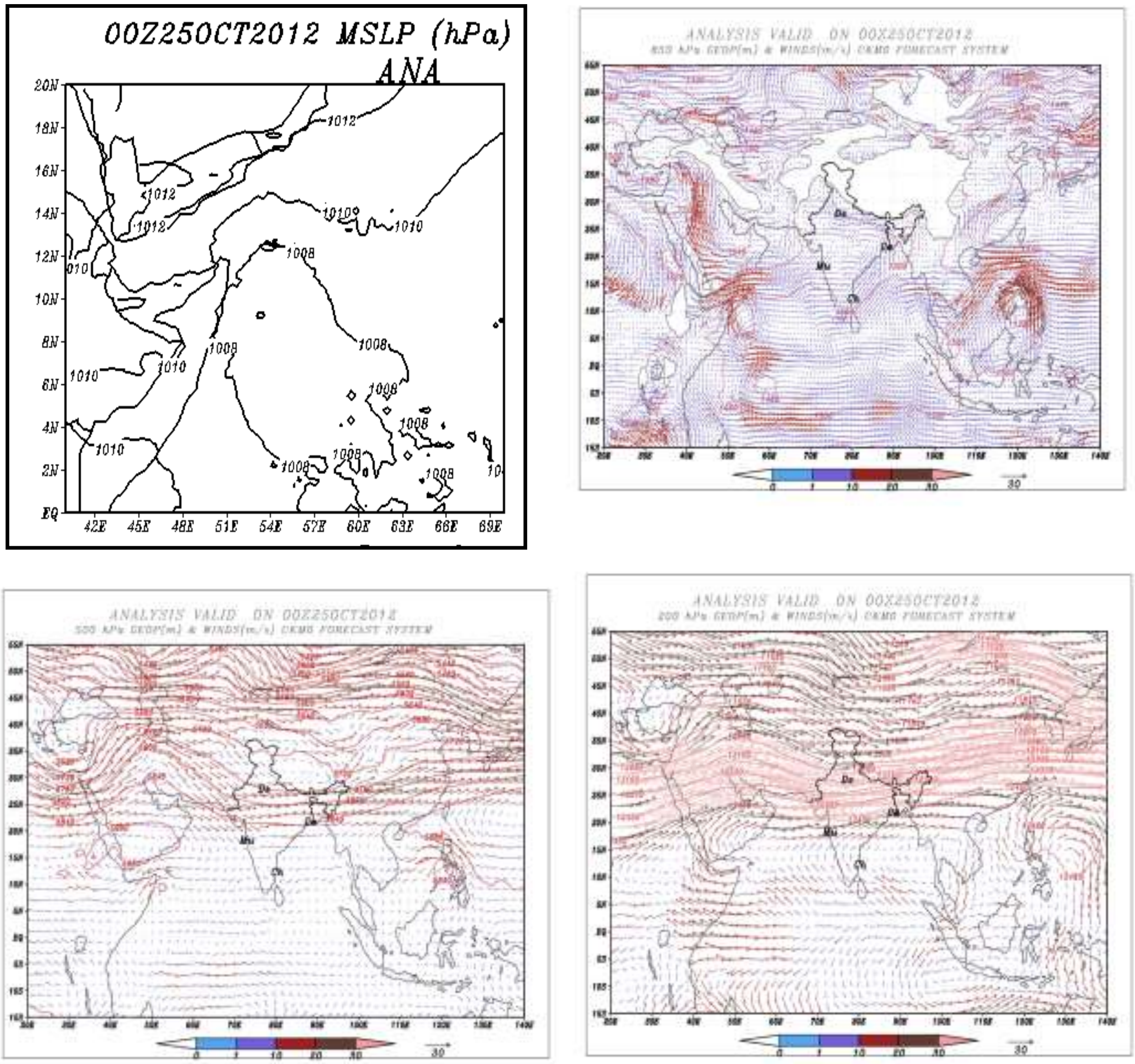


Fig. 2.1.3(c) UKMO analysis of MSLP and wind at 850, 500 & 200 hPa. levels based on 0000 UTC of 25 October, 2012

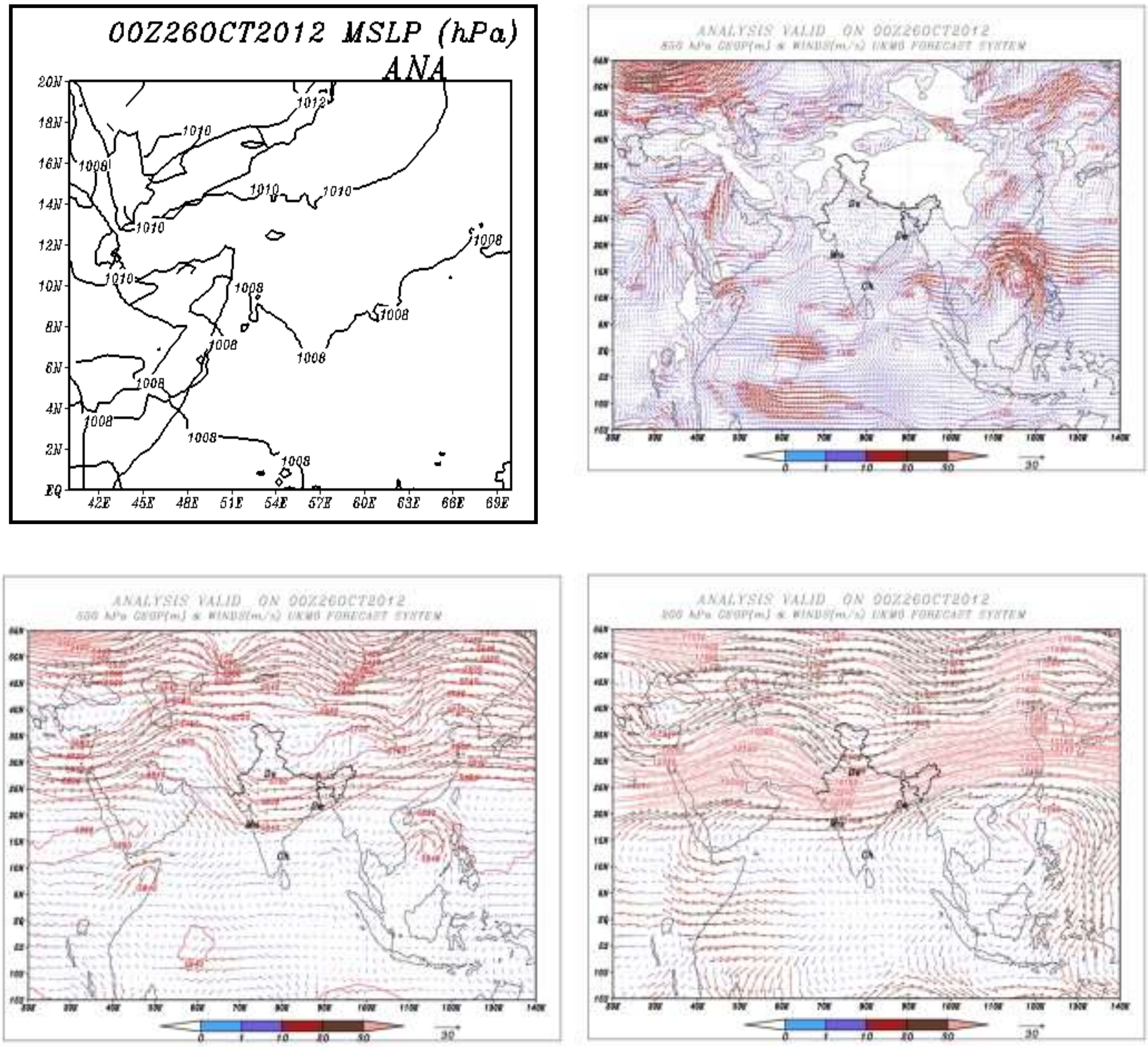


Fig. 2.1.3(d) UKMO analysis of MSLP and wind at 850, 500 & 200 hPa. levels based on 0000 UTC of 26 October, 2012

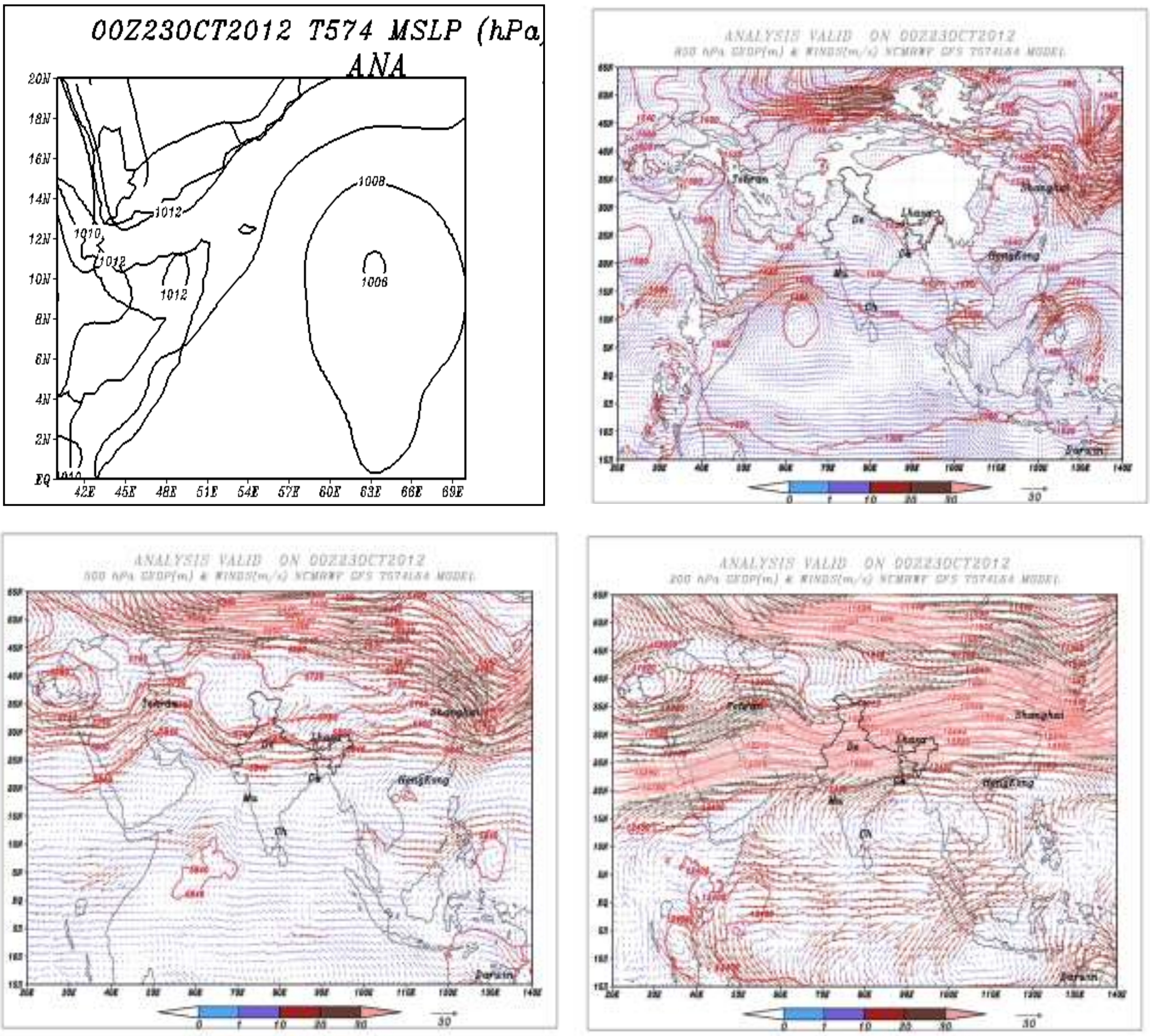


Fig. 2.1.4(a) NCMRWF GFS 574L64 analysis of MSLP and wind at 850, 500 & 200 hPa based on 0000 UTC of 23 October, 2012

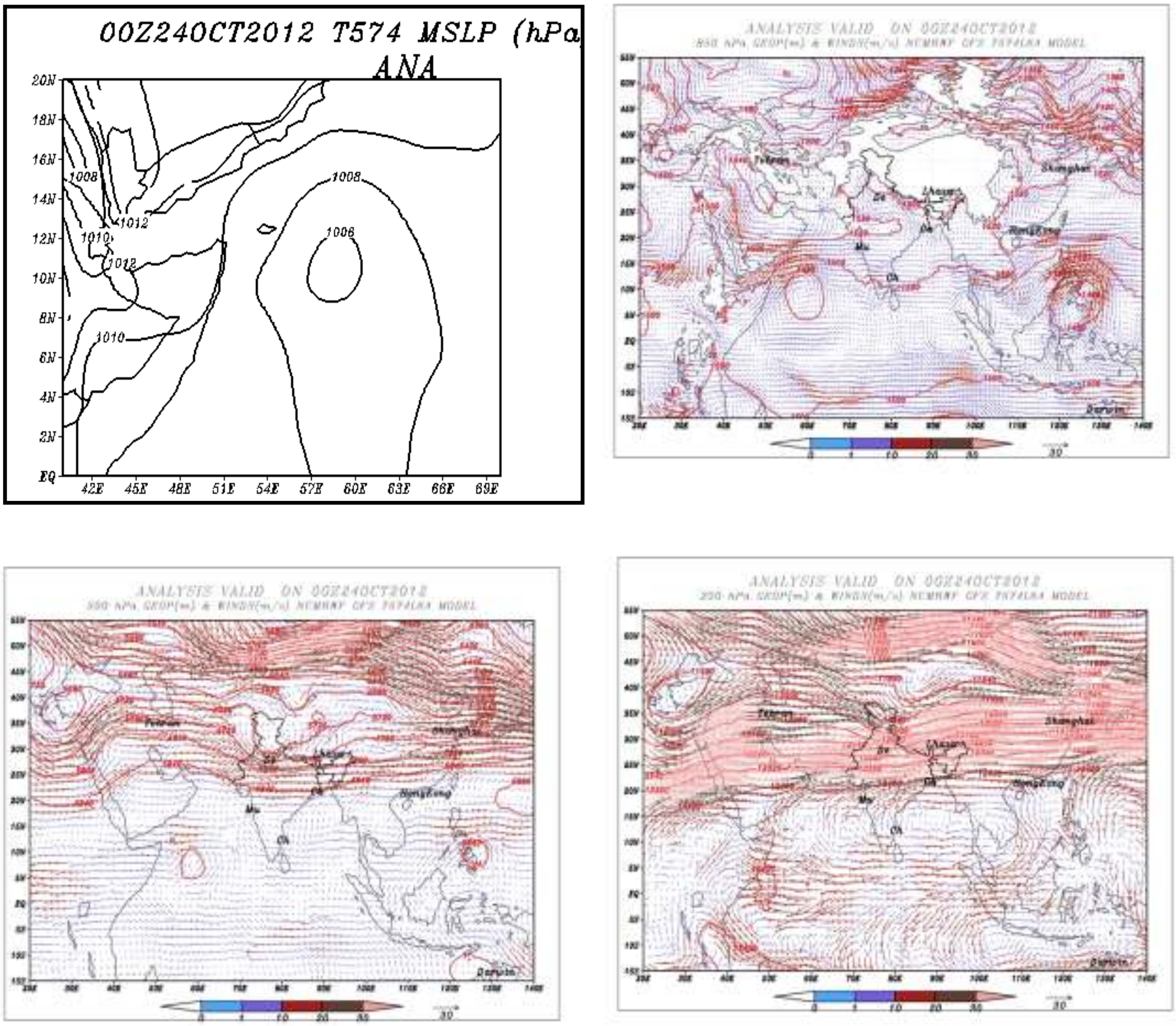


Fig. 2.1.4(b) NCMRWF GFS 574L64 analysis of MSLP and wind at 850,500 & 200 hPa levels based on 0000 UTC of 24 October, 2012

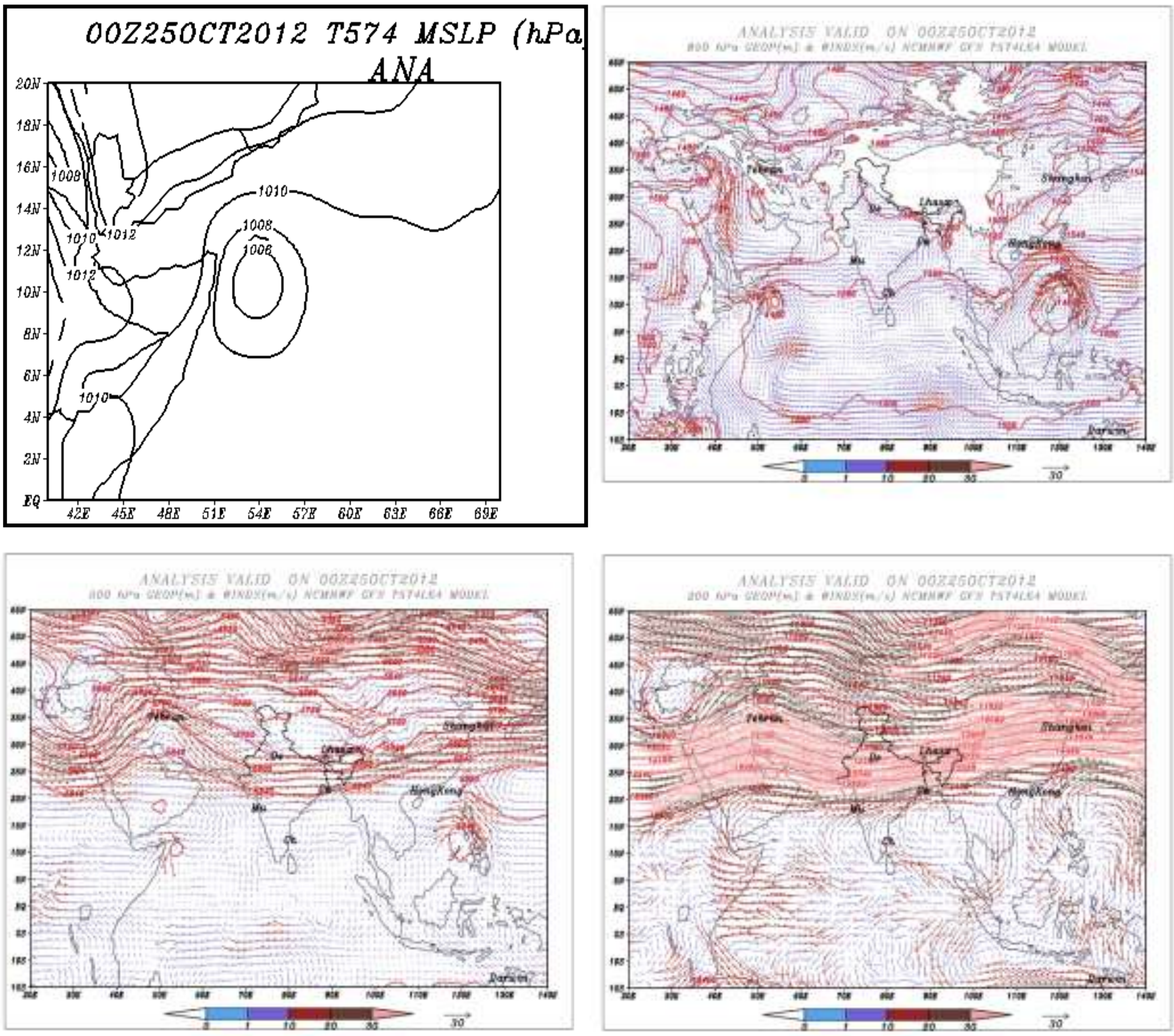


Fig. 2.1.4(c) NCMRWF GFS 574L64 analysis of MSLP and wind at 850, 500 & 200 hPa levels based on 0000 UTC of 25 October, 2012

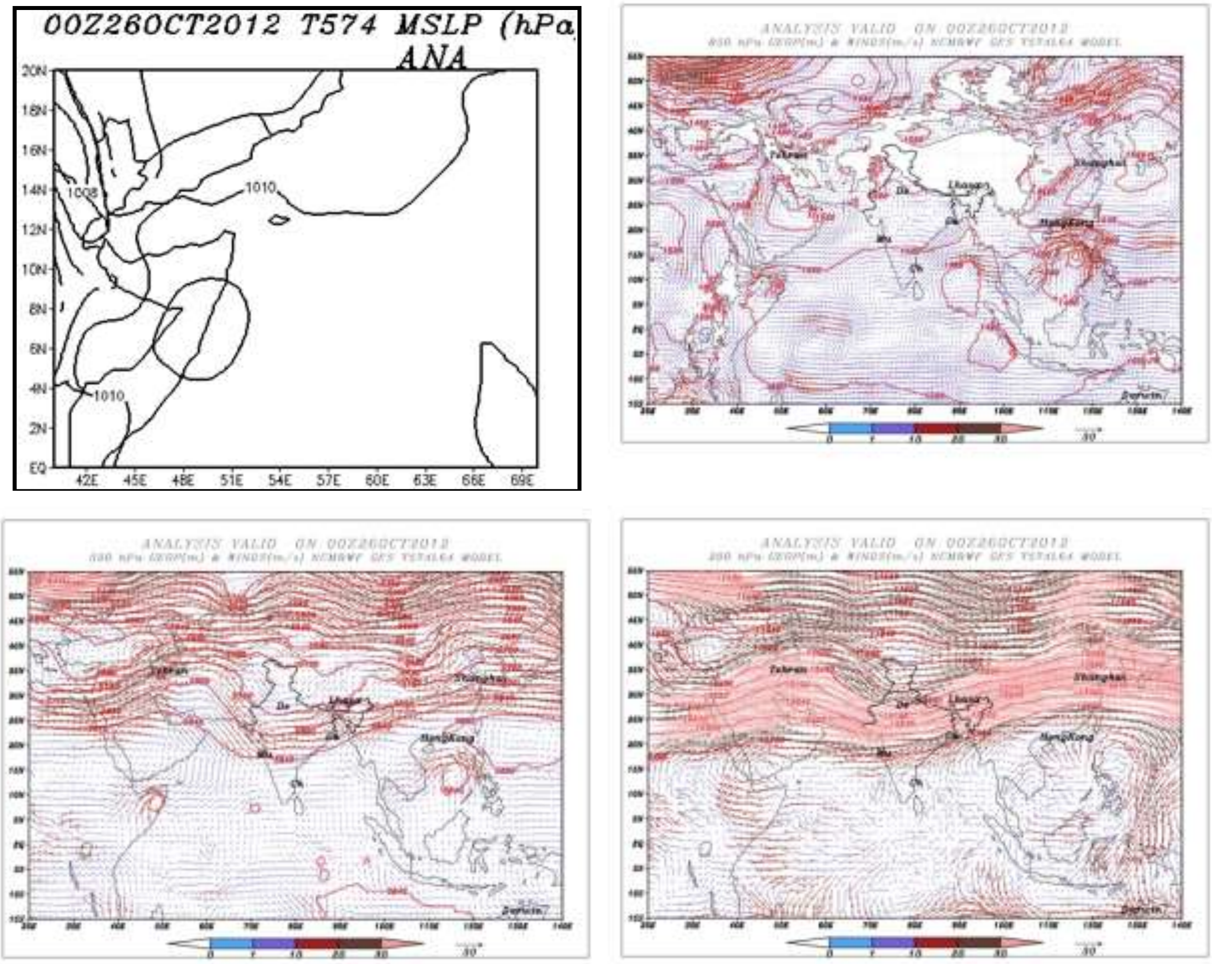


Fig. 2.1.4(d) NCMRWF GFS 574L64 analysis of MSLP and wind at 850, 500 & 200 hPa levels based on 0000 UTC of 26 October, 2012

2.2 Cyclonic Storm, NILAM over Bay of Bengal (28 October- 01 November, 2012)

2.2.1 Introduction

A cyclonic storm, NILAM crossed Tamilnadu coast near Mahabalipuram (south of Chennai) in the evening of 31st October 2012 with a sustained maximum wind speed of about 80 kmph. The salient features of this storm are as follows.

(i) It followed a unique track with many rapid changes in direction of movement. It initially moved westwards, remained practically stationary for quite some time near Sri Lanka coast and then moved north-northwestwards till landfall. It moved west-northwestwards initially over land up to south interior Karnataka and then moved northwest and northwards. The remnant low pressure area moved northeastwards across Andhra Pradesh

(ii) It moved very fast on the day of landfall, i.e. 31st October 2012.

(iii) Maximum rainfall occurred over southwest sector of the system centre and heavy to very heavy rainfall extended up to 300 km during landfall.

(iv) Over the land surface, the cloud mass was significantly sheared to the northeast of system centre during its dissipation stage leading to heavy rainfall activity over entire Andhra Pradesh and adjoining Odisha.

2.2.2 Monitoring and Prediction

The cyclonic storm, NILAM was monitored mainly with satellite supported by meteorological buoys and coastal and island observations. It was monitored by Doppler Weather Radar (DWR), Chennai and Sriharikota from the night of 29th October, when the cyclonic storm was at about 500 km southeast of Chennai. While coastal surface observations were taken on hourly basis, the half hourly INSAT/ Kalpana imageries and every 10 minutes DWR imageries and products were used for monitoring of cyclonic storm.

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

2.2.3 Genesis:

A remnant cyclonic circulation from the south China Sea entered into south Andaman Sea on 25th October 2012 across the Gulf of Thailand. It gradually moved westwards and concentrated into a low pressure area in the early hours of 27th October. It further concentrated into a depression over southeast and adjoining southwest Bay of Bengal at 0600 UTC of 28th October 2012 near latitude 9.5^{0}N and longitude 86.0^{0}E.

Considering the satellite observations, the convection increased gradually in terms of its height and organization from 27th to 28th October. The lowest cloud top temperature (CTT) was about -70^{0}C at the time of formation of depression, i.e. at 0600 UTC of 28th October 2012.

Considering the environmental features, the sea surface temperature on the day of genesis was 29-30^{0}C over south Bay of Bengal and the Ocean thermal energy was about 50-80 KJ/cm^2 around the area of genesis. The Madden Julian Oscillation (MJO) index lay over phase 2, which is favourable for cyclogenesis. The upper tropospheric ridge at 200 hPa level ran along 13^{0}N and provided required upper level divergence for intensification of the system. The lower level convergence and the vorticity also increased from 27th to 28th October. The vertical wind shear between 200 and 850 hPa levels was low to moderate (10-20 knots) over the region, which was also favourable for genesis and intensification.

The best track parameters of the system is shown in Table 2.2.1. The best track is shown in Fig.2.1.

Table 2.2.1 Best track positions and other parameters of the Cyclone, 'Nilam' over the Bay of Bengal during 28 October-01 November, 2012

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
28-10-2012	0600	9.5/86.0	1.5	1004	25	3	D
	1200	9.5/85.0	1.5	1003	25	3	D
	1800	9.5/84.5	1.5	1002	25	4	D
29-10-2012	0000	9.5/84.0	2.0	1000	30	4	DD
	0300	9.5/83.5	2.0	1000	30	4	DD
	0600	9.0/83.0	2.0	1000	30	4	DD
	1200	9.0/82.5	2.0	1000	30	5	DD
	1800	9.0/82.0	2.0	1000	30	5	DD
30-10-2012	0000	9.0/82.0	2.0	999	30	5	DD
	0300	9.0/82.0	2.5	998	35	6	CS
	0600	9.0/82.0	2.5	996	35	6	CS
	0900	9.5/82.0	2.5	996	35	6	CS
	1200	9.5/82.0	2.5	994	40	8	CS
	1500	9.5/82.0	2.5	994	40	8	CS
	1800	10.0/82.0	2.5	992	40	8	CS
	2100	10.0/82.0	2.5	990	40	10	CS
31-10-2012	0000	10.5.81.5	3.0	988	45	12	CS
	0300	11.0/81.0	3.0	987	45	13	CS

	0600	11.5/81.0	3.0	987	45	13	CS
	0900	12.2/80.5	3.0	987	45	13	CS
	The system crossed north Tamilnadu coast near Mahabalipuram, south of Chennai (near latitude 12.5^{0}N and longitude 80.2^{0}E) between 1030 and 1130 UTC						
	1200	12.7/79.8		991	35	8	CS
	1500	13.0/79.5		996	35	7	CS
	1800	13.0/78.5		998	30	5	DD
01-11-2012	0000	13.0/77.5		999	20	4	D
	0300	13.5/77.0		1002	20	3	D
	0600	13.5/77.0		1002	20	3	D
	1200	14.0/77.0		1002	20	3	D
	1800	14.5/77.0		1004	20	3	D
02-11-2012	0000	Weakened into a well marked low pressure area over Rayalaseema and neighbourhood					

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

2.2.4 Intensification and movement

In association with favourable environmental conditions like low to moderate wind shear, increase in convergence and vorticity in lower levels, increase in upper level divergence and its location to the south of upper tropospheric steering ridge, the depression moved the depression continued to move westwards and intensified into a deep depression and lay centred at 0000 UTC of 29th over southwest Bay of Bengal near Lat. 9.5^{0}N/Long. 84.0^{0}E, about 550 km southeast of Chennai. Continuing the westward movement, it lay centred at 0300 UTC over southwest Bay of Bengal near Lat. 9.5^{0}N/Long. 83.5^{0}E, about 530 km southeast of Chennai and at 1200 UTC of 29th near Lat. 9.0^{0}N/ Long. 82.5^{0}E, about 500 km south-southeast of Chennai.

Similar favourable environmental conditions continued on 29th and 30th October. As a result, the deep depression further intensified into a cyclonic storm Nilam and lay centred at 0300 UTC of 30th over southwest Bay of Bengal near Lat. 9.0^{0}N / Long. 82.0^{0}E, about 500 km south–southeast of Chennai. Further, it moved northwards and lay centred at 1200 UTC of 30th near Lat. 9.5^{0}N/ Long. 82.0^{0}E, about 450 km south-southeast of Chennai. The cyclonic storm moved very slowly during 0000 UTC of 29th to 1200 UTC of 30th, remaining almost stationary.It then moved northwestwards and lay centred at 0300 UTC of 31st over southwest Bay of Bengal near Lat. 11.0^{0}N/Long. 81.0^{0}E, about 260 km south-southeast of Chennai. Moving north-northwestwards, it crossed north Tamil Nadu coast near Lat. 12.5^{0}N / Long. 80.2^{0}E, south of Chennai, near Mahabalipuram between 1030 and 1130 UTC of 31 and lay centred at 1200 UTC of 31st near Lat. 12.7^{0}N/Long. 79.8^{0}E, about 50 km south–southwest of Chennai. It moved west-northwestwards and weakened into a **deep depression** and lay centred over north Tamil Nadu and adjoining areas of Rayalaseema and interior Karnataka at 1800 UTC of 31st October, near Lat. 13.0^{0}N/ Long. 78.5^{0}E, about 180 km west–northwest of Chennai. It further moved west-northwestwards and weakened into a depression over Rayalaseema and adjoining areas of south interior Karnataka and lay centred at 0000 UTC of 1st November 2012 near Lat. 13.0^{0}N / Long. 77.5^{0}E, about 75 km, south of Anantpur and at 0300 UTC over south Interior Karnataka, near Lat. 13.5^{0}N / Long. 77.0^{0}E, close to Chitradurga. It moved further northward and lay centred at 1200 UTC near Lat. 14.0^{0}N/ Long. 77.0^{0}E and at 1800 UTC of 1st November 2012 near Lat. 14.5° N/ Long. 77.0° E. It further weakened into a well marked low pressure area over Rayalaseema and neighbourhood in the morning of 2nd November. It further weakened into a low Pressure area over Telangana and neighbourhood on 3rd and over North coastal Andhra Pradesh and neighbourhood on 4th November. It became less marked on 5th November.

According to survey report, “NILAM” crossed North Tamil Nadu coast, south of Kalpakkam and north of Koovathur, a small coastal village situated close to river Palar Estuary (landfall near 12^0 27’ and 80^0 09’) between 1040 and 1110 hrs UTC of 31st October 2012. The crucial observations showing the landfall point and time of cyclone, Nilam are shown in Fig.2.2.1

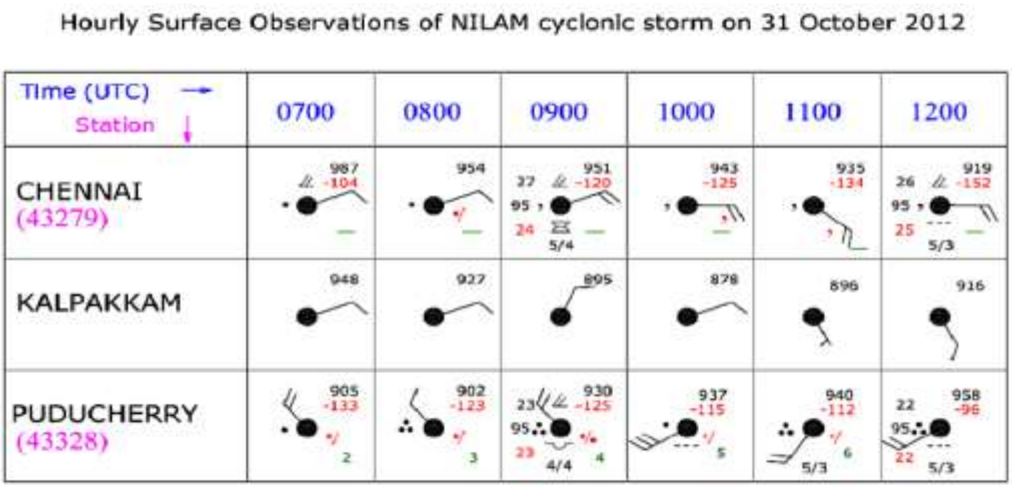


Fig.2.2.1 Hourly surface observations indicating landfall point and time of Nilam.

2.2.5 Lowest pressure and maximum wind

The lowest estimated central pressure (ECP) was 986 hPa *(post cyclone survey report)*. The lowest observed pressure was 987.8 hPa at 1040 UTC of 31st October at Kalpakkam (ISRO-AWS) located south of Chennai The maximum estimated mean wind speed was 45 knots. Maximum sustained wind speed of 74 kmph (40 kts) has been reported over Chennai (Nungambakkam) at 1110 UTC of 31. The high wind speed recorder (HWSR) at Karaikal reported maximum wind speed of westerly/37 kts on 31st October. The lowest pressure and maximum wind reported by a few coastal stations at the time of landfall are shown in Table 2.2.2 and 2.2.3

Table 2.2.2. Lowest mean sea level pressure reported by coastal observatories at the time of landfall

SN	STATION	SLP in hPa (Lowest)	TIME OF OCCURRENCE in IST	Location
1	CHENNAI NUNGAMBAKKAM	992.3	31.10.2012 / 1730hrs	North of Kalpakkam
2	*KALPAKKAM [ISRO-AWS]*	*987.8*	*31.10.2012 / 1610 hrs*	South of Chennai
3	PUDUCHERRY	989.4	31.10.2012/ 1415 hrs	South of Kalpakkam

Table 2.2.3 Maximum sustained surface wind reported by coastal observatories at the time of landfall

			speed
1	Chennai [Nungambakkam]	31/1640 hrs IST	NE/74 Kmph
2	Kalpakkam	31/1610 hrs IST	NE/50-55 Kmph
3	Puducherry	31/1630 hrs IST	SSW/62 Kmph Gusting to 70kmph
4	Mylam AWS [NW of Puducherry]	31/1400 hrs IST	SSW/38 Kmph

The pressure and wind observations from the Kalpakkam observatory which is nearest to landfall point are shown in Fig.2.2.2. It indicates clearly the landfall time of the cyclone

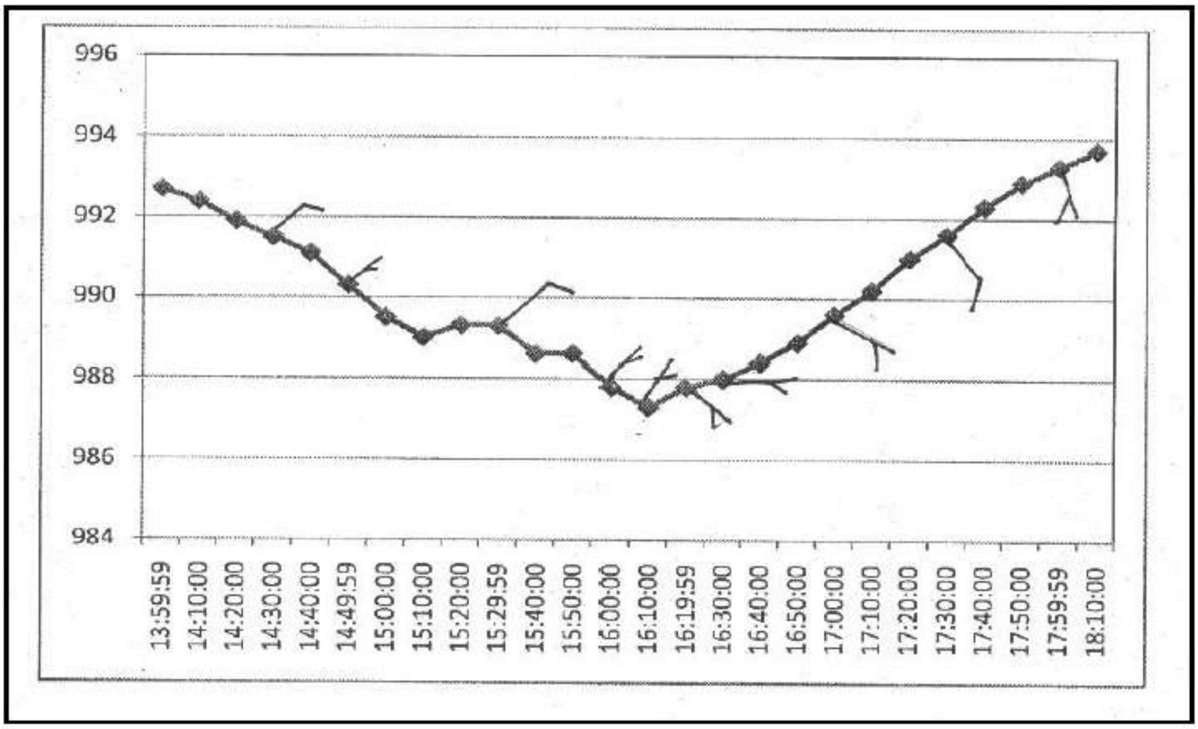


Fig. 2.2.2 Kalpakkam Pressure & Wind data on 31st Oct. (Time in hrs IST)

2.2.6 Satellite observations

The system was monitored mainly with satellite supported by meteorological buoys, coastal and island observations during genesis phase and its intensification into cyclonic storm on 29th October. Typical satellite imageries of the system are shown in Fig.2.2.3.

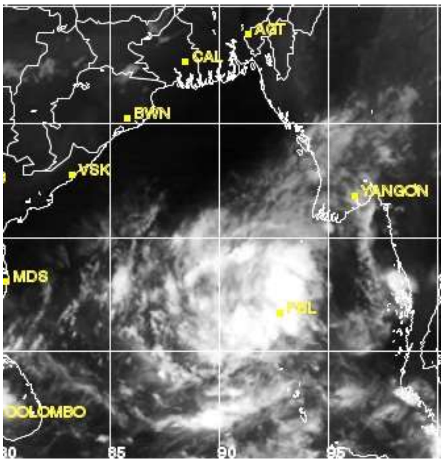
According to satellite observations, a low level circulation developed over south-east Bay of Bengal around 1200 UTC of 25th October 2012, which organized into vortex (T1.0) on next day (26th October 2012) at 1500 UTC centreed near 12.0^{0}N/91.5^{0}E. It intensified up to T3.0. The system was of curved band pattern till 1800 UTC of 30th October. Then it changed into central dense overcast (CDO) pattern. The satellite based T number and CTT are shown in Table 2.2.4.

Table 2.2.4. Satellite based observations of cyclone, Nilam

Date	Time (UTC)	Lat (E)	Long (E)	T. No.	C.T.T (C)
25.10.12	1200	-	-	LLC	-
26.10.12	1500	12.0	91.5	1.0	-75
	1700	12.0	91.5	1.0	-71
	2100	12.2	91.5	1.0	-81
27.10.12	0000	12.2	91.5	1.0	-80
	0300	12.0	91.0	1.0	-79
	0600	12.0	91.0	1.0	-79
	0900	12.0	90.5	1.0	-76
	1200	12.0	90.0	1.0	-79
	1500	12.0	90.0	1.0	-85
	1700	12.0	89.5	1.0	-87
	2100	11.5	88.5	1.0	-88
28.10.12	0000	11.0	87.5	1.0	-91
	0300	10.0	87.5	1.0	-87
	0600	9.5	87.0	1.5	-84
	0900	9.5	86.0	1.5	-83
	1200	9.5	85.0	1.5	-86
	1500	9.5	84.5	1.5	-83
	1700	9.5	84.5	1.5	-91
	2100	9.5	84.5	1.5	-91
29.10.12	0000	9.5	84.0	2.0	-86
	0300	9.3	83.3	2.0	-80
	0600	8.9	82.8	2.0	-81
	0900	8.7	82.5	2.0	-85
	1200	8.7	82.5	2.0	-84
	1500	8.7	82.2	2.0	-79

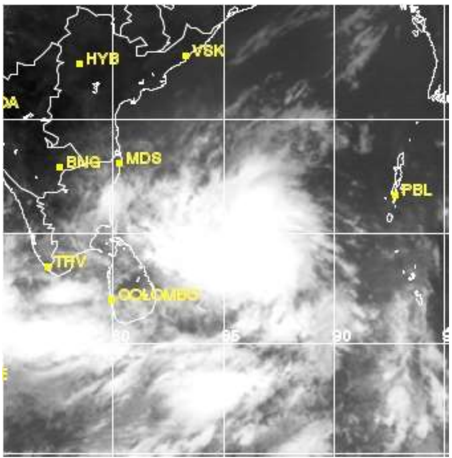
	1700	8.7	82.2	2.0	-83
	2300	8.7	82.0	2.0	-84
30.10.12	0000	8.7	82.0	2.0	-83
	0300	9.0	82.0	2.5	-85
	0600	9.2	82.0	2.5	-82
	0900	9.3	82.0	2.5	-85
	1200	9.5	81.9	2.5	-88
	1500	9.5	81.9	2.5	-89
	1700	9.6	81.8	2.5	-93
	2100	10.2	81.8	2.5	-94
31.10.12	0000	10.4	81.7	3.0	-96
	0300	10.5	81.1	3.0	-85
	0600	11.0	80.9	3.0	-84
	0900	11.7	80.3	3.0	-86
	1200	12.5	80.0	Overland	-85

Formation of vortex



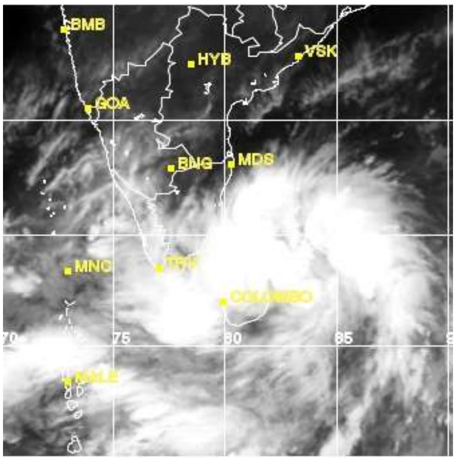
26.10.12, 1500 UTC (T1.0)

Intensified into Depression



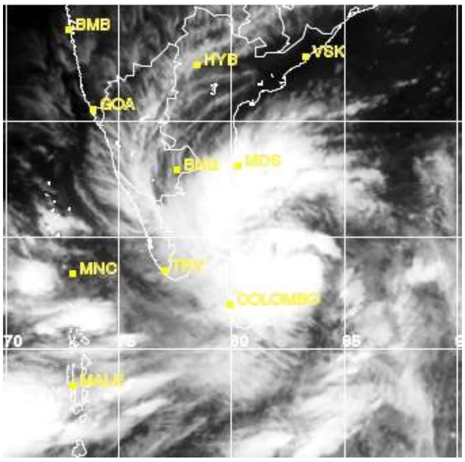
28.10.12, 0600UTC (T1.5)

Intensified into Deep Depression



29.10.12, 0000UTC (T2.0)

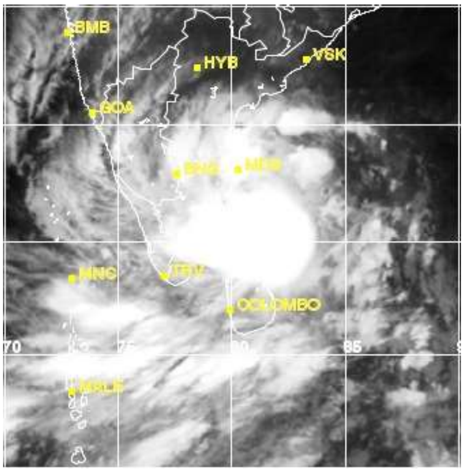
Intensified into Cyclonic storm



30.10.12, 0300UTC (T2.5)

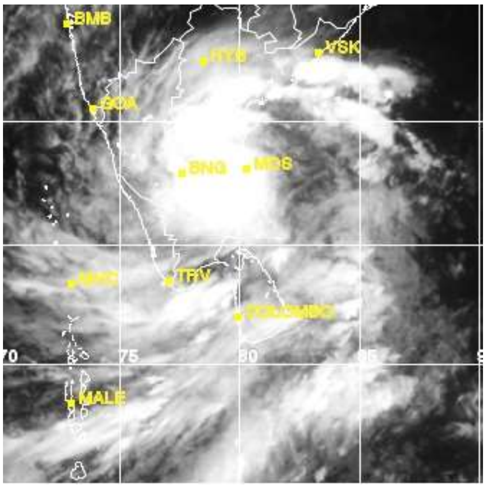
Fig. 2.2.3 IR Imageries based on 15 UTC of 26th Oct., 06 UTC of 28th Oct., 00 UTC of 29th Oct. and 03 UTC of 30th Oct.,2012 in association with different stages of cyclonic storm, NILAM over Bay of Bengal

Intensified further to T3.0



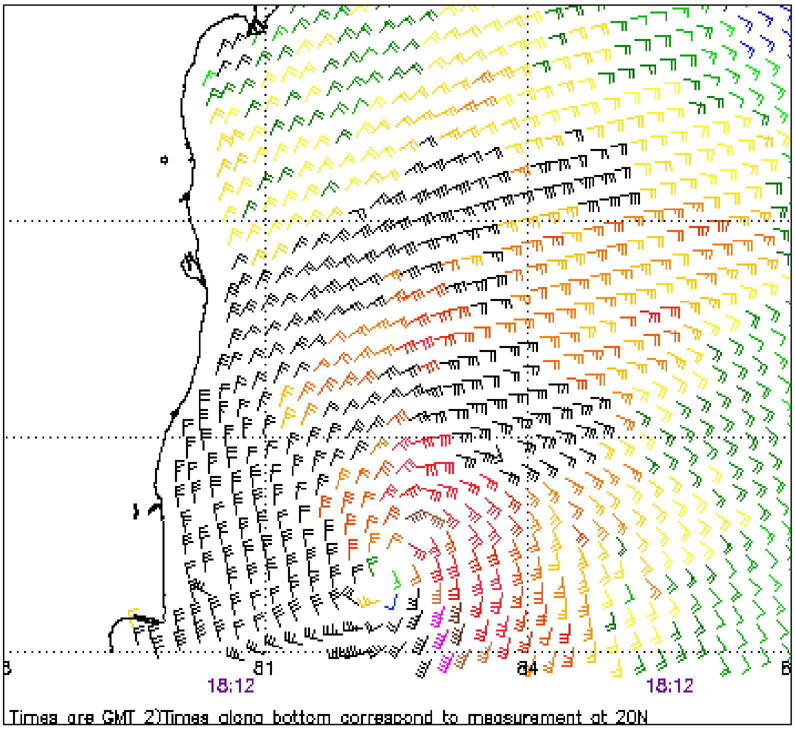
31.10.12, 0000UTC (T3.0)

Landfall of the system



31.10.2012, 1200 UTC (T3.0)

Oceansat-II based surface wind



30.10.12 1812UTC

Fig. 2.2.3(Contd.) IR Imageries based on 00 and 12 UTC of 31st Oct. and Oceansat II based surface wind at 1812 UTC of 30th October 2012.

2.2.7 Radar observations

The cyclonic storm, NILAM was monitored was also monitored by DWR Chennai and Sriharikota and conventional S-band RADAR, Karaikal.

DWR Chennai monitored the system from the night of 29th October, when the cyclonic storm was about 500 km southeast of Chennai. The DWR performance during the cyclone surveillance period had been very good with optimum power output, sensitivity and stability without any trouble except during the period from 0615 to 0710 UTC (Radome door inter lock switch opened due to strong wind). Prominent features of eye could not be seen persistently. Radar-echoes in some parts of spiral bands were stronger than the eye-wall echoes on many occasions. Maximum observed reflectivity was around 55 dBZ. The wind field was less symmetric to the eye. Maximum velocity of about 30 mps observed in the cyclone field was associated with the spiral band.

The typical radar imageries of the system from DWR, Chennai are shown in Fig.2.2.4. Features observed through radar are also shown in Table 2.2.5

Table 2.2.5. Features observed through DWR, Chennai

Bulletin No	Date & Time in UTC	Observation	Remarks
1-3	30.10.2012/17 to 19	Eye was apparently visible	When the system was away from DWR VIEW [400KM]
4, 5 & 8,12 & 15	30/20,21 & 31/00,05 & 09	Ill defined eye was noticed	When the system was within RADAR preview.
6 & 7	30/22 & 23	Closed eye observed	-do- Closer to coast
9,10 , 11&13	31/01 to 03 & 06	Eye NOT visible	-do- Closer to coast
14	31/0800	Eye distorted	-do- closer to coast
16	31/10	Open elliptical eye	-do- closer to coast
17	31/11	Eye confidence poor	System apparently crossed the coast near Mahabalipuram

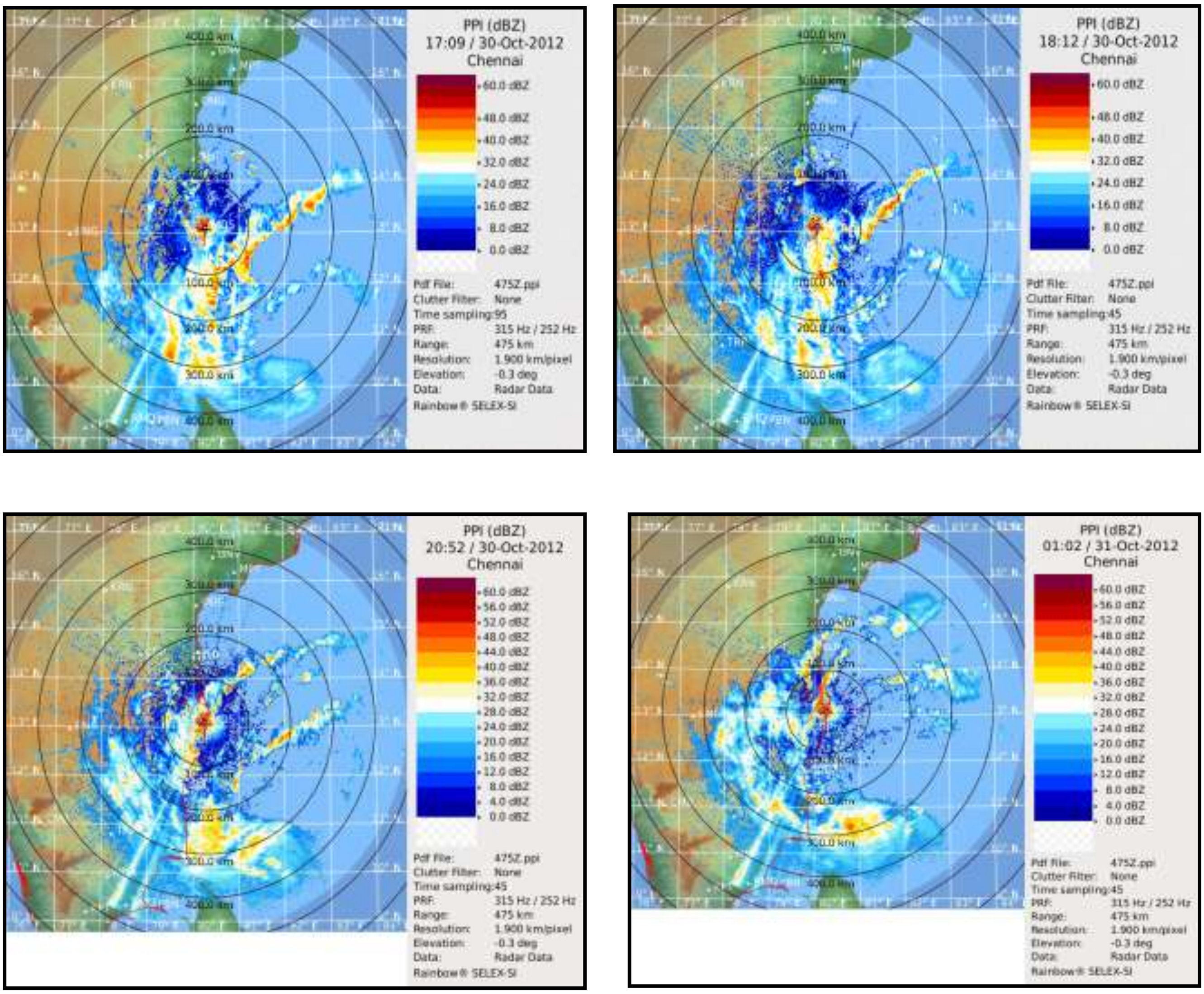


Fig. 2.2.4(a) DWR Chennai imageries based on 17, 18 & 21 UTC of 30th and 01 UTC of 31st Oct 2012 during Cyclonic Storm, NILAM over Bay of Bengal.

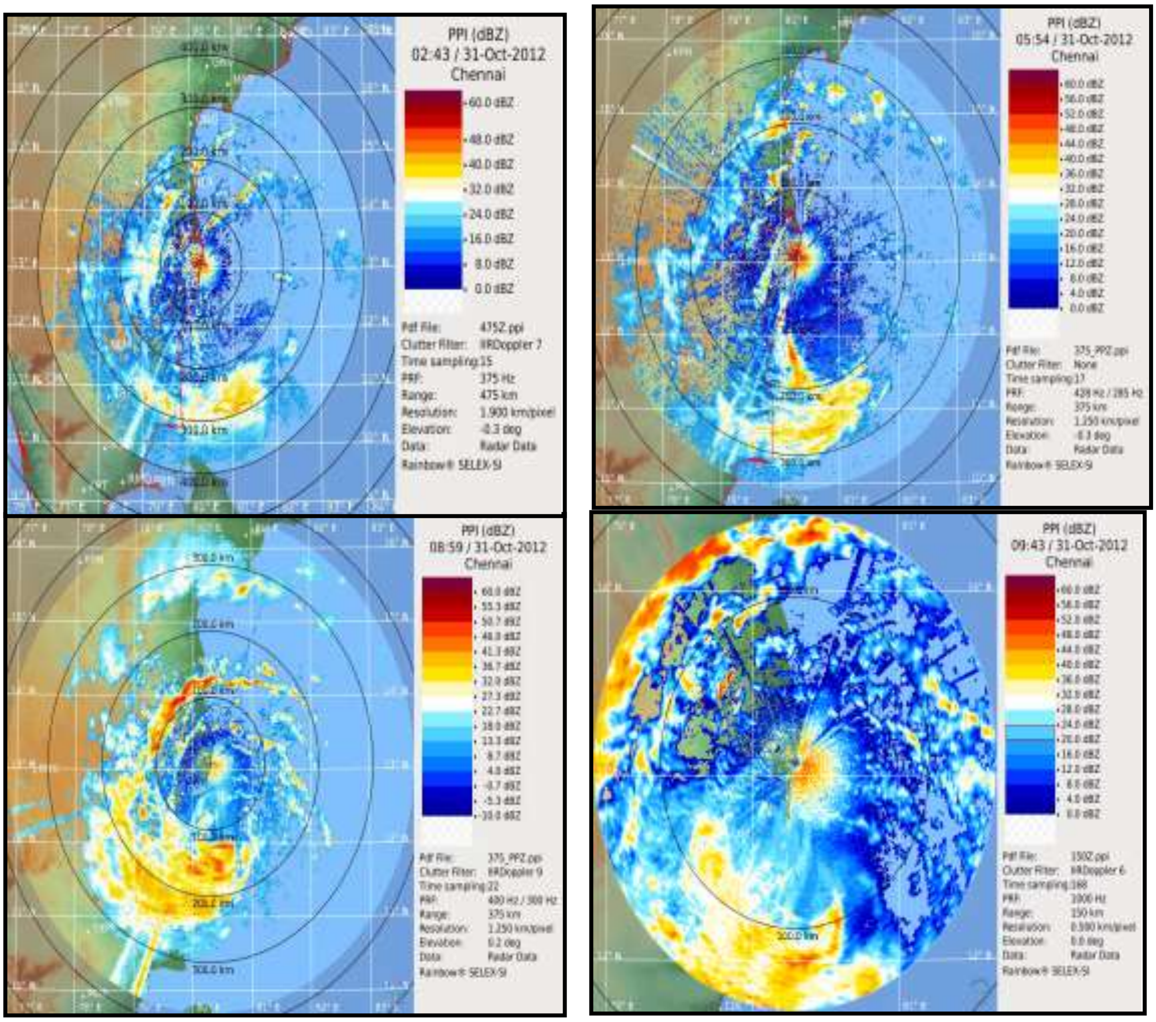


Fig. 2.2.4(b) DWR Chennai imageries based on 03, 06, 09 & 10 UTC of 31st Oct 2012 during Cyclonic Storm, NILAM over Bay of Bengal

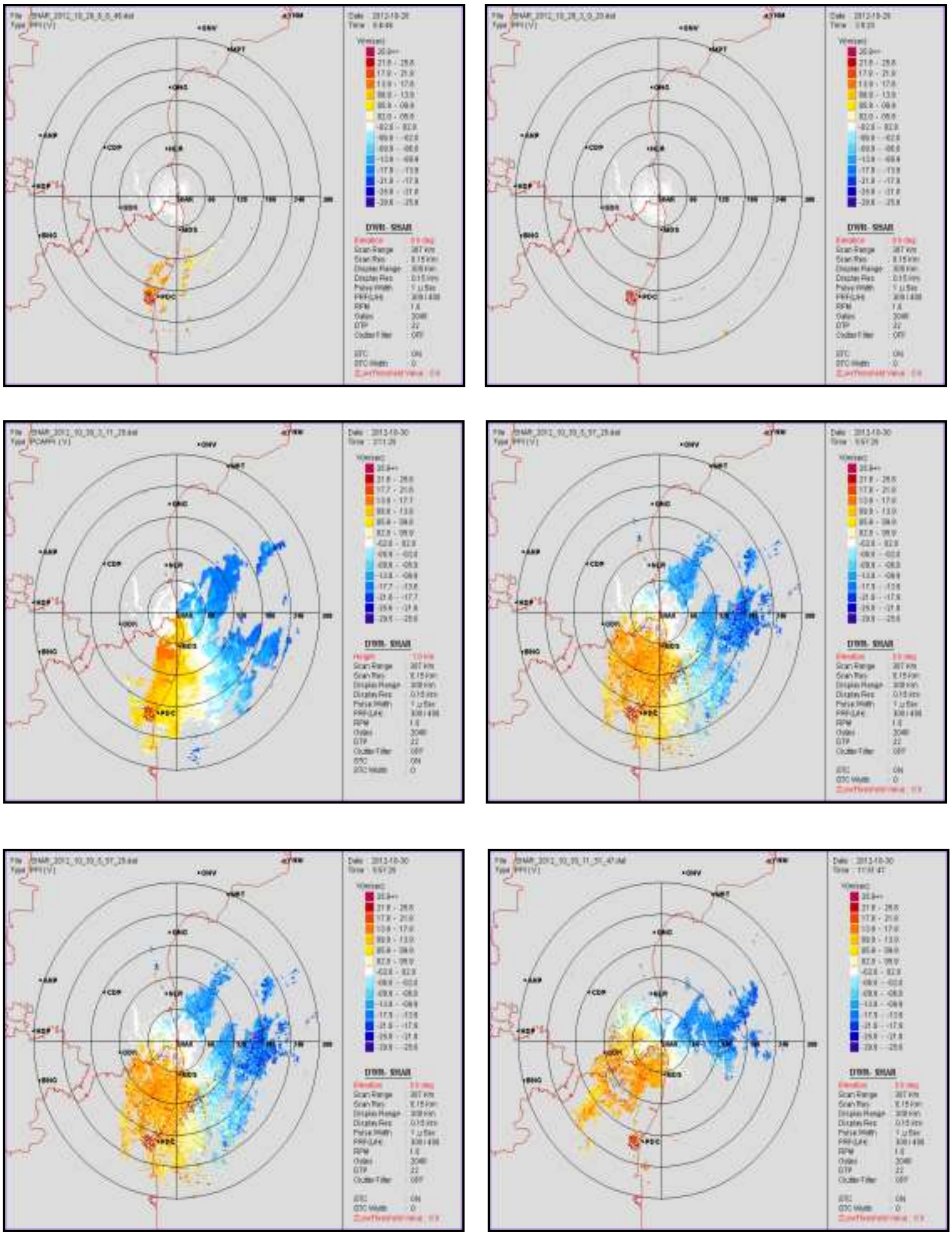


Fig. 2.2.4(c) DWR SHAR PPI_V imageries based on 06 UTC of 28th, 03 UTC of 29th and 03, 06, 09 & 12 UTC of 30th Oct. 2012

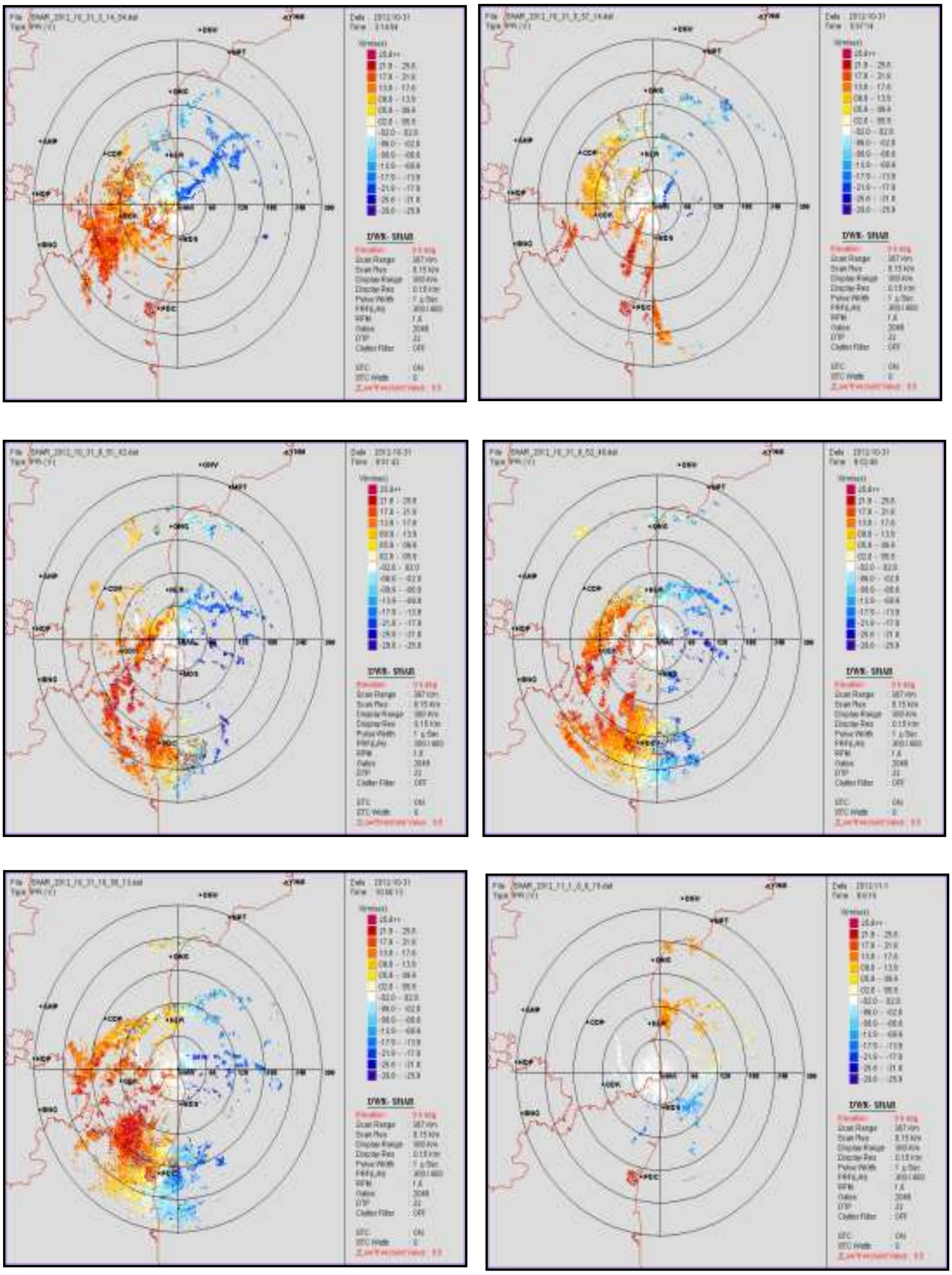


Fig. 2.2.4(d) DWR SHAR PPI_V imageries based on 03, 06 09, 10 & 11 UTC of 31st Oct. and 06 UTC of 1st Nov. 2012

2.2.8. Features observed through NWP model analyses

The mean sea level pressure analysis, 850 hPa, 500 hPa and 200 hPa wind analyses of various models are shown in Fig.2.2.5-2.2.8. The performance of various models for detection and prediction of this system showed large scale variation with respect to genesis, track and intensification. However, the models guidance converged to each other, as the system came closer to coast.

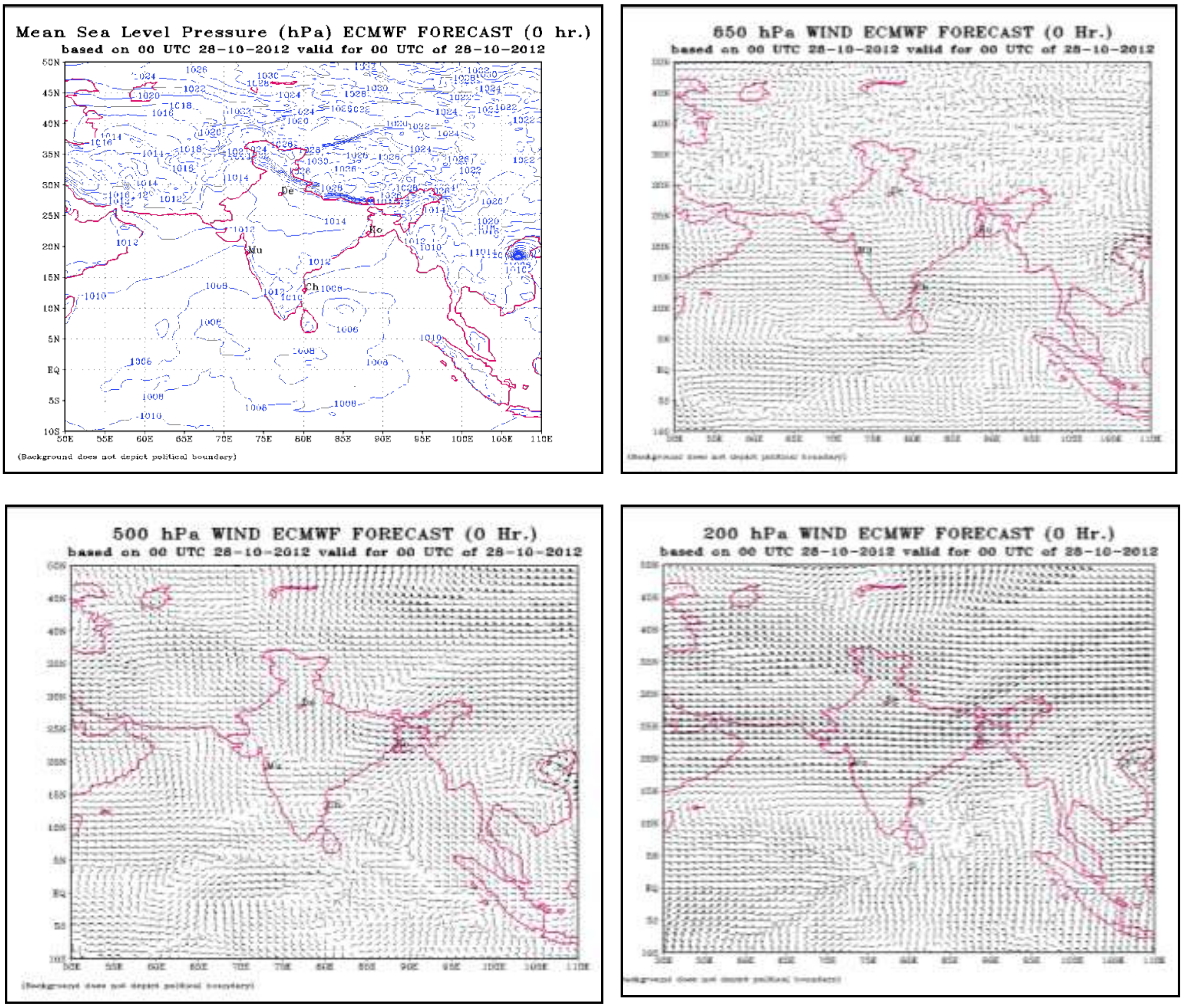


Fig. 2.2.5(a) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 28th Oct. 2012

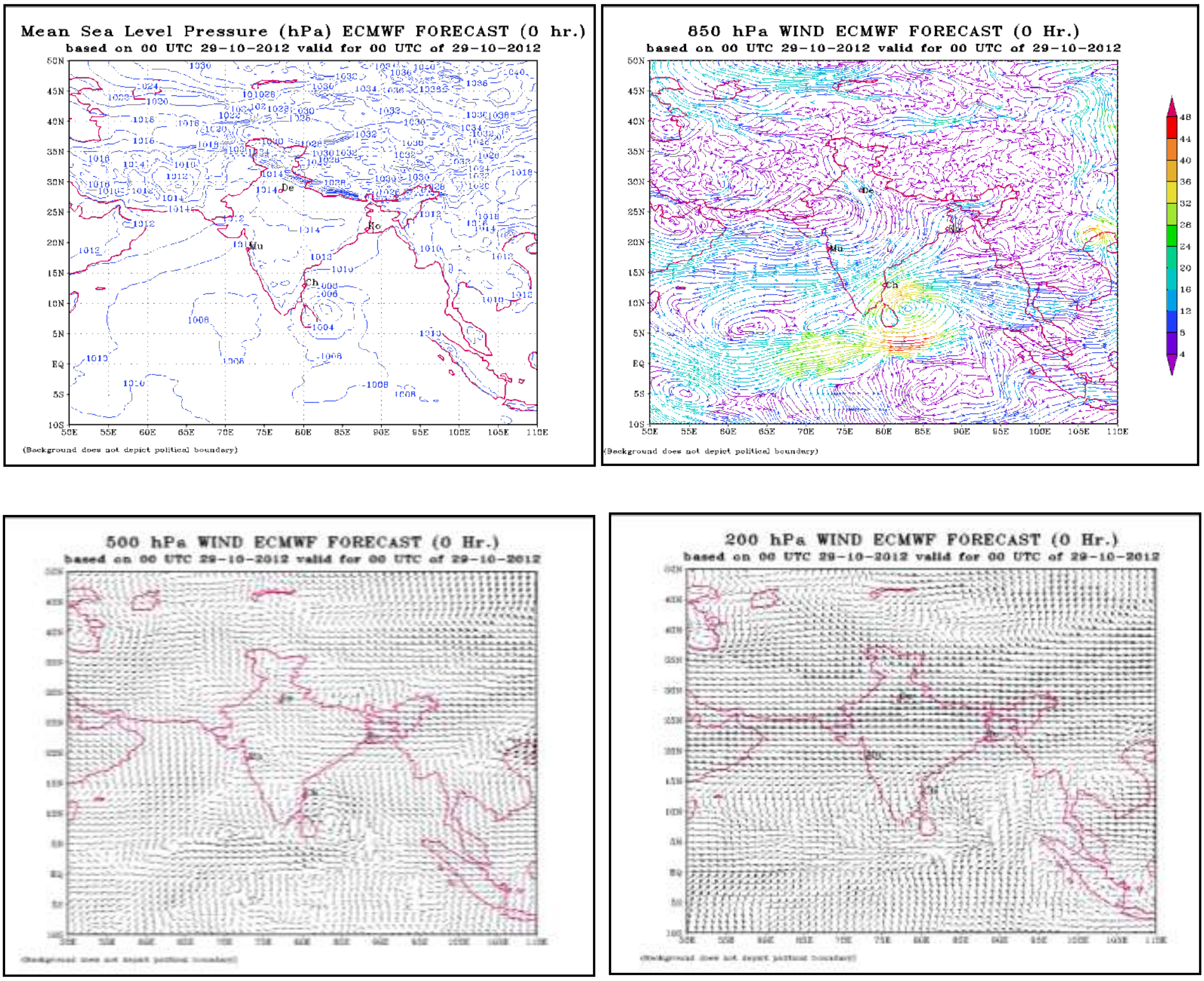


Fig. 2.2.5(b) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 29th Oct. 2012

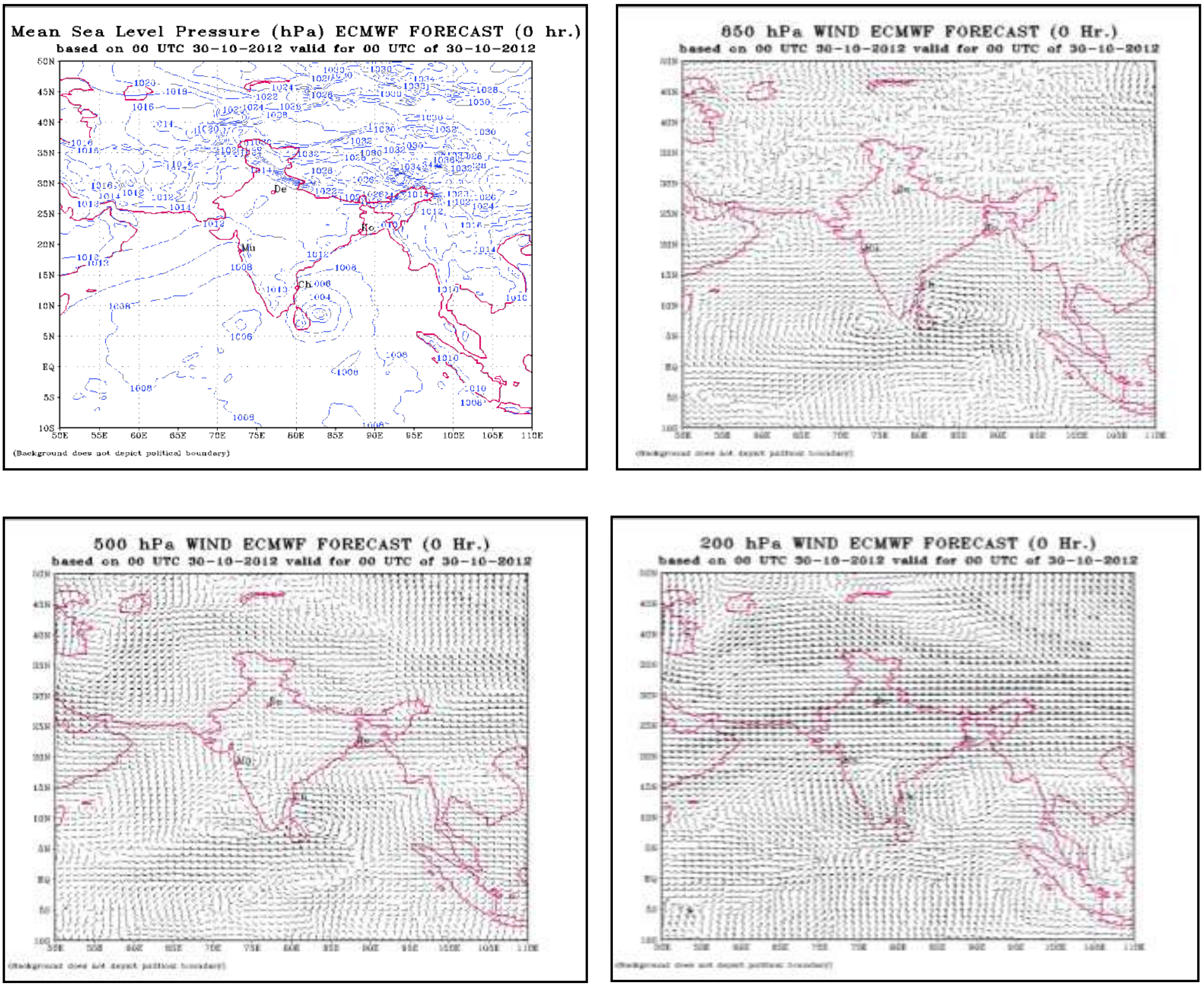


Fig. 2.2.5 (c) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 30th Oct. 2012

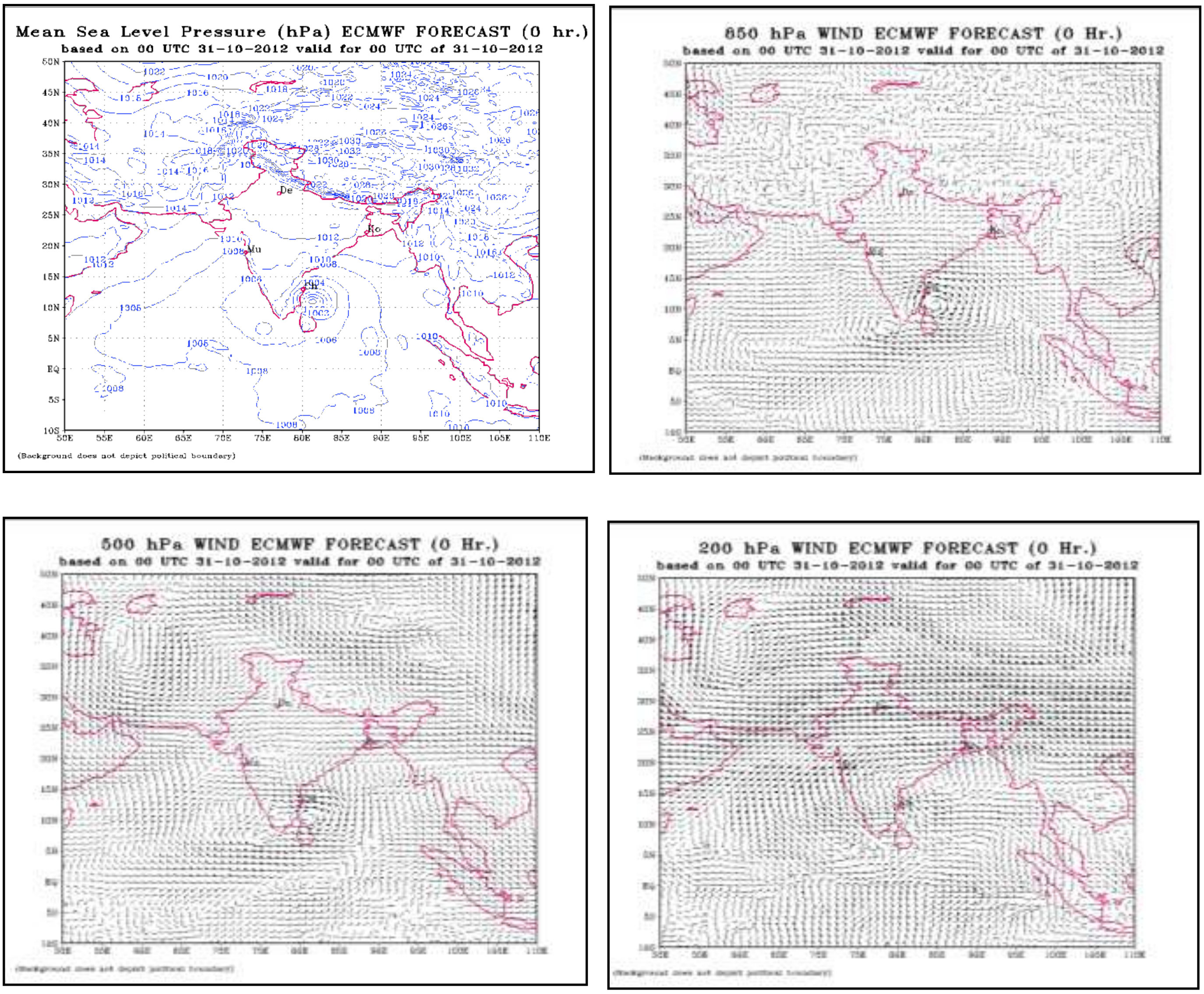


Fig. 2.2.5(d) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 31st Oct. 2012

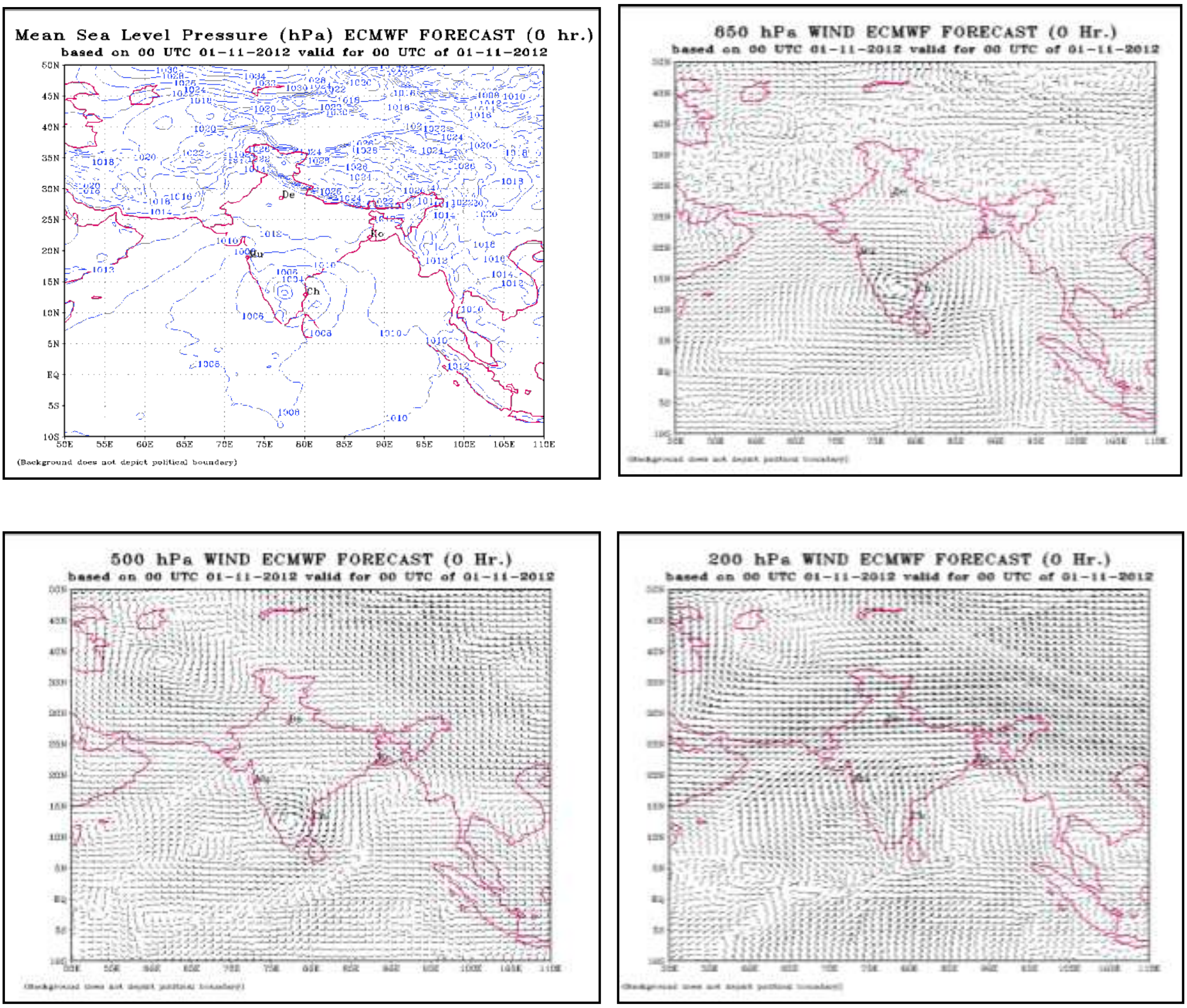


Fig. 2.2.5(e) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 1st Nov. 2012

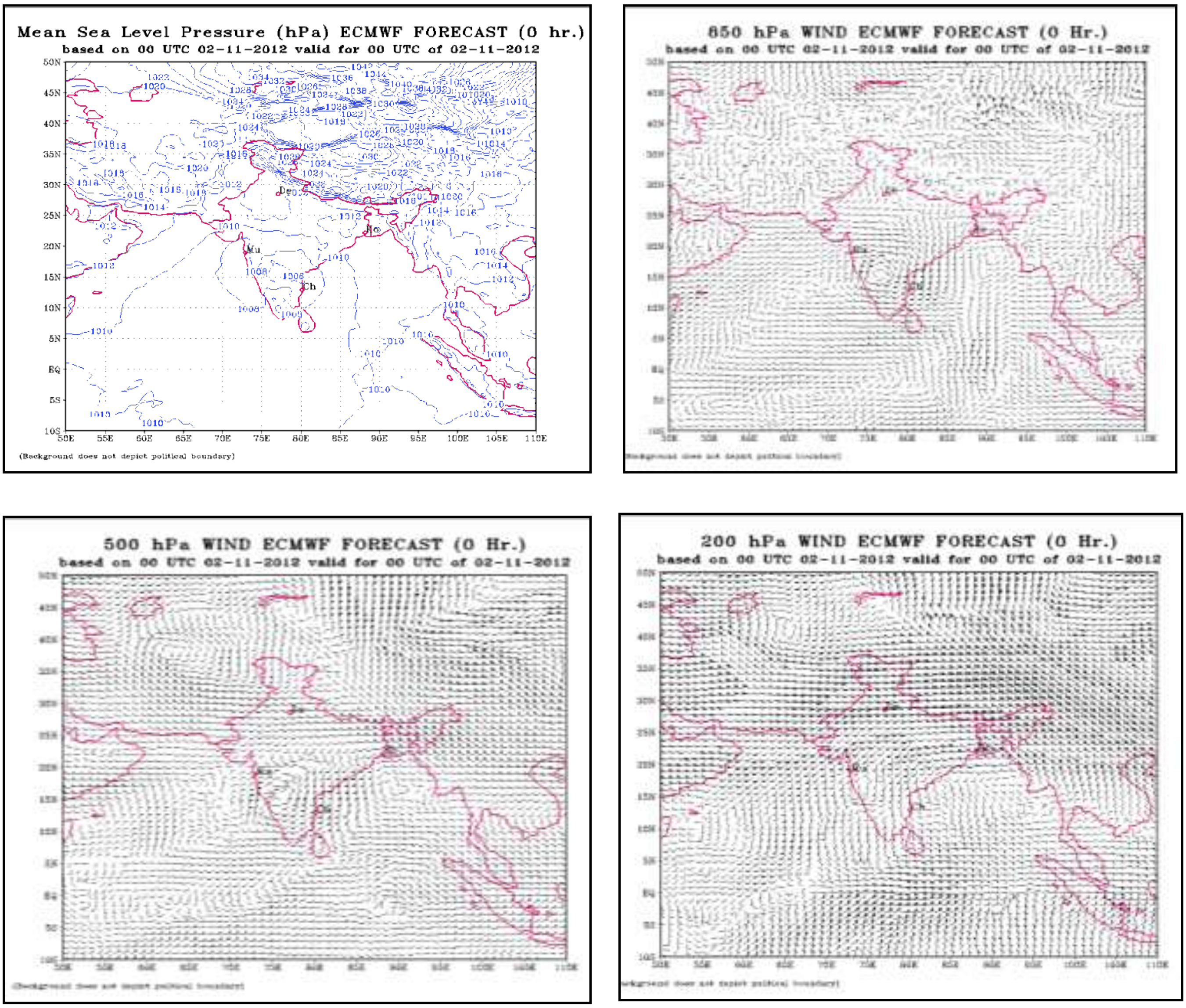


Fig. 2.2.5(f) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 2nd Nov. 2012

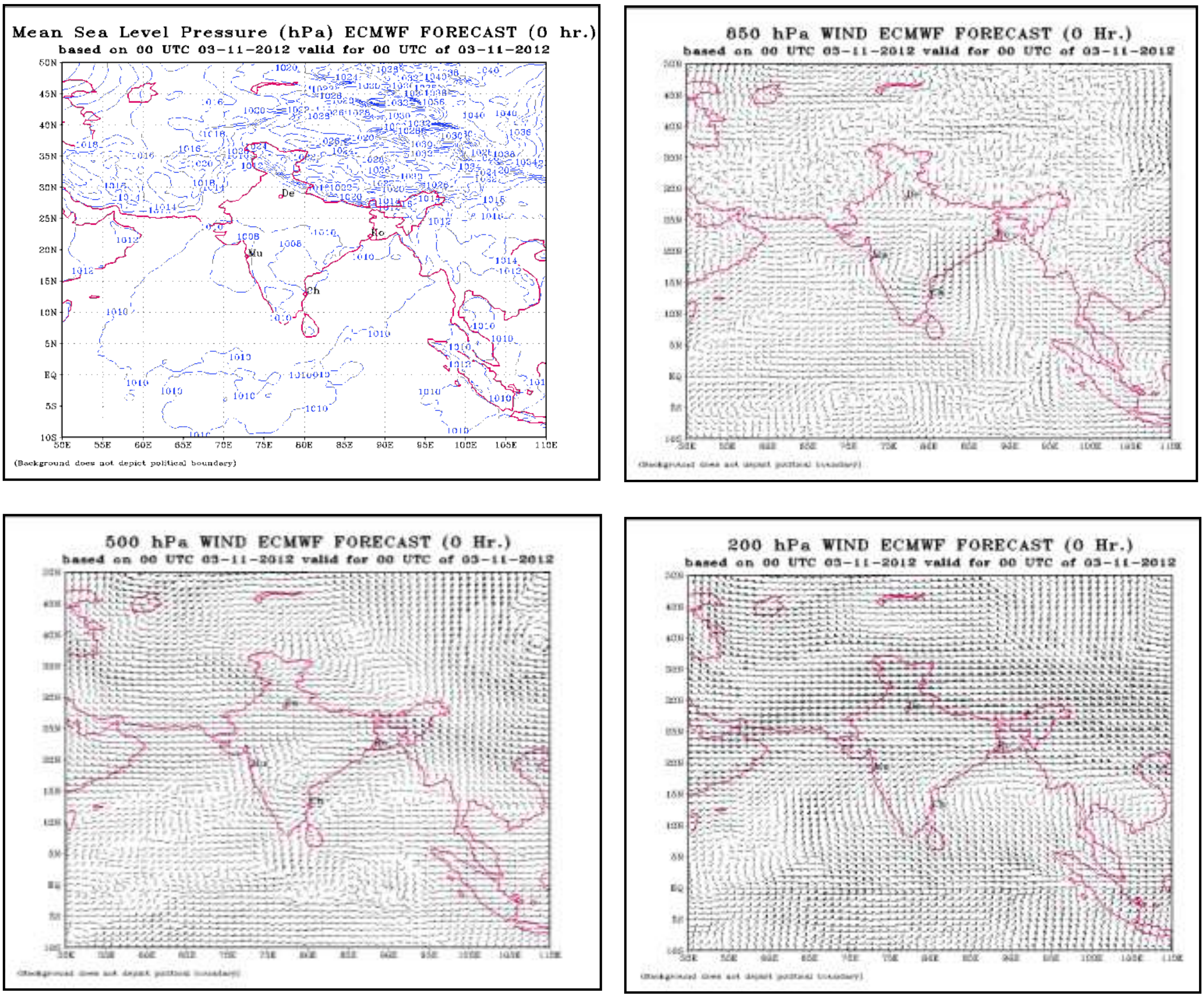


Fig. 2.2.5(g) ECMWF MSLP and 850, 500 & 200 hPa levels wind analysis based on 00 UTC of 3rd Nov. 2012

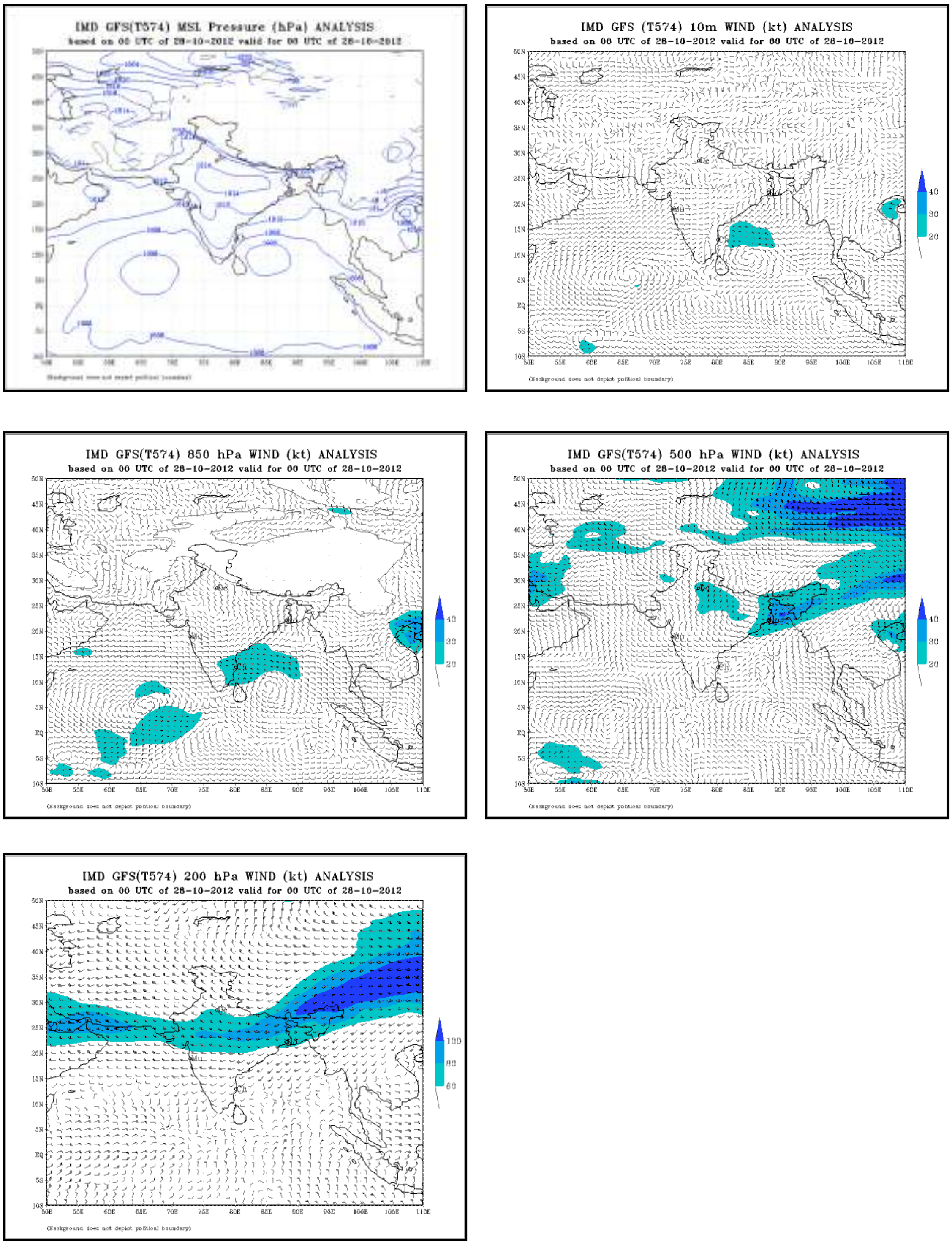


Fig. 2.2.6(a) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 28th Oct. 2012

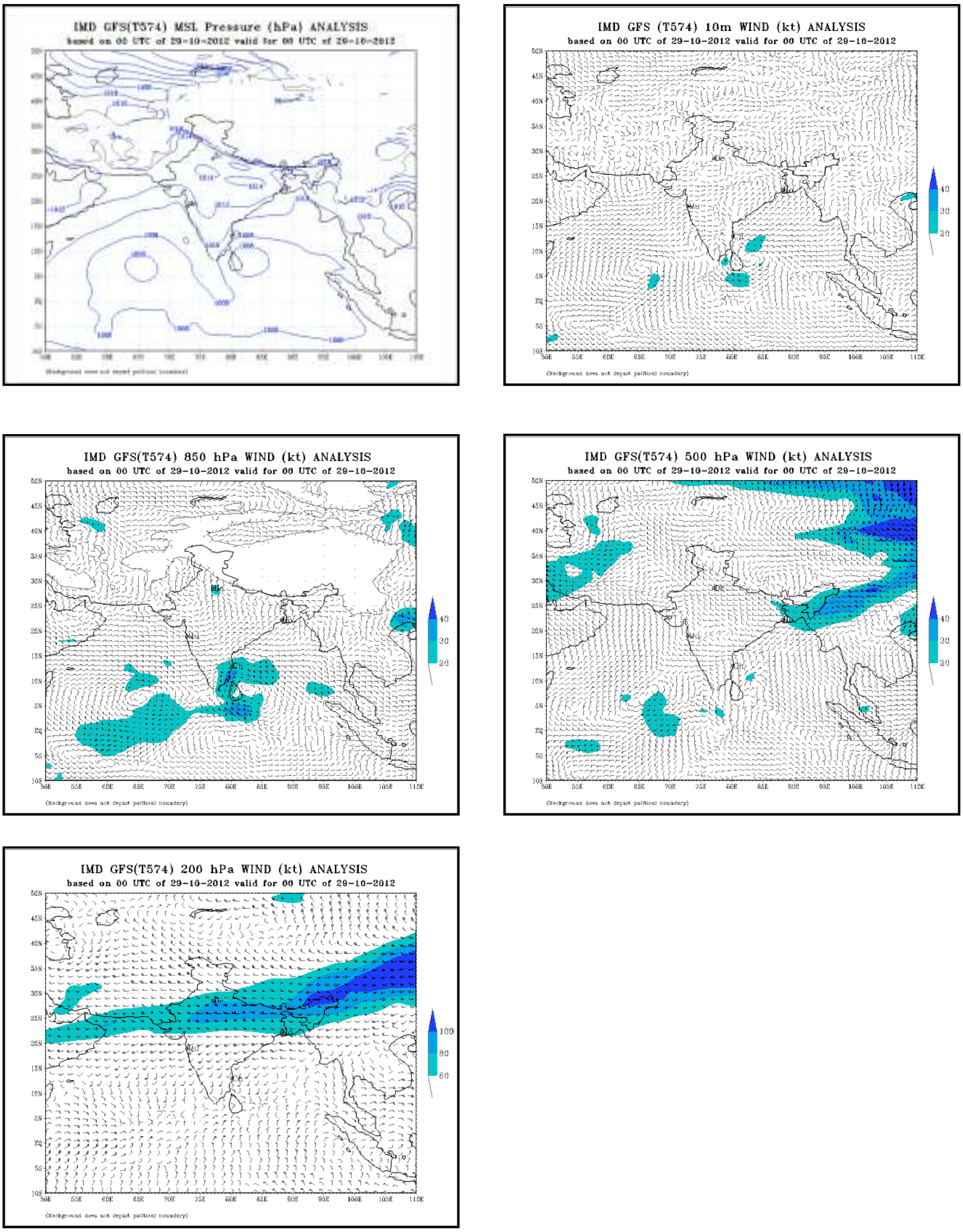


Fig. 2.2.6(b) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 29th Oct. 2012

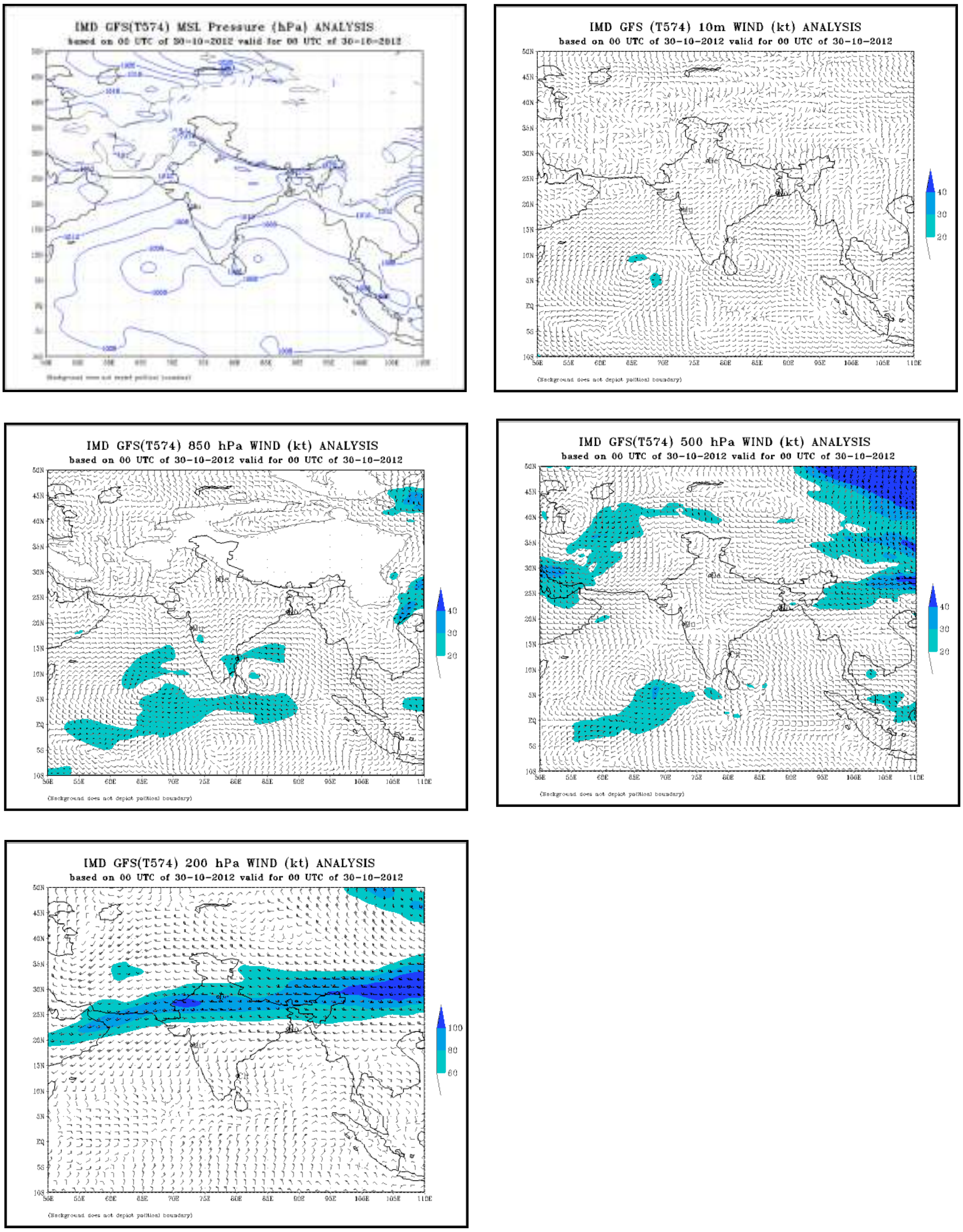


Fig. 2.2.6(c) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 30th Oct. 2012

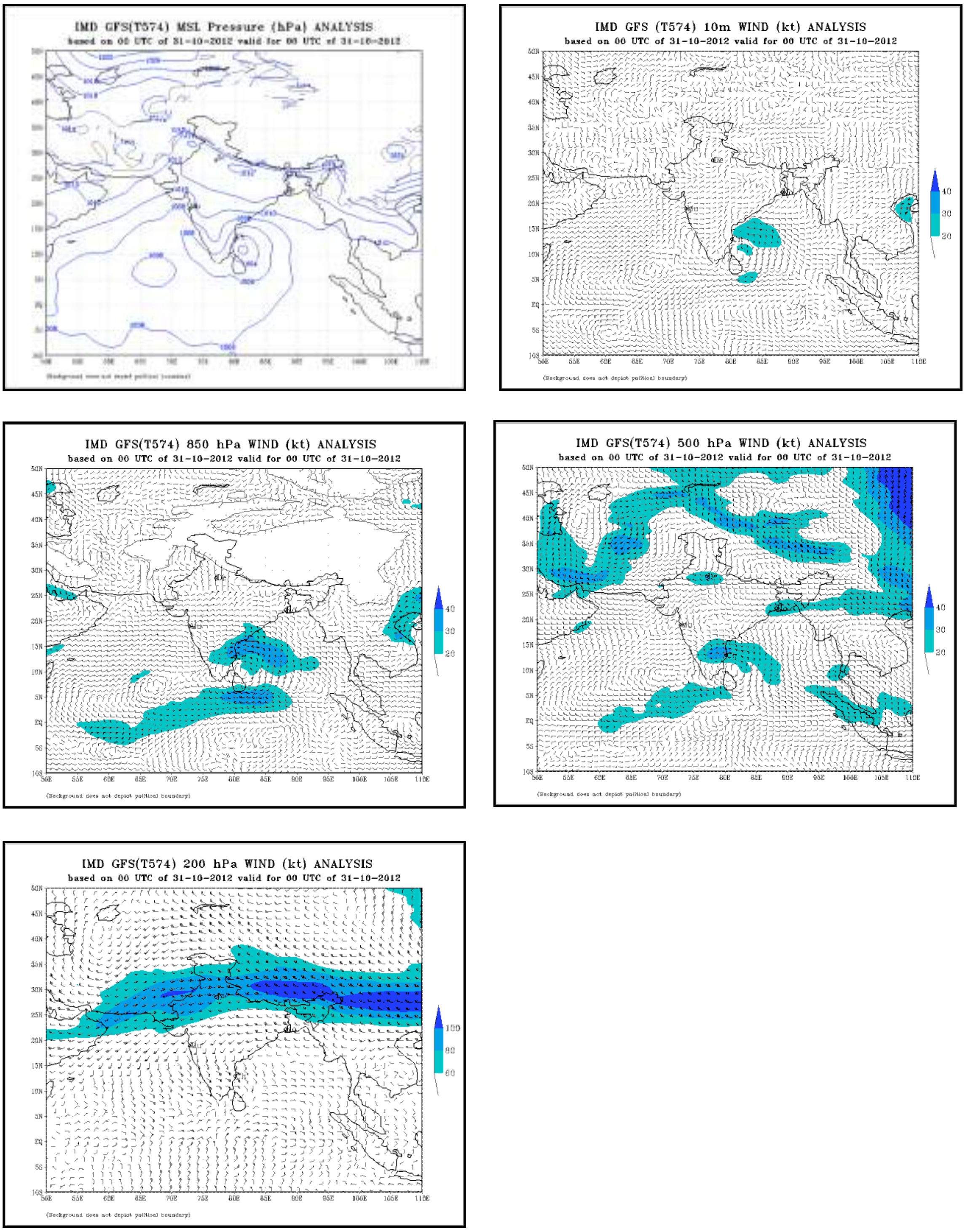


Fig. 2.2.6(d) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 31st Oct. 2012

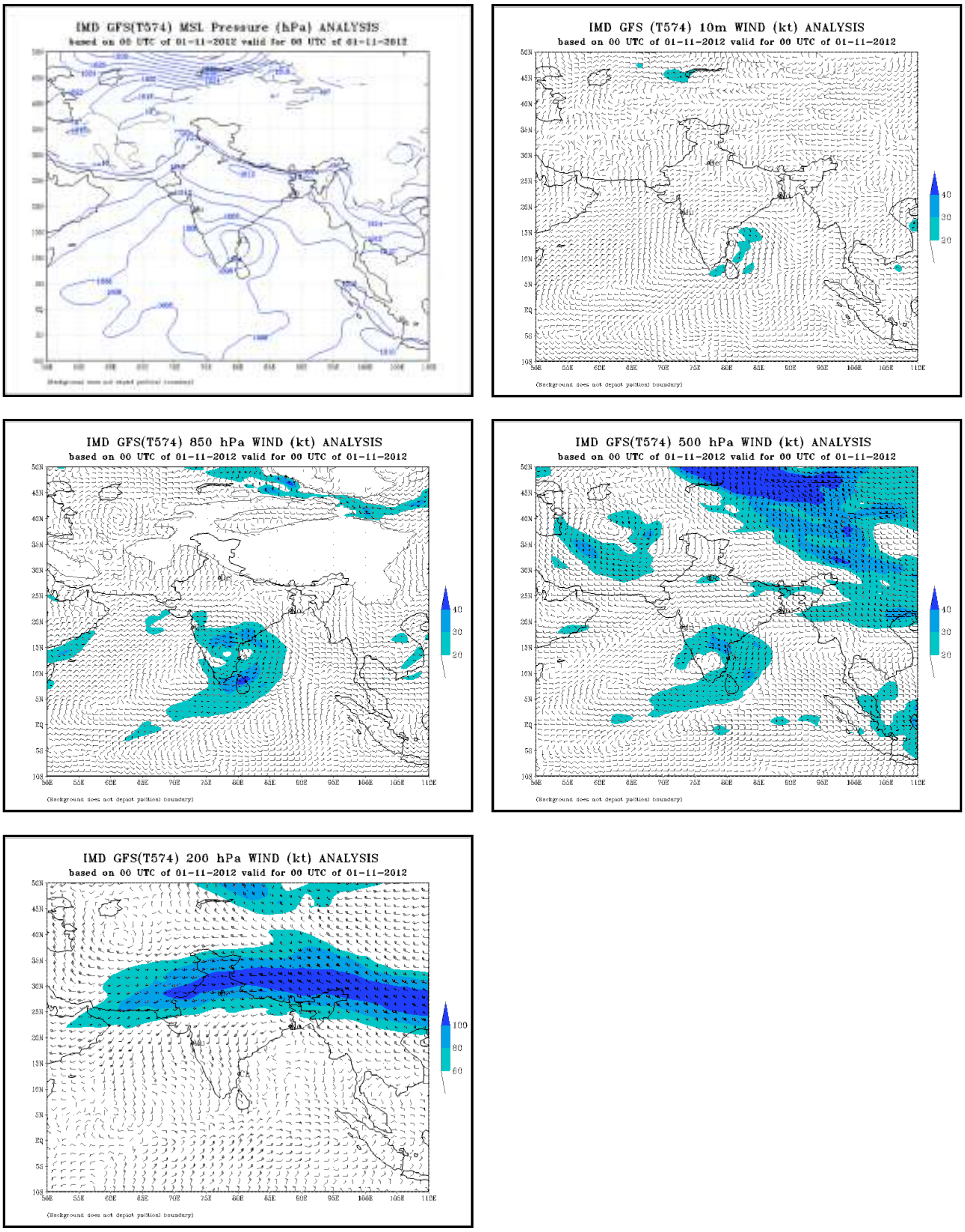


Fig. 2.2.6(e) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 1st Nov. 2012

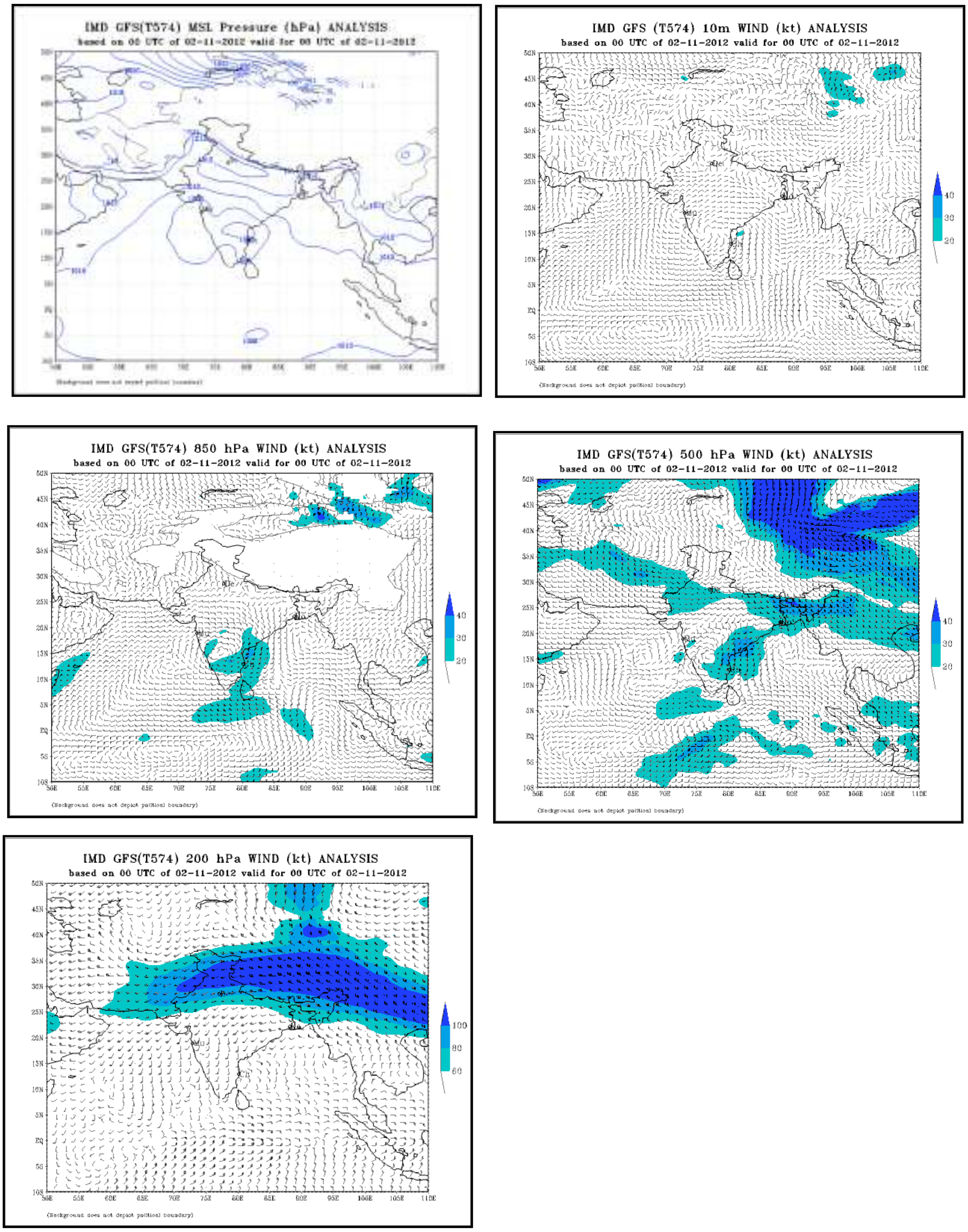


Fig. 2.2.6(f) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 2nd Nov. 2012

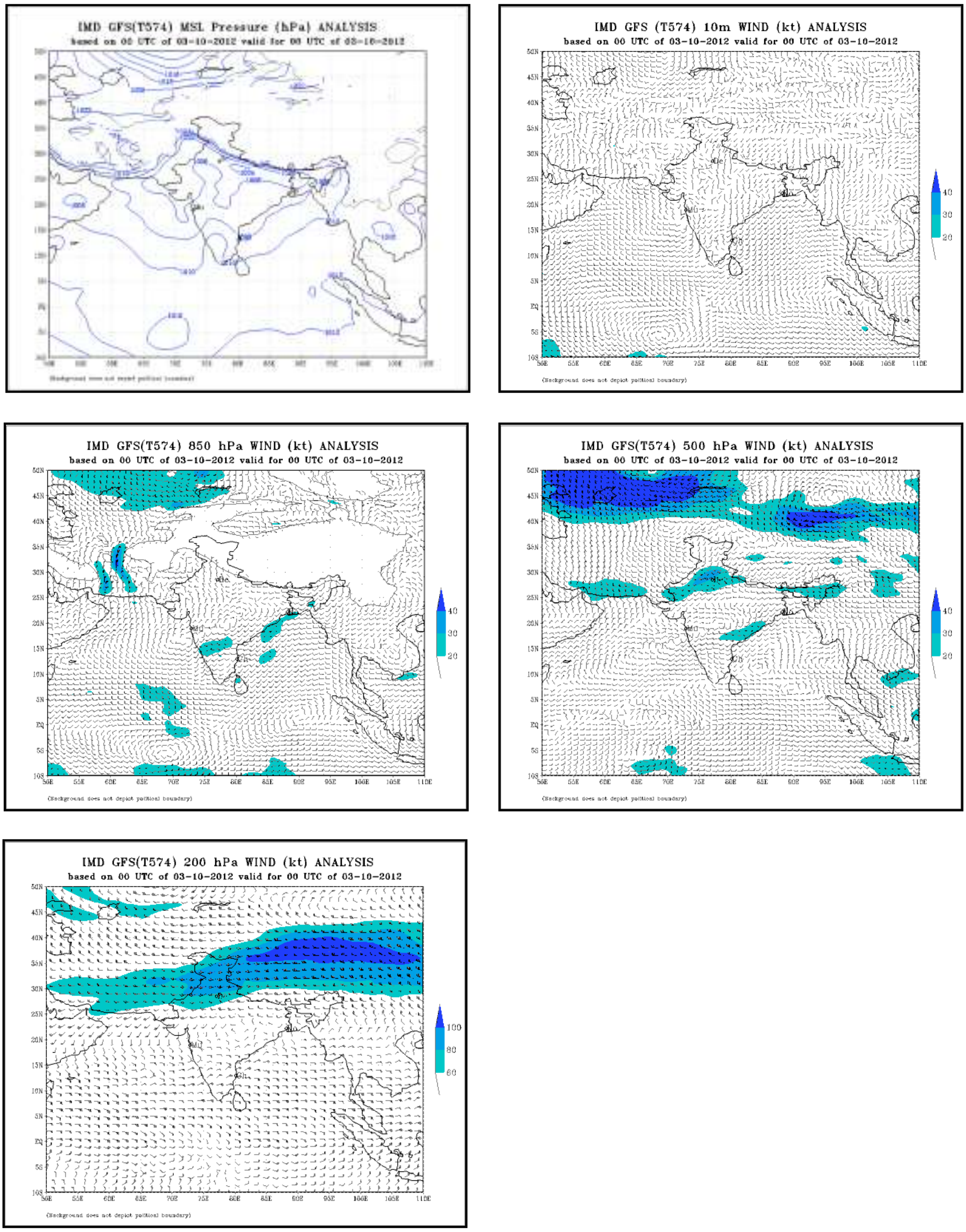


Fig. 2.2.6(g) IMD GFS MSLP, 10m wind and winds at 850, 500 & 200 hPa levels analysis based on 00 UTC of 3rd Nov. 2012

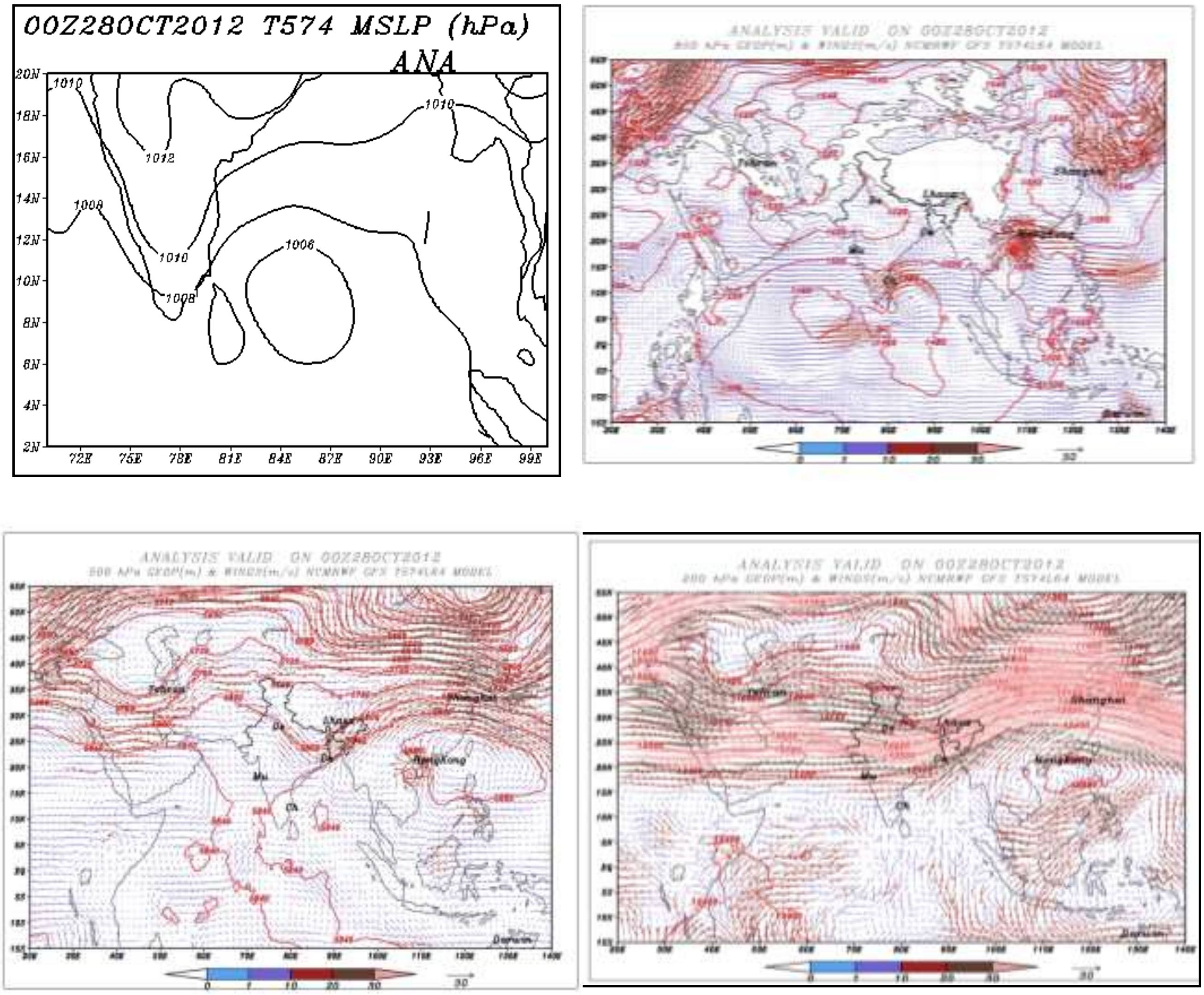


Fig. 2.2.7(a) NCMRWF GFS T-574 model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 28th Oct. 2012

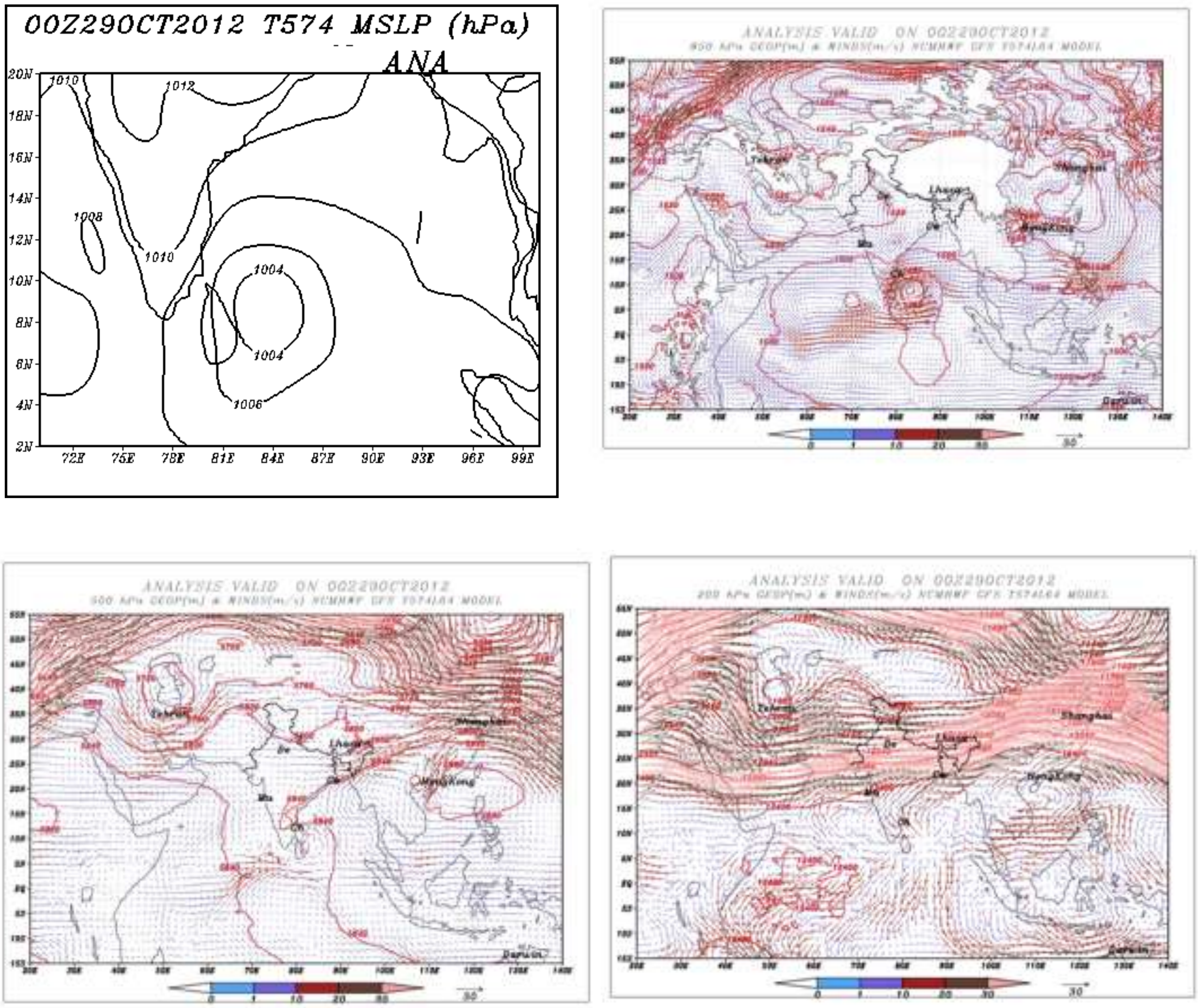


Fig. 2.2.7(b) NCMRWF GFS T-574 model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 29th Oct. 2012

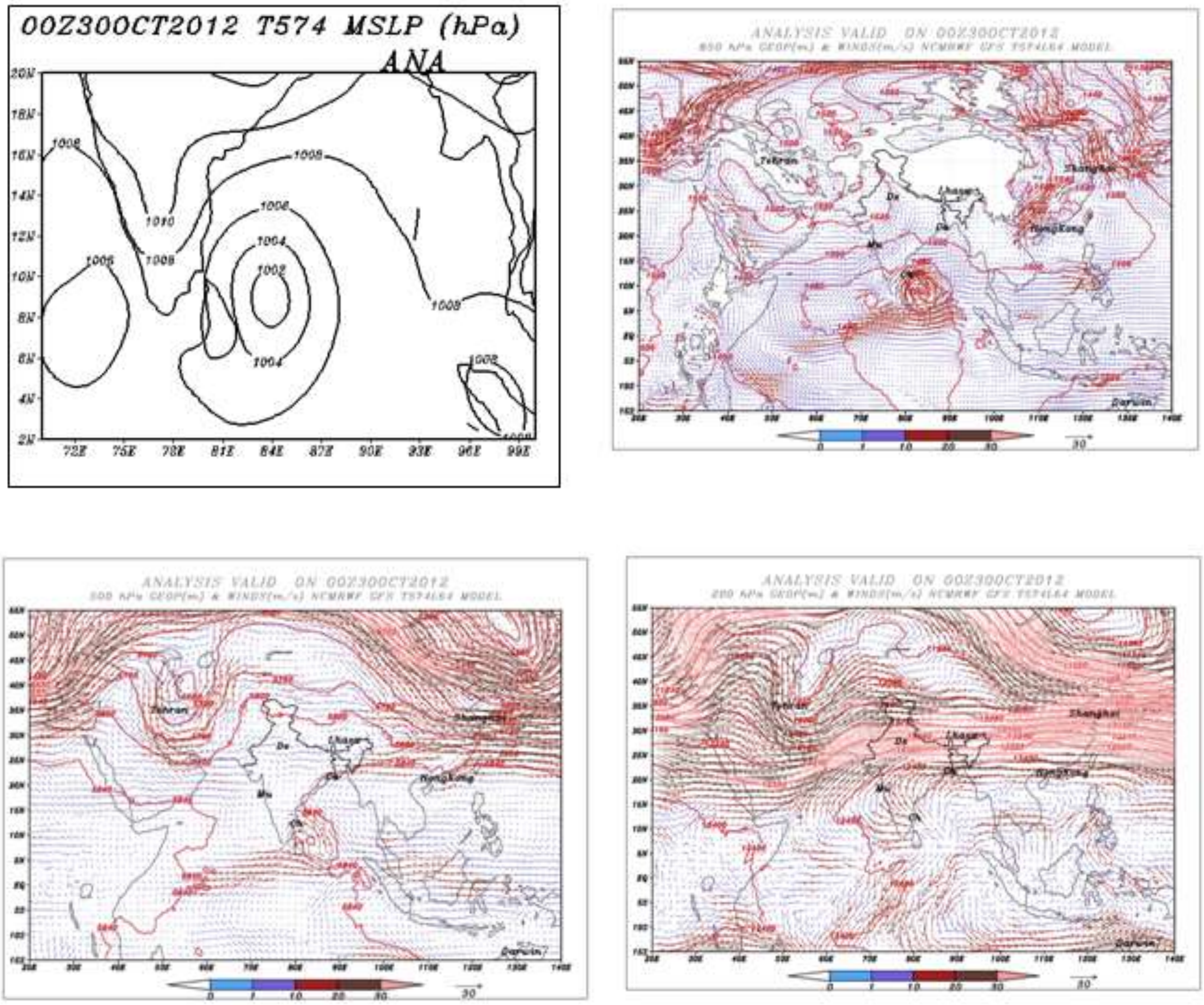


Fig. 2.2.7(c) NCMRWF GFS T-574 model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 30th Oct. 2012

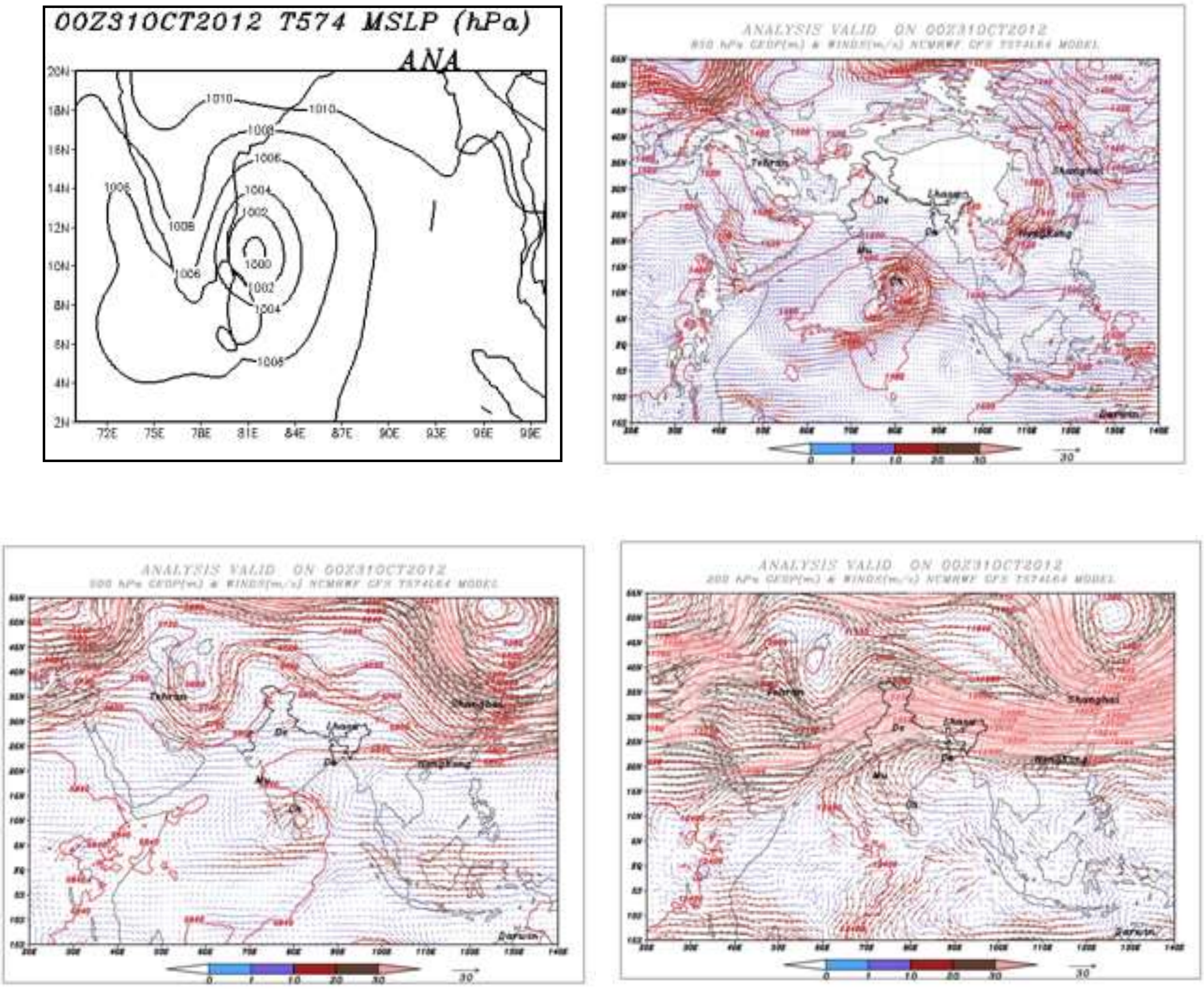


Fig. 2.2.7(d) NCMRWF GFS T-574 model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 31st Oct. 2012

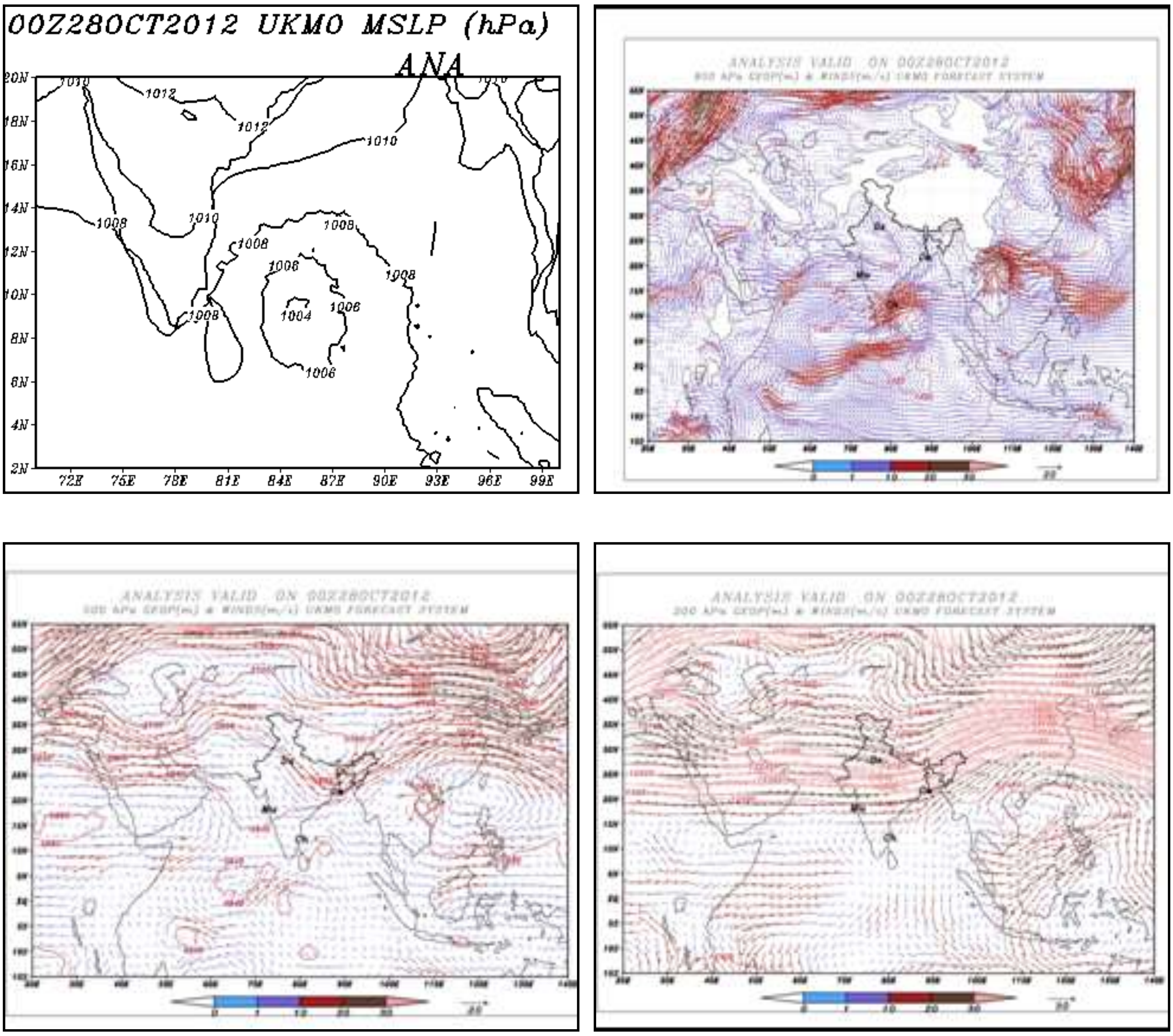


Fig. 2.2.8(a) UKMO model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 28th Oct. 2012

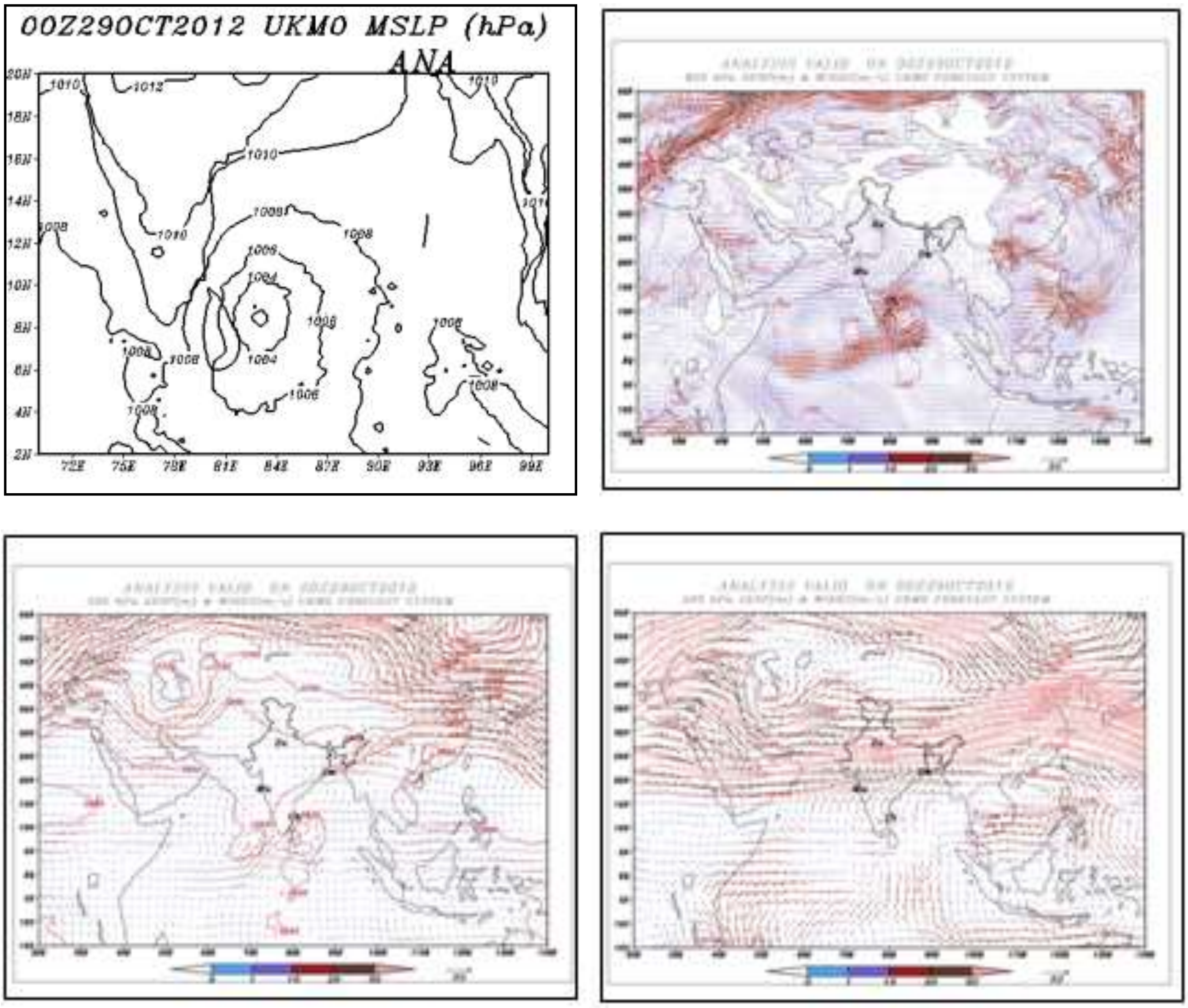


Fig. 2.2.8(b) UKMO model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 29th Oct. 2012

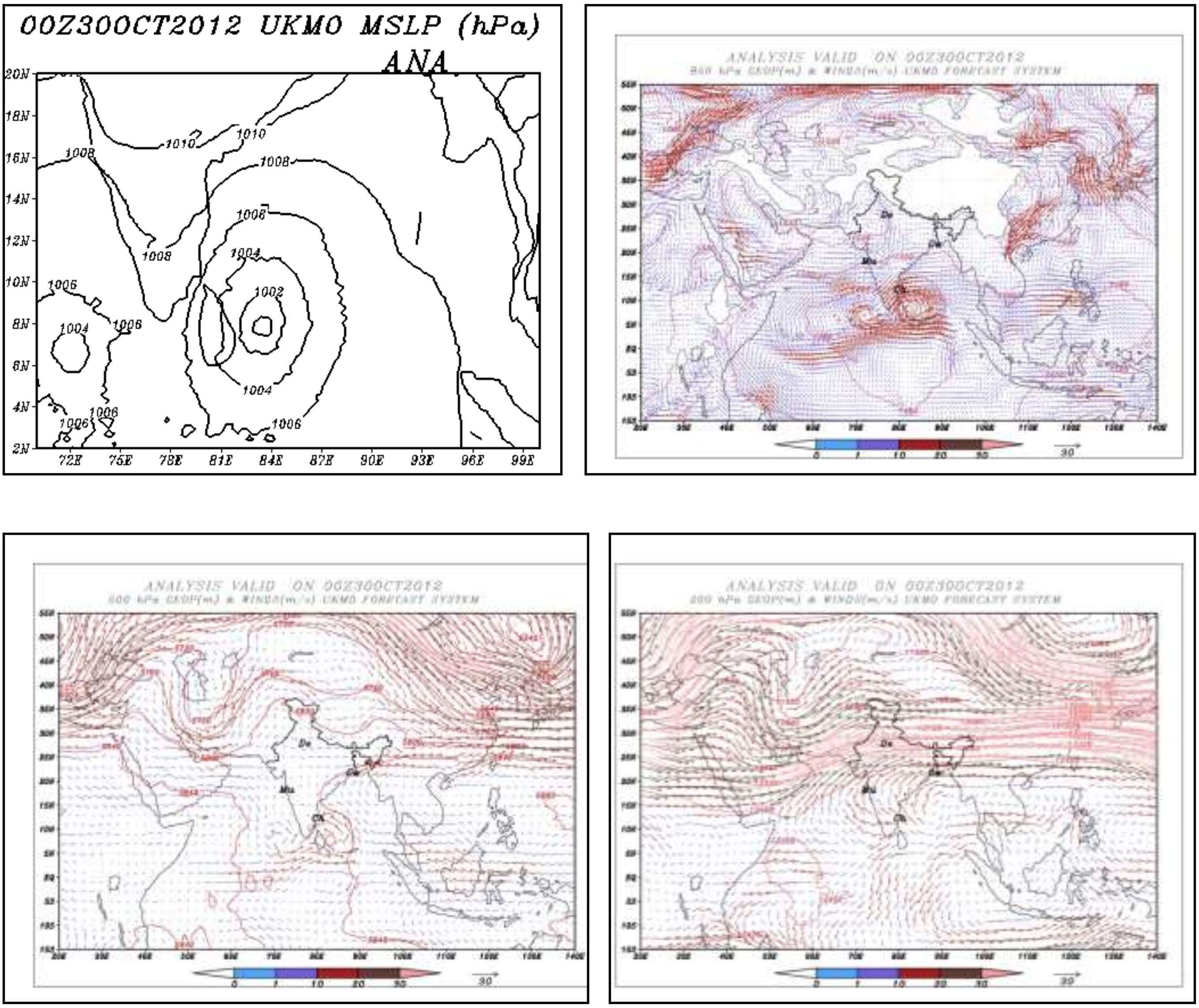


Fig. 2.2.8(c) UKMO model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 30th Oct. 2012

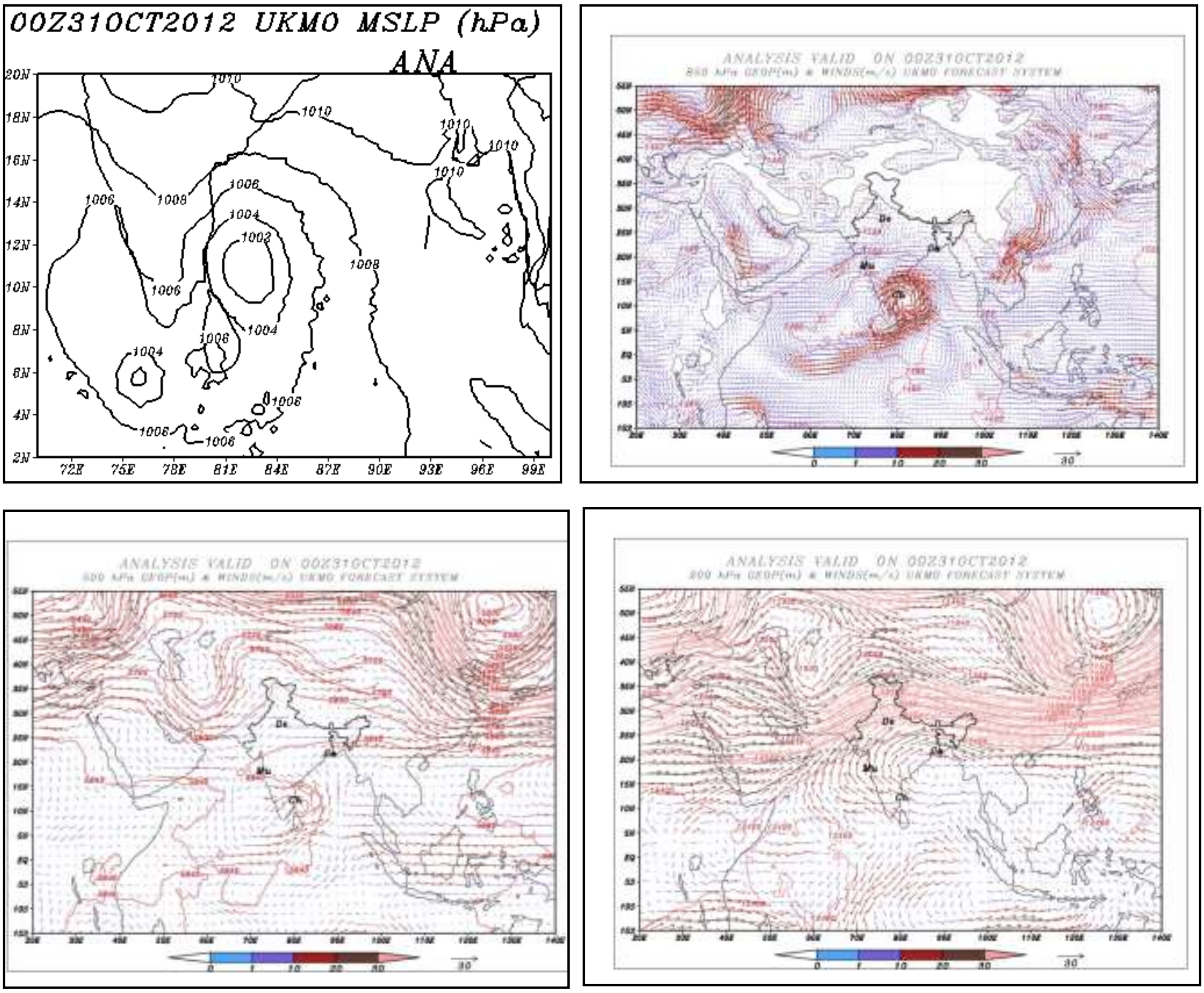


Fig. 2.2.8(d) UKMO model MSLP, 850, 500 and 200 hPa wind analysis based on 00 UTC of 30th Oct. 2012

2.2.9. Realized Weather

Under its influence gale wind speed reaching 70-80 kmph prevailed along and off north coastal Tamil Nadu, Puducherry and adjoining south Andhra Pradesh coast Available observations from meteorological observatories indicate that the maximum wind speed of 75 kmph has been reported over Chennai & 65 kmph over Kalpakkam at the time of landfall.

Rainfall at most places with scattered heavy to very heavy rainfall occurred over north coastal Tamil Nadu. Rainfall at most places with isolated heavy to very heavy rainfall also occurred over north interior Tamil Nadu on 31st October and 1st November 2012. During weakening phase as a low over Andhra Pradesh, it caused rainfall at most places with scattered heavy to very heavy rainfall and isolated extremely heavy rainfall over coastal Andhra Pradesh and isolated heavy to very heavy rainfall over Telengana, Rayalaseema and south Odisha during 2nd to 5th November 2012. Chief amounts of 24 hrs rainfall (7 cm or more) ending at 0300 UTC of 31st Oct-3rd Nov 2012 are given below.

Tamil Nadu and Puducherry:

31. 10. 2012

Vedaranyam (Nagapattinam Dist) and Mahabalipuram (Kancheepuram Dist) 13 each, Trangambadi (Nagapattinam Dist) 10, Ennore AWS (Tiruvallur Dist), Chennai Nungambakkam (Chennai Dist), Nagapattinam (Nagapattinam Dist), Kalpakkam (Kancheepuram Dist) and Tiruvarur (Tiruvarur Dist) 9 each, Madavaram AWS (Tiruvallur Dist), Thiruthuraipoondi and Nannilam (both Tiruvarur Dist), Kelambakkam and Chennai Airport (both Kancheepuram Dist), Karaikal (Karaikal Dist) and Anna University (Chennai Dist) 8 each, Tambaram (Kancheepuram Dist), Sirkali and Mayiladuthurai (both Nagapattinam Dist), Kodavasal and Muthupet (both Tiruvarur Dist), Marakkanam and Vanur (both Villupuram Dist), Chengalpattu (Kancheepuram Dist), Cholavaram (Tiruvallur Dist), Puducherry (Puducherry Dist) and DGP office (Chennai Dist) 7 each,

01. 11. 2012

Yercaud (Salem Dist) 24, Alangayam (Vellore Dist) 20, Vandavasi (Tiruvannamalai Dist) 19, Tirukoilur (Villupuram Dist) 14, Vanur and Tindivanam (both Villupuram Dist) 13 each, Gingee, Villupuram and Mylam AWS (all Villupuram Dist), Ambur and Tirupattur (both Vellore Dist) and Valangaiman (Tiruvarur Dist) 11 each, Sirkali (Nagapattinam Dist), Kodavasal (Tiruvarur Dist), Polur (Tiruvannamalai Dist), Sethiathope and Tozhudur (both Cuddalore Dist), Thali (Krishnagiri Dist), Melalathur (Vellore Dist) and Naduvattam (Nilgiris Dist) 10 each, Parangipettai (Cuddalore Dist), Trangambadi and Kollidam (both Nagapattinam Dist), Penucondapuram (Krishnagiri Dist), Needamangalam (Tiruvarur Dist) and Arani (Tiruvannamalai Dist) 9 each, Chengam and Tiruvannamalai (both Tiruvannamalai Dist), Mayiladuthurai (Nagapattinam Dist), Mannargudi (Tiruvarur Dist), Colachel (Kanyakumari Dist), Chidambaram and Cuddalore (both Cuddalore Dist), Pallipattu (Tiruvallur Dist) and Tirukattupalli (Thanjavur Dist) 8 each, Aravakurichi (Karur Dist), Barur, Hosur, Denkanikottai, Krishnagiri, Uthangarai and Pochampalli (all Krishnagiri Dist), Kattumannarkoil, Chidambaram AWS and Neyveli AWS (all Cuddalore Dist), Thanjavur, Thiruvidaimaruthur, Kumbakonam, Madukkur, Vallam, Aduthurai AWS and Grand anaicut (all Thanjavur Dist), Sankarapuram (Villupuram Dist), Nannilam and Thiruthuraipoondi (both Tiruvarur Dist), Vaniaymbadi (Vellore Dist), Puducherry (Puducherry Dist), Pappireddipatti and Dharamapuri (both Dharmapuri Dist), Thuvakudi and Pullambadi (both Trichy Dist), Eraniel (Kanyakumari Dist)a nd Kothagiri (Nilgiris Dist) 7 each,

Karnataka:

01.11.2012

Bagepalli (Chikaballapura dt) 14, Koratagere (Tumkur dt) 11, Kolar, Rayalpadu (Kolar dt), GKVK (Bengaluru Urban dt), Hoskote (Bengaluru Rural dt) 10 each, Srinivaspura (Kolar dt), Doddaballapura (Bengaluru Rural dt), Nayakanahatti (Chitradurga dt), CN Halli, Madhugiri (Tumkur dt), Thondebhavi, Gudibande (both Chikaballapura dt) 9 each, MM Hills (Chamarajanagar dt), Mulbagal, Bangarpet (both Kolar dt), Bengaluru City, Bengaluru HAL AP, Nelamangala (Bengaluru Rural dt), Hiriyur (Chitradurga dt), Kibbanahalli, Kunigal, Bargur (all Tumkur dt), Chintamani, Gowribidanur (both Chikaballapura dt) 8 each, Panchanahalli, Kadur (both Chikmagalur dt), Arasikere (Hassan dt), Bandipura (Chamarajanagar dt), Maddur (Mandya dt), Malur (Kolar dt), TG Halli (Bengaluru Urban dt), Devanahalli (Bengaluru Rural dt), Jagalur (Davangere dt), Hosanagara (Chitradurga dt), Chitradurga, Gubbi, Sira (both Tumkur dt), Sidlaghatta (Chikaballapura dt), Magadi, Channapatna, Kanakapura (all Ramanagara dt), Ramanagara 7 each,

Coastal Andhra Pradesh

01.11.2012:

Distt. Nellore: Vinjamur-16, Kavali-13, Rapur- 12, Kavali(a)- 11, Venkatagiri Town-11, Udayagiri-10, Atmakur-8, Gudur-8, Nellore- 8, Seetharampuram-7.
Distt. Prakasam: Ongole-15, Darsi-14, Addanki-13, Darsi(a)-13, Cumbam-13, Podili-12.
Distt. Krishna: Avanigadda- 10,.
Distt. East Godavari: Kakinada –7.
Distt. Vishakhapatnam: Bhimunipatnam-12,

02.11.2012:

Distt. Prakasam: Addanki-9, Darsi(a)-9, Ongole-8, Podili-7.
Distt. Guntur: Sathenapalli- 14, Atchempet-10, Lam(a)-8, Bapatla- 8, Guntur- 7, Bapatla(a)-7, Macharla-7, Tenali-7.
Distt. Krishna: Vijayawada (AP)-13, Nandigama- 11, Nuzvidu- 11, Gudivada-10, Vuyyuru(a)-9, Tiruvuru-8, Avanigadda-8, Kaikalur-7.
Distt. West Godavari: Koderu-10, Tanuku-8, Eluru-7.
Distt. East Godavari: Prathipadu-11, Tuni-9, Kakinada-8.
Distt. Vishakhapatnam: Chintapalli-8, Araku Valley-8, Yellamanchili-7.
Distt. Vizianagaram: Salur-14, Bobbili- 10, Vijayanagaram- 9, Gajapathinagaram- 9, Srungavarapukota-9, Cheepurupalli-7, Parvatipuram-7.
Distt. Srikakulam: Palasa-8.

03.11.2012:

Distt. Guntur: Mangalgiri-18, Bapatla-14, Bapatla(a)-13, Rapalle-12, Tenali-11, Guntur-9, Lam(a)-8.
Distt. Krishna: Tiruvuru-21, Gudivada-15, Vuyyuru(a)-13, Avanigadda-11, Nuzvidu-9, Nandigama-8, Kaikalur-7.
Distt. West Godavari: Chintalapudi-17, Bhimavaram-14, Tanuku-13, Eluru-13, Tadepalligudem-13, Polavaram-10, Bhimadole-9, Koyyalagudem-8.
Distt. East Godavari: Rajahmundry-8.
Distt. Vishakhapatnam: Chintapalli-15, Chodavaram-9, Narsipatnam-8, Araku Valley-7.
Distt. Vizianagaram: Srungavarapukota-18, Therlam-8, Parvatipuram-7, Salur-7, Gajapathinagaram-7.
Distt. Srikakulam: Sompeta-8, Itchapuram-7.

04.11.2012:

Distt. West Godavari: Narasapur(a)-31, Koderu-23, Tanuku-17, Tadepalligudem-16, Narsapuram-16, Bhimavaram-14, Polavaram-12.
Distt. East Godavari: Amalapuram-27, Rajahmundry-25, Kakinada-20, Tuni-19, Peddapuram-17, Prathipadu-15.
Distt. Vishakhapatnam: Yelamanchili(a)-25, Chodavaram-22, Narsipatnam-21, Yellamanchili-18, Anakapalli-18, Anakapalle(a)-17, Visakhapatnam Ap-17, Bhimunipatnam-17, Visakhapatnam-15, Paderu-9, Araku Valley-7.
Distt. Vizianagaram: Vijayanagaram-19, Srungavarapukota-16, Cheepurupalli-9, Therlam-9, Gajapathinagaram-9, Salur-7.
Distt. Srikakulam: Ranasthalam-16, Gudivada-10, Palakonda-7, Kaikalur-7.

05.11.2012:

Distt. Vishakhapatnam: Narsipatnam-9, Bhimunipatnam-8.
Distt. Srikakulam: Kalingapatnam-26, Tekkali-11, Pathapatnam-9, Palasa-8.

Rayalseema

31.10.2012:

Distt. Chittoor: Srikalahasthi-11, Tirumalla(a)-8, Chittoor-7.

01.11.2012:

Distt. Chittoor: Tirumalla(a)-15, Venkatagirikota-11, Chittoor-9, Thambalapalli-8, Arogyavaram-8, Srikalahasthi-7, Punganur-7, Puttur-7.
Distt. Cuddapah: Rajampet-9.
Distt. Anantapur: Madakasira-8, Amarapuram-7, Penukonda-7, Kadiri-7.

(02-04).11.2012:

Nil

05.11.2012:

Distt. Chittoor: Chittoor-8.

Telangana

02.11.2012:

Distt. Khammam: Khammam-9, Madhira-9.

03.11.2012:

Distt. Khammam: Dummugudem-15, Aswaraopet(a)-14, Venkatapuram-9, Yellandu-7.
Distt. Warangal: Eturnagaram-13.
Distt. Medak: Ramayampet-9.

The spatial distribution of rainfall activity associated with this weather system on different days from 1st to 6th November is shown in Fig. 2.2.9. It shows north-northeast ward movement of rainfall activity associated with the system. Associated with the system, heavy to very heavy rainfall was reported over Coastal Andhra Pradesh and adjoining area from 2nd to 5th November.

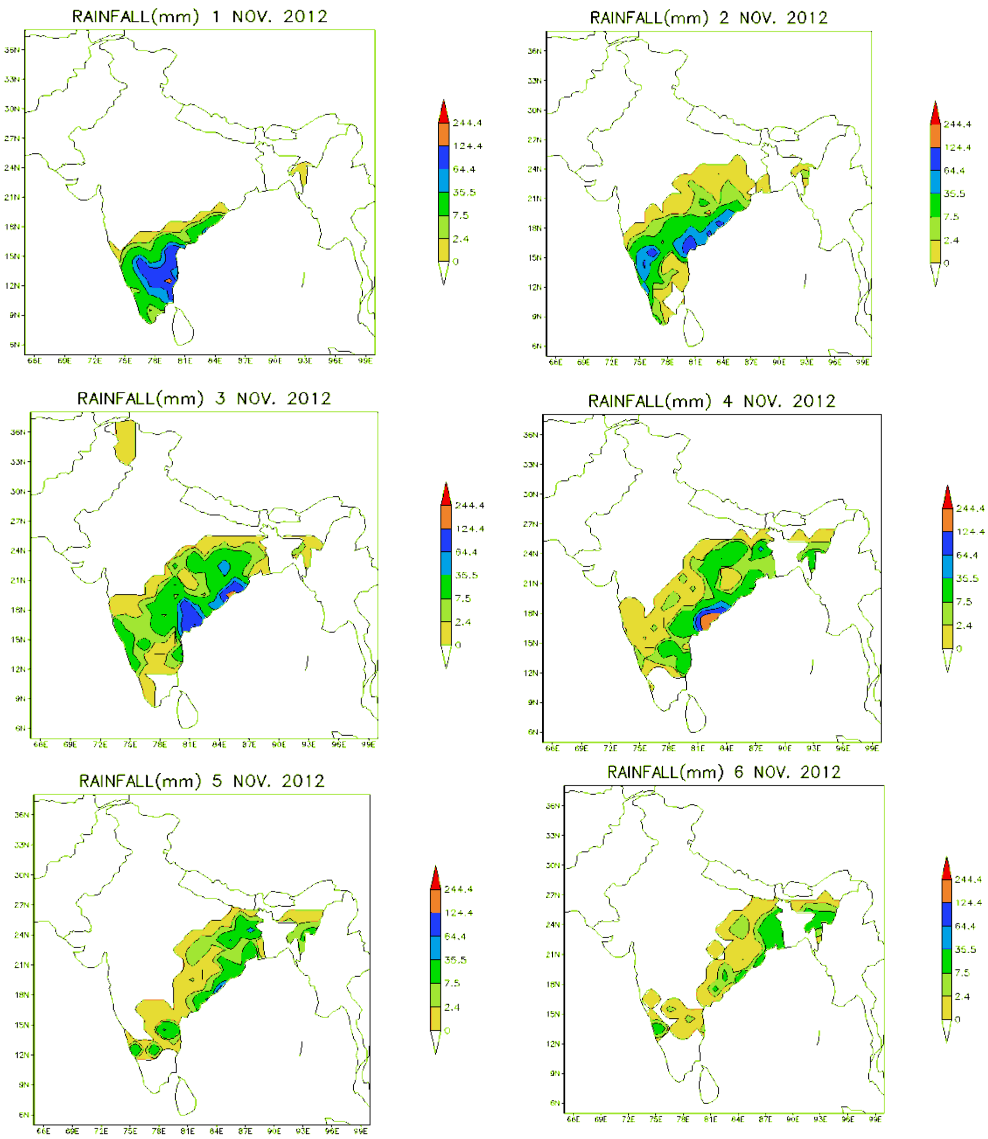


Fig.2.2.9. Spatial distribution of rainfall (mm) activity during 1st to 6th November 2012. The shading is based on IMD classification of rainfall like very light, light, moderate, rather heavy, heavy, very heavy and extremely heavy rainfall

2.2.10. Damage:

<u>Tamil Nadu</u>

In Tamil Nadu the incessant heavy rains caused flash floods leading to extensive damage. 17 people were killed and loss of live stock was 298. Paddy crop of 4646 hectares was submerged in Tiruvarur district due to heavy rains. About 5000 electric poles were damaged during the storm period. 415 huts were fully damaged and 3283 were partially damaged. 242 km of roads and 3 bridges were damaged by its impact. Samaanthipuram bridge was washed away in the flash floods in the upper reaches of Eastern Ghats. Damage photographs due to CS NILAM are shown in Fig. 2.2.9.

In Samanthipuram (Lat $12^0$39’ N and Lon $79^0$6’ E) village situated under foothills of Eastern Ghat in Tiruvannamalai district a bridge of length 100 m was washed away in the flash floods which occurred in the upper reaches of Eastern Ghat. This

Samaanthipuram Bridge is vital road link for neighboring three tribal villages. The flood water reaching Shenbahathope Dam breached near river sluice in the dam causing flash flood in KamandalaNaga Nadi- a tributary of Palar river.

Andhra Pradesh

In Prakasham district there was severe flooding. On November 1, more than 200 boats ran aground due to strong winds. As Nilam weakened, heavy rainfall continued affecting south coastal Andhra Pradesh, Rayalaseema and Telangana with heavy rains and flash flooding. The Kandaleru-Poondi part of the Telugu Ganga project near Gudur, overflowed cutting transportation across the river. Several villages in and around Ongole were inundated by floodwater. Severe flooding had blocked transportation between Ongole and the villages, stranding the villagers. Heavy rains in Visakhapatnam district led to a train derailment in Araku Valley. In East Godavari district, floodwater overflew a railway bridge. Around 500,000 hectares of cropland was ruined while 68,000 people were evacuated and taken to flood relief camps. A total of around 495 km (308 mi) of roads, 406 km (252 mi) of drains, 107 km (66 mi) of water supply lines, 10,882 street lights and 36 municipal buildings were left in ruins, after the storm. A total of 44 people were confirmed dead and the state suffered economic losses worth ₹200 crore.

Sri Lanka

The storm brought torrential rains to Sri Lanka. The Puttalam — Mannar road had come under about a meter of water near Eluwankulama due to the overflowing of the Kala Oya river. About 1,000 houses were damaged by the storm. Across Sri Lanka, ten people were killed in events related to Cyclone Nilam.

Photographs showing damage due to cyclonic storm, NILAM in Tamil Nadu

CHAPTER-III

CONTRIBUTED PAPERS *ON* CYCLONES & DEPRESSION

Abstract of Papers Published in Quarterly Journal, *'MAUSAM'*

1. Doppler Weather Radar analysis of short term cyclonic storm

D. PRADHAN and U. K. DE*
Doppler Weather Radar, New Secretariat Building, Kolkata - 700 001, India
* School of Environmental Studies, Jadavpur University, Kolkata - 700 017, India
e mail : pradhandev1960@gmail.com

ABSTRACT. On the east coast of India. during South-West monsoon period severe cyclonic storms are very rare and if they are short term cyclones then their prediction becomes very difficult due to rapid change in the intensity of the system. Though synoptic observations failed and satellite observations also cannot give decisive picture about such systems, in that case timely warning can not be issued by the weather agencies. Such a system was formed on 19 September, 2006 at about 250 km South-East of Kolkata (India). Very heavy rainfall associated with the system caused several human casualties and extensive damage to the property. According to news agencies, more than 100 people died and a million people became homeless due to heavy rainfall and strong winds associated with the cyclone during 19 September -21, 2006. At 0600 UTC, Doppler Weather radar (DWR) at Kolkata observed initial signatures of the system like a depression. Subsequently at 0900 UTC the observations indicated that the intensification of the system has taken place to a higher stage of deep depression and at about 1200 UTC clear spiral bands with a circular eye recorded by DWR confirmed for a fully developed severe cyclonic storm. The system weakened in to a deep depression at 1630 UTC after the landfall but again became a cyclonic storm at 2100 UTC of 19 September, 2006. Present study establishes that DWR is very useful for prediction of this short term cyclonic storm, its direction of movement and heavy rainfall associated. The maximum radial winds of the magnitude 32 m/s (64 knots! 115 km/h) were also recorded by DWR at an altitude of 2.5 km in the eye wall region of the system. The high wind speed and the well defined structure of the cyclone observed by DWR confirmed that the system was a Severe Cyclonic Storm of T number 3.5. Records are available with surface observatories in the region for strong winds of the order of 110 km/h. This study also revealed that an early warning for strong winds and heavy rainfall could have been issued for development of such a short duration tropical cyclone using DWR data well in advance.

Key words - Doppler Weather Radar, Severe cyclonic storm, Depression, Tropical cyclone.

2. Statistical prediction of seasonal cyclonic activity over North Indian Ocean

S. BALACHANDRAN* and B. GEETHA
India Meteorological Department, Meteorological Centre, Bangalore, India
(Received 27 April 2010, Modified 6 December 2010)
e mail : balaimd@gmail.com

ABSTRACT. The Northeast monsoon season of October to December (OND) is the primary season of cyclonic activity over the North Indian Ocean (NI). The mean number of days of cyclonic activity over NIO during this season is about 20 days. In the present study, statistical prediction for seasonal cyclonic activity over the North Indian Ocean during the cyclone season of October to December is attempted using well known climate indices and regional circulation features during the recent 30 years of 1971-2000.

Potential predictors are identified using correlation analysis and optimum numbers of predictors are chosen using screening regression technique. A qualitative prediction for number of Cyclonic Disturbance (CD) days is attempted by analysing the conditional means of the number of CD days during OND over NIO for different intervals of each predictor based on the 30 year data of 1971-2000. Predictions and their validations for the subsequent test period of 2001 to 2009, based on this scheme, are discussed. An attempt for quantitative prediction is also made by developing a multiple regression model for prediction of number of CD days over the NIO during OND using the same predictors. The regression model accounts for 70% of the inter annual variance. The root mean square error of estimate is 5 days and the bias error is 0.36 days. The regression model is cross validated by Jackknife method for each individual year using the data of 29 years from the sample excluding the year under consideration. The model is also tested for independent dataset for the years 2001 to 2009. Salient features of the model performance are discussed.
Key words - Statistical prediction, Cyclonic activity, North Indian Ocean, Correlation, Screening regression, Conditional mean, Multiple regression, Validation. Jackknife method.

3. Rainfall estimation of landfalling tropical cyclones over Indian coasts through satellite imagery

CHARAN SINGH, SUNIT DAS*, R. B.VERMA, B. L. VERMA and B. K. BANDYOPADHYAY

India Meteorological Department, New Delhi – 110 003, India

**Regional Meteorological Centre, Guwahati, India*

(*Received 19 November 2009, Modified 27 January 2011*)

e mail : csingh1964@gmail.com

ABSTRACT. One of the most significant impacts of landfalling tropical cyclones is caused by the copious rainfall associated with it. The main emphasis of present study is to provide some guidance to the operational forecasters for indicating the possible rainfall over the areas likely to be affected by the cyclones after landfall. Study of 14 past landfalling cyclones reveals that the maximum rainfall occurred in the first forward quadrant of tropical cyclone movement, followed by the second quadrant and the areas near the track of the cyclones. Isohyetal analysis of 24 hours rainfall for each cyclone reveals that occurrence of heavy rainfall is generally confined up to 150 kms radius from the storm centre and rainfall is found to generally extend up to 300 kms with gradual decrease in amount. The rainfall receiving areas are mostly covered with convective clouds with cloud top temperatures of -80 to -60 ºC, prior to and after the landfall of the systems. In 93% of tropical cyclones out of the 14 cases studied, 70 % convection lay to the right of the track. To examine the rainfall asymmetry due to asymmetry in distribution of convection, cloud top temperatures derived from satellite infrared imagery data have been taken as the proxy of strong convection. It is also revealed in the study that the slow moving tropical cyclones cause heavy rain rather than fast moving tropical cyclones. The Bay of Bengal cyclones which crossed coast as cyclonic storm and very severe cyclonic storm caused 71.4% rainfall within the range 0- 10 cm, 22.8% rainfall in the range 11-20 cm and 4.3% rainfall within the range 21-30 cm in the area of radius of 300 kms from the centre of the cyclonic storms. For the Arabian Sea tropical cyclones, in general, about 70% rainfall occurred within the range 16-25 cm in 24 hours.

Key words – Convection, Cloud top temperature, Land falling tropical cyclone, Rainfall asymmetry, Sectors.

CHAPTER-IV

Activities of the PTC Secretariat during Inter-sessional Period (March 2012 to February 2013)

Summary of the PTC activities during inter-sessional period March 2012 to February, 2013 is given below.

- As decided by PTC at its 39th Session (Nay Pyi Taw, Myanmar from 5 - 9 March, 2012), the PTC Secretariat developed the web space for the PTC Working Group on Hydrology (WG-H) and requested the Panel Member countries (through their respective PRs with WMO) for nomination of appropriate focal points from their respective NMHSs or the Offices responsible for the provision of hydrological services in their countries. Response from the member countries is awaited. On receipt of the nominations from Members, PTC Secretariat would prepare the list of experts/ Focal Points for WG-H and the same would be communicated to NMHSs of all Member countries, the Chair and Co-chair of WG-H, Focal Points for WG-H, UNESCAP and WMO. The information pertaining to WG-H is available at the web link: www.ptc-wmoescap.org/working group

- PTC Secretariat collected the contributions from Member countries for PTC Newsletters and published two issues of PTC Newsletter "Panel News" (Issue No.33 and 34) and distributed these issues among the PTC Member countries, UNESCAP, WMO and the other concerned international organizations. The electronic versions of the PTC Newsletters were also uploaded on the PTC website at the web link: www.ptc-wmoescap.org/newsletters

- As decided by PTC at its 39th Session (Nay Pyi Taw , Myanmar from 5 - 9 March, 2012), WMO made arrangements with the Indian Institute of Technology (IIT), New Delhi for the attachment of two storm surge experts - one each from Oman and Sri Lanka. PTC Secretariat extended invitation for this training to both countries through their PRs with WMO. The training for Storm Surge Experts was hosted by IIT, New Delhi during the period from 10 - 21 December, 2012. Financial support in lieu of travel and per diem was provided to the participants from the PTC Trust Fund through WMO.

- As per recommendation of PTC during its 39th Session, WMO in cooperation with Oman made arrangement to organize a workshop in order to conduct case study by participation of RSMC New Delhi and the PTC Members concerned. The primary purpose of the workshop was to allow the RSMC and the PTC Members to fully share the scientific bases for the operational tropical cyclone forecasting and thereby enhance the warning services in the PTC region. The workshop was hosted by Oman from 17-19 December, 2012 and the PTC Secretariat extended invitation to RSMC, New Delhi and PTC member countries Bangladesh, India, Myanmar, Oman, Pakistan and Sri Lanka. Financial support in lieu of travel and per diem was provided to the participants from the PTC Trust Fund through WMO.
- PTC has been collaborating with Typhoon Committee (TC) in the implementation of joint project "Synergized Standard Operating Procedures for Coastal Multi-Hazards Early Warning System (SSOP). PTC Secretariat strongly urged the

Panel beneficiary countries to actively participate in the activities of SSOP project in order for its successful implementation within time frame.

- With the support of Panel, Secretary of PTC represented the PTC during the 9th Session of the Intergovernmental Coordination Group for Indian Ocean Tsunami Warning and Mitigation (ICG/IOTWS-IX) (27-30 November, 2012, Jakarta, Indonesia). The purpose of his participation was to promote and enhance the cooperation between the two organizations and to complement each other's programmes and activities. The opportunity was also used to share PTC programmes and activities, especially related to the development of integrated multi hazard early warning system for the coastal areas of the Bay of Bengal and the Arabian Sea countries. The ICG/IOTWS Secretariat acknowledged the activities of PTC Secretariat and showed their interest in project as being complementary to ICG/IOTWS objectives.

- As decided by PTC at its 39th Session (Nay Pyi Taw Myanmar from 5-9 March, 2012) WMO made arrangements with the RSMC, New Delhi for the attachment of three Tropical Cyclone Forecasters - one each from Bangladesh, Myanmar and Oman. PTC Secretariat extended invitation for this training to these countries through their PRs with WMO. The training for the Tropical Cyclone Forecasters will be hosted by RSMC, New Delhi, India during the period from 01-12 April, 2013. Financial support in lieu of travel and per diem would be provided to the participants by WMO and from PTC Trust Fund.

- PTC at its 39th Session (Nay Pyi Taw, Myanmar from 5-9 March, 2012) urged PTC Members to again collect the valuable knowledge and research papers on the impact of climate change on tropical cyclone activities available in their respective countries and send their updated feedback and research papers/reports to the Adhoc Group (established during PTC-38, under the Chairmanship of the Secretary of PTC). The preliminary report has been prepared on the basis of feedback received from Panel Member countries and supplemented with information obtained from other sources. The same has been uploaded on PTC Website alongwith relevant research papers/reports at the weblink:http://www.ptc-wmoescap.org/AdhocGroup_workingGroups3.htm

- Information regarding financial support by WMO from the PTC Trust Fund and detailed breakup of expenses incurred by PTC Secretariat during the intersessional period (2012-2013) is attached as **Appendix-II.**

Appendix-I

Workshop on Tropical Cyclone Analysis and Forecasting
Muscat, Oman, (17 - 19 December 2012)
(DRAFT)
FINAL REPORT
WMO/ESCAP PANELS ON TROPICAL CYCLONES
Working Group on Meteorology

1. INTRODUCTION

At the kind invitation of the Government of Oman, Workshop on the Tropical Cyclone Analysis and Forecasting was held in Muscat, Oman from 17 to 19 December 2012. The workshop was organized by the Working Group on Meteorology (WGM) of the WMO/ESCAP Panel on Tropical Cyclones (PTC) according to the recommendation of the 39th session of PTC (5-9 March, 2012; Nei Pyi Taw, Myanmar).

2. BACKGROUND AND OBJECTIVE

At the 39th session, a problem was presented by the Members about inconsistencies between the advisories of RSMC New Delhi and the forecasts of NMHSs of the Members which were found in some cases of the tropical cyclones affecting the region during the 2011 cyclone season. In view of more adequate and consistent forecasting/warning services in the region, PTC decided to hold a face-to-face meeting of WGM with participation of RSMC and the Members concerned for achieving the better coordination among the Panel Members in the operational tropical cyclone analysis and forecasting procedures.

3. ORGANIZATION OF THE WORKSHOP

The workshop was attended by the forecasters of Bangladesh, India, Myanmar, Oman, Pakistan and Sri Lanka. It was also attended by the staff members of the Meteorology and Air Navigation of Oman as observers.

Workshop was focused mainly on 1) RSMC advisories distributed to the Members, 2) operational forecasting procedures in RSMC and the Members, 3) case studies on the cyclones with significant discrepancies between RSMC and the Members forecasts, and 4) general discussion for improvement of the situation and recommendations.

Members of different participating countries appreciated the cooperation extended by RSMC, New Delhi, especially in terms of issue of bulletins like tropical weather outlook & tropical cyclone advisory bulletins, cyclone best track data and graphics in electronic form available in IMD website and the reports on individually cyclonic disturbances prepared by RSMC, New Delhi and shared with the member countries. PowerPoint presentations made by RSMC and the Members during the workshop are also available from the WMO/TCP website together with this final report at http://www.wmo.int/pages/prog/www/tcp/Activities.html.

INCONSISTENCIES BETWEEN RSMC ADVISORIES AND NMHSS FORECASTS

Current status :

Various agencies involved in monitoring and prediction of tropical cyclones (TCs) over different Ocean basins perform analysis of TCs to determine the best estimate of a TC's position and intensity during its lifetime. This process is described as "best tracking". However, the best tracking process is temporally inhomogeneous by construction because available data and techniques and general knowledge have changed over time. Furthermore, it is also inhomogeneous spatially, as procedures and data availability differ at each agency. Thus, the resulting best track and intensities from any Regional Specialised Meteorological Centre (RSMC) sometimes vary from those estimated by National Meteorological and Hydrological Services (NMHSs). These differences in estimates create problems for disaster managers and public to combat with the disasters due to cyclones.

Currently, the location of the centre of the system is determined based on (a) Synoptic, (b) Satellite and (c) radar observations. The satellite is the main source of locating centre of cyclonic disturbances (CDs) over the mid-oceanic region. However, the observational data from ships and buoys support the decision sometimes. It is the case when the CD is far away from the coast and not within the radar range. When the system comes closer to the coast, radar position gets maximum preference followed by the satellite. When the system is very close to coast or over the land surface, the coastal observations get the highest preference followed by radar and satellite observations.

Intensity of a CD is generally reported as the maximum sustained surface wind (MSW) over a specified time period. Operationally, the value of MSW is almost never measured. The procedure followed in estimating the intensity necessarily deals with estimation of associated MSW, estimated central pressure and pressure drop at the centre with the available observations in the region. Currently, the intensity estimation takes into consideration (a) satellite (Geostationary, Polar and scatterometer etc), (b) Radar (conventional S-band cyclone detection radar and S-band Doppler weather radar) and (c) synoptic analyses. Like the location of the system, when the system is far away from the coast and not within the radar range, satellite estimated intensity based on Dvorak's technique (Dvorak, 1984) gets maximum weight.

When the system comes closer to the coast, radar estimated intensity is considered along with satellite estimated intensity. When the system is very close to coast or over the land surface, the coastal observations get the highest preference followed by radar and satellite observations for estimating the intensity.

REASONS FOR DIFFERENCE IN ESTIMATES OF RSMC AND NMHSS

(i) Observational data

Operational procedures to produce TC best track depend on the way the data are estimated and reported. The data available to forecasting centres at the time of decision making may be different for different centres.

- While most of the GTS data are common for all NMHSs and concerned RSMC, there may be the situation of availability/ non-availability of those data through failure of GTS link or slow speed of the link.
- Synoptic data may not be available to all centres on real time basis

- Data through special campaigns e.g. Ocean Cruise etc. during cyclone period by any agency may not be available to others
- The availability of latest observational tools like Doppler weather radar and high wind speed recorder, meteorological buoys etc may not be uniform at all centres.

(ii) Tools and techniques

The tools and techniques available for analysis of various layers of data including surface, upper air, satellite and radar etc. are not uniform for all the NMHSs and the concerned RSMC.

- The data plotting and analysis procedure is still subjective and manual in certain centres whereas, it is very objective in some centres.
- The location and intensity estimates by Dvorak's technique vary from centre to centre, as availability of the satellite imagery and products may vary from centre to centre.
- While some centres use microwave imageries to fine tune the Dvorak's estimates, some are still using manual estimation from visible/IR imageries. Some are also using objective Dvorak's technique (ODT).

(iii) Analysis procedure

- The criteria for classification also vary from centre to centre yielding different nomenclature for the same intensity of the system
- While some countries maintain round the clock watch and analyse every three hourly, some maintain dawn to dusk watch. Some countries though maintain round the clock watch, issue the bulletins twice a day or four times a day. As a result there may be variation in timing of up gradation/degradation of intensity of the system by different centres.

(iv) Decision making

The decision regarding the location and intensity of the system mainly depends on above factors. However, the human factor also plays a dominant role.

- The experience and expertise of the cyclone forecaster in decision making differ within and among the NMHSs and RSMC.
- Local knowledge and experience also helps in proper diagnosis of the system.

Recognizing the facts and circumstances it appears that

(i) Panel member countries National Tropical Cyclone Warning centre (NTWC's) should be set up or prepared in such a way that National Tropical Cyclone Warning Centre (NTWC's) can provide reliable and timely early warning independently to its own national authority to save lives and reduce loss of properties in case of communication cut off/failure among RSMC and National Tropical cyclone warning centre (NTWC's) during tropical cyclone or any disaster situation.

(ii) During the last 40 years NWP and Satellite communication has developed tremendously and more high computing technology compared to the past are available now. Projects should be undertaken to develop location specific (Bay of Bengal & Arabian Sea) Tropical Cyclone Model that can address climate change in the region for the benefit of the panel member countries.

(iii) More lead time for early warning can be obtained from high resolution NWP. Upper Air Observation or vertical profile of the atmosphere is one of the most important input for three dimensional analysis of weather systems and NWP model. Members should take initiative to strengthen upper air observations.

(iv) For the introduction and inclusion of the last 40 years progress and achievements in the field of science of meteorology into the NTWC's of panel countries, an in-depth gap analysis or need assessments of the NTWC's with respect to Physical infrastructure , data, products, analytical and forecasting procedures is required.

RECOMMENDATIONS

1. The workshop reiterated that analysis and forecasting of tropical cyclone should be performed based on the scientifically agreeable data and procedures.
2. There should be a mechanism to ensure sharing of all available data and products on real time basis among the RSMC and all members of panel countries, such as Website (RSMC and member countries websites – V-Lab etc…) in addition to GTS. It will ensure the uniformly available information to all forecasting centres to arrive at decision making.
3. There should be a discussion forum through internet or telephonic conversations, where the opinions of forecasters can be exchanged. In the absence of such discussion forum, a group mail can be created. Oman has volunteered to create a discussion forum within V-Lab project.
4. A status and need assessment reports of various NMHSs with respect to data, products, analytical and forecasting procedures to be prepared by WGM of WMO/ESCAP Panel on Tropical Cyclones (PTC).
5. PTC is requested to coordinate regionally for tools and technology transfer among panel member countries and to improve the tropical cyclone monitoring and prediction based on need assessment reports prepared by WGM. It also request WMO to carry out such technology transfers between the panel and other regional committees. Expert from the countries outside PTC can be invited for sharing of knowledge in future workshops.
6. The training of cyclone forecasters of panel members may be arranged on Dvorak's technique and application of various tools including Ensemble Prediction System (EPS) for tropical cyclone monitoring and prediction by PTC Members support from WMO.
7. The workshop reaffirmed that upgrade of a storm from deep depression to cyclonic storm is consistent between the members and RSMC.
8. At the end of the year post-analysis should be carried out internally by all PTC Members and RSMCs to determine the best track and intensity of a system. In case of the discrepancies between RSMC and NMHSs, those can be presented in the annual Review Meeting conducted each year and final decision can be taken on best track and intensity. The same will be published in the Annual RSMC Report for all purposes. Feedback from member countries on post analysis should be sent to RSMC.
9. A resource library on research studies with respect to tropical cyclones over north Indian Ocean may be created. Oman volunteered to host and

maintain this library within the V-Lab project as part of the panel PTC activities. In this regard PTC will promote research activities of the members. There should be research on short-lived suddenly intensifying cyclonic disturbances near the panel members countries coasts.

10. The participants felt that such case study workshops are very useful for sharing of knowledge and expertise also to improve tropical cyclone monitoring and prediction systems. Hence, such workshops may be conducted in regular basis, preferably once a year.

Appendix-II.

Statement of PTC Secretariat Accounts
(2012 - 2013)

S. No.	Opening Balance and Receipts.	Amount in Pak Rs.
1.	Balance after 39th Session of PTC	494,000/-
	Total	**494,000/-**
	Expenditures	
1.	Printing of 33rd and 34th Issues of the Panel News	90,000/-
2.	PTC Website Hosting Fee etc.	10,000/-
3.	Services for PTC website design/updation support	10,000/-
4.	Services for compilation work of Panel News Issues	35,000/-
5.	Stationery, envelops, postages and other miscellaneous items etc.	15,000/-
6.	Honorarium to Meteorologist-PTC Secretariat @ US$150/= per month (equivalent to Pak Rupees)	153,900
7.	Purchase of Cooler Toner for Colour Laser Jet printer	Nil
	Total I	**313,900/=**
	Net Balance in hand	**180,100/=**