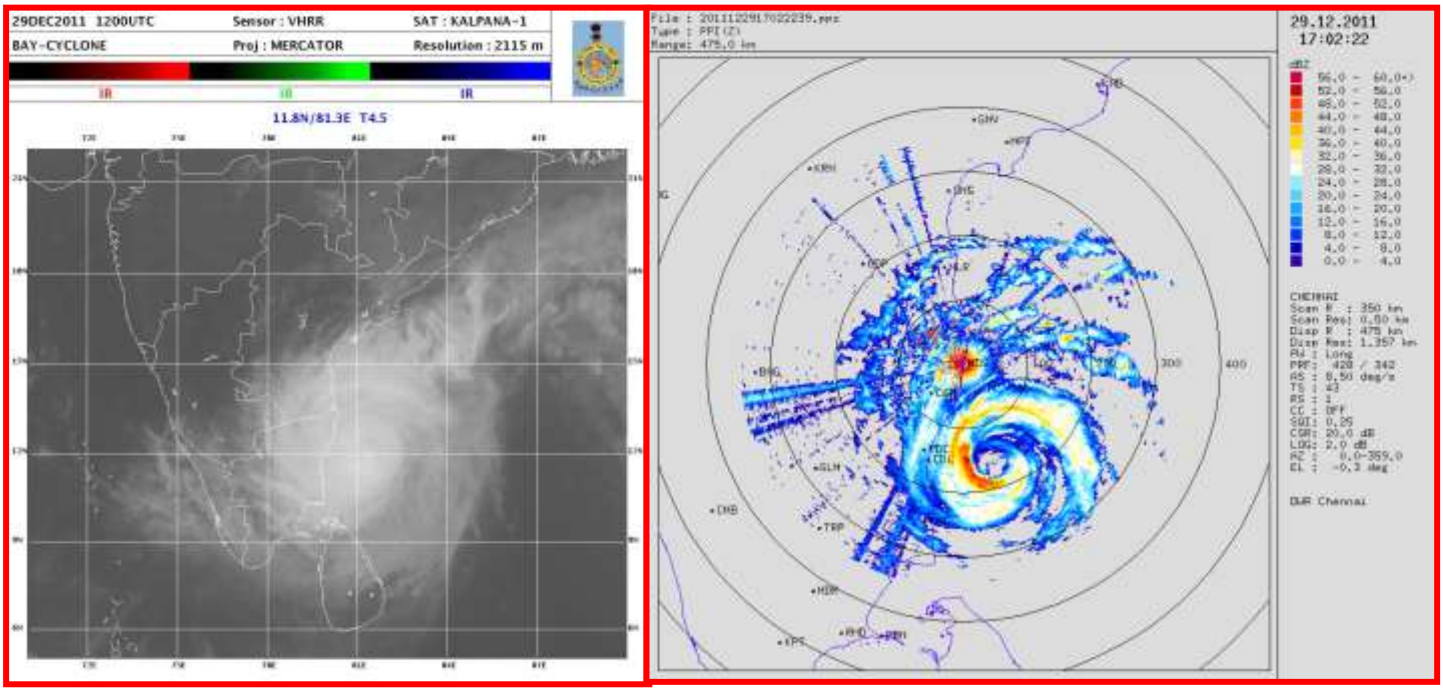
WMO/ESCAP
PANEL ON TROPICAL CYCLONES
ANNUAL REVIEW 2011



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

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

WMO **ESCAP**

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PANEL ON TROPICAL CYCLONES
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PREFACE

First commenced in 1997, the publication of ***WMO/ESCAP Panel*** *- Annual Review* has entered thirteenth year of issue for the year 2011. 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, 2011 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 upto 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.

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Vice-Chairman : Dr Thein Tun (Myanmar)
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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-2011 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 2011 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 2011. Based on the real time and climatological data available with India Meteorological Department (IMD), India, special features of the 2011 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 2011-2012

CHAPTER-I

WMO/ESCAP PANEL ACTIVITIES IN 2011

1.1 METEOROLOGICAL ACTIVITIES

Activities of member countries on WMO/ESCAP Panel for the year 2011 were presented at the thirty-eighth session of the WMO/ESCAP Panel on tropical cyclones held at Nay Pyi Taw, Myanmar from 5 - 9 March 2012. 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:

Bangladesh

a. Surface Observation

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

b. Upper Air Observation

(i) There are 3(Three) Rawinsonde observatories in (BMD).
(ii) (ii) There are 10(Ten) Pilot Balloon observatories in (BMD).

c. Brief description of ground equipment

(i) Cyclone Detection Radars:

- In 2007, two S-band Doppler radar systems were established and operational by replacing the conventional radar at Cox's Bazar and Khepupara.
- These two S-band Doppler Radars are utilized to monitor tropical cyclones and quantitative rainfall forecasting in the coastal belt.

(ii) Radar for Flash Flood Warning

- In 2009, another Hydrological cum Meteorological S-band Doppler Radar System was set up at Moulvibazar (northeastern side of Bangladesh) with the grant aid of Japan.
- The flash floods due to heavy rainfall from severe convection over the steep hilly region of India in the north eastern part of Bangladesh causes enormous loss to crops and infrastructure within a short span of

time. To monitor this and its associated rainfall this Radar System is being used.

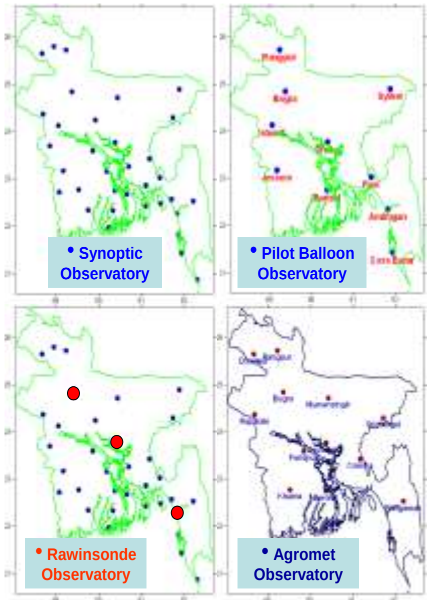
(iii) Storm Detection Radars

There is One (1) Radar at Rangpur, North-western part of Bangladesh to monitor local severe storms (Locally known as Kalboishakhi) in the north-western part and central part of Bangladesh.

(iv) Automatic Weather Station(AWS)

6(Six) AWS stations have been installed at six different observatory in BMD under Japan International Cooperation Agency (JICA) project on **"**Development of Human Capacity on Operation of Weather Analysis and Forecasting.**"**

d. Meteorological Satellite Reception and data processing System



Observational Facilities
a. Synoptic observatories : 35
b. Pilot Observatories : 10
c. Rawinsonde Observatories : 3
d. Agromet observatories : 12
e. RADAR Stations : 5
(operational, three are Doppler Radar)
f. Earthquake Monitoring Stations: 4

- Under the programme of JICA, BMD is receiving **MTSAT** satellite image at 30 minutes interval.
- Recently BMD is using MICAPS 3.1 to receive satellite imagery from **FY2D** through Chinese Meteorological Administration (CMA).

e. Numerical Weather Prediction (NWP) in BMD

Weather Research and forecast (WRF) Model:

Current Status:

- WRF model is running in BMD since July 2010.
- Using Global Forecast System (GFS) data from National Centre for Environmental Prediction (NCEP).
- Time : 72 hours, at 00 UTC
- Resolution : 27 Kms
- Start at : 10:00 AM
- Time required: About 1 hour 20 min.
- Products Generating: Rainfall forecast for 24, 48 & 72 hours and same with district boundary.
- Initially model ran manually but recently model running automatically.

Requirement:

- Technical support and Training for different levels including Advance WRF.
- Model run using European Centre for Medium Weather Forecast (ECMWF) data and Global Spectral Model (GSM) data of Japan Meteorological Agency (JMA).
- Data assimilation
- Large computing power to increase resolution and decrease run time.
- Validation using different statistical technique.

IIT-Delhi Storm Surge Model:

Current Status:

- Operationally used in BMD
- Well tested and simulated for different cyclones with different parameter.
- Both LINUX and Windows version are installed in BMD.
- People of BMD are capable to run the model.
- BMD people received several training on this model.

Requirement:

- High resolution output
- Input data from other models

MRI Storm Surge Model

Current Status:

- ✓ BMD arranged a 5-day long training workshop in December 2010, facilitated by RIMES Bangkok
- ✓ Other model products (surface wind, pressure) can be used as input of the model.

- ✓ GSM data of JMA are used to run the model along with conventional parameters.
- ✓ BMD people are capable to handle the model.
- ✓ Not yet tested well

Requirement:

- Further training at different levels including advance level is needed.
- More tuning needed for Bay of Bengal (BoB) Basin
- Coupling with WRF or other model
- Use ECMWF data or other model data as input.

BMD has been using JMA GSM for NWP since October 2010. The resolution for the surface is 0.25°x0.25° and for upper air is 0.5°x0.5°. The model outputs are updated everyday accordingly at BMD's website www.bmd.gov.bd

Telecommunication Network in BMD

Meteorological Data from Regional Telecommunication Hub (RTH) New Delhi and 10 synoptic observatories of BMD are exchanged on routine basis through WMO's Global Telecommunication GTS. All the 35 observatories of BMD have been connected with National Meteorological Computing Centre (NMCC) Dhaka either by Tele Printer (TP) or Telephone and single sideband (SSB) etc. or by all the three systems. Some of the observatories are connected through internet with NMCC and data are collected on real time basis by using Meteorological Data Acquisition software. The communications between Storm Warning Centre (SWC) and Radar Station at Cox's Bazar and Khepupara have been upgraded to Very Small Aperture Terminal (VSAT) link. NMCC uses Message Switching System (MSS) software obtained from WMO/UNDP Regional Computer Network programme for reception and transmission of all meteorological data.

All the observatories and operational offices of BMD are functional round the clock under the direct administrative and technical control of the two Regional Meteorological Centers. Staff are available to run BMD activities in 24x7 mode.

Coastal Inundation Forecasting Demonstration Project (CIFDP)

Bangladesh Sub-Project – CIFDP-B

The Bangladesh CIFDP sub-project, denoted as CIFDP-B, formally started after achieving the Initial National Agreement in October, 2011. Immediately thereafter, a Stakeholders Workshop, encompassing both a user requirements component and a technical component, was organized and held during 28 November - 1 December 2011, hosted at the BMD in Dhaka.

The Stakeholders Workshop involved more than 50 participants including members of the Project Steering Group and other international experts as well as a large number of stakeholder agencies in Bangladesh, including the BMD, Bangladesh Water Development Board (BWDB), Cyclone Preparedness Programme (CPP), Disaster Management Bureau (DMB), and Bangladesh Coast Guard (BCG), Regional Integrated Multi-Hazard Early Warning System For Africa and Asia (RIMES), and many others.

The outcomes of the Workshop included a Definitive National Agreement (DNA) and Terms of Reference (TOR) for the CIFDP-B National Coordination Team (NCT), as well as a proposed work plan for the first year of the project. The DNA and ToR has been submitted for senior management approval of the signatory agencies.

Information of BMD's Sixth Five Year Plan (2011-2015)

Sl. No	Project Name & Implementation period	Goals	Targets	Activities (program/project)
1.	Development of Human Capacity on Operation of Weather Analysis and Forecasting. July 2010- Dec 2012	The overall goal of the Project is to improve the capacity of Meteorological Service through improving the weather analysis and forecasting by NWP technique. It will also improve the capacity of BMD in climate data management and its application in climate change impact assessment and scenario development, management of climate data and running of climate model. Through calibration of all the radar, the issuance of the quantitative rainfall forecast by BMD will be	This Project is targeted on the development of human capacity of BMD on weather analysis and forecasting, introduction of basic knowledge and methods of the aforesaid modern weather analysis technologies as well as utilizing the equipment which are and to be established under the grant aid assistances of the Government of Japan including the other systems utilized for the weather forecasting and analysis.	To conduct the training on Meteorological Observation, basic NWP system, data acquisition and quality control and maintenance of the instruments. To revise the existing guideline on Meteorological Observation in accordance with latest WMO edition. To establish the correlation between actual rainfall and estimated rainfall for quantitative rainfall forecasting.

		improved.		
2	Establishment of NWP System (2nd Phase) July 2011- June 2014	To achieve a new sophisticated quantitative weather forecasting technique for disaster mitigation & socio-economic development.	To improve forecasts for longer lead time and accuracy. Quantitative precipitation forecasts for 6 or 12 or 24 hourly, 36 hours, 72 hours. NWP capability is integrated with other developments, e.g. radar, automation of terrestrial observation stations including all future development.	□ Renovation of the existing observatories. □ Training of BMD's personnel to run NWP system. □ Installation of super computer and others NWP equipment □ Real time data dissemination.
3	Establishment of Automatic Meteorological Observing System and Wind Profilers for BMD. July 2011- June 2014	The medium and long term goals are to contribute to the improvement of living standard of the people of Bangladesh and to the sustainable development of socioeconomic activities including activities of any sector through the provision of improved hazardous weather and climate information to meet the future needs and help the government and the public in taking development programs in more planned manner and also contribute to effective development of all	• Data collection system to be replaced by the AWSs and dissemination through a reliable telemetry on real time basis. • Seasonal climate forecast for agriculture and climate scenario-development in local perspective for proper adaptation and mitigation of climate change. • Improved aviation forecast for the International aircrafts through wind profilers.	□ To establish AWSs and dissemination through a reliable telemetry on real time basis. □ Up-gradation of existing system to AWS for integration in NWP. □ To make safe air navigation, landing and take off.

		sectors in Bangladesh.		
4	Up-gradation of Agro-Meteorological Services July 2009- June 2013	Overall goal of the project is to provide weather information for agriculture, shipping, fishing and aviation and daily weather forecasts to the general public.	The Project is targeted to use science of meteorology to the service of agriculture in all its various forms and facts to improve the sensible use of land to help to maximize food production and to avoid the irreversible abuse of land resources. Farmers will be guided by agro meteorological advisories and specially tailored forecasts for operations such as proper timing for sowing, planting, harvesting, irrigation, fertilizer application, spraying of pesticides etc. This will help to increase production, reduce losses and decrease costs and ensure food security.	For proper maintenance & technical adoption and manpower training and capacity strengthens for timely and accurate forecast/warning.
5	Establishment of Solar Panels in Existing Observatories Bangladesh. July 2013- June 2015	To introduce the renewable energy for meeting up the deficit of commercial power of Bangladesh for continuous running of the observatories and communication system.	Installation of the solar panel system at the roofs of all the observatories of BMD to have uninterrupted Power Supply for continuous operation of BMD.	* Installation of photo voltaic cell of solar panel system. * Physical connection of all the sensor. * Power back up during load shading time.
6	"Preparation of Wind Map of Coastal Areas	For assessing the potential location regarding wind	Access of a systematic assessment of wind resource and	

	/ Feasible Areas of Bangladesh for Assessing Power Generation Potential" July 2011- June 2013	generation to design an efficient wind mill.	generation of wind energy which will play a vital role in the field of socio-economic development. Power generation source will be Enriched to provide energy in national power grid.	
7	Establishment of 1st Class Observatory at Five Places [Panchagar (Tetulia), Kishoregonj (Nikli), Khagrachari (Dighinala), Cox's Bazar (St. Martin) and Bandarban Jan 2009-June 2013	To mitigate disasters and sustainable agricultural development in Bangladesh.	To take observation of local weather system & to collect agro meteorological parameters for issuing agro meteorological bulletin/advisory.	• Acquisition and development of land • Construction of buildings. • Equipment installation • Manpower developed
8	Improvement of DMO Sylhet and PBO Feni & Construction of Residential Building at Dhaka For Operational Officers and Staffs of BMD Dec2011- June 2014	To upgrade the observation system and to solve residential problem of operational people. To help the disasters mitigation and socio-economic development of the country to elevate poverty.	To Improve the existing Meteorological Observatories at Sylhet and Feni and to install digital Meteorological equipment along with telemetry, to provide residential building for operational officers & staff of BMD performing operational activities in feeding digital Meteorological data to the national forecasting and warning center SWC to reduce the major losses of lives and properties by natural disasters.	□ Proper maintenance & technical adoption. □ Upgrade of observation system and dissemination of Met. data. □ Solvency of accommodation facilities of operational people.

India

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

a. Surface Observatories

The network of surface meteorological observatories consists of total 1073 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 (Dept.)	55	53	30	29	17	16	200
II (b), II (c), II (d), III & IV, V, VI Io & EMO (Non Dept.)	108	71	46	32	47	25	329
V (Non Dept. HMO)	64	17	55	21	12	11	180
TOTAL	227	141	131	82	76	52	709

RMC*: Regional Meteorological Centre

High Wind Speed Recorders (HWSRs)

A newly designed HWSR system has been installed at Puri and same is already installed at other coastal stations along Bay of Bengal. These are Digha Visakhapatnam, Chennai, Nellore, Machilipatnam & Karaikal and on the West coast Mumbai (Colaba).

AWS Network

Under the modernization project for installation of 550 AWS, an earth station has been installed and so far 382 AWSs have been installed & commissioned. Under the project for installation of 1350 Automated Rain Gauges (ARGs), 356 ARGs have been installed.

Recent Achievements

a. Augmentation of surface ozone network: Installation of Surface Ozone Instruments at 10 stations.
b. Comparison of AWS data received through kalpana – 1 Satellite with Co-located obsy. data is in progress.
c. Installation of integrated Airport Meteorological Instruments (AMI) has been completed at Mumbai, New Deihi, Chennai, Guwahati, Chennai , Hyderabad, Jaipur Airports.

d. Installation of Transmissometers at 6 Airports.
e. Installation of sky radiometers at 13 stations.
f. 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.

Future Plans

Several developmental schemes/plans are under way at different stages. Some of these are:

- Commissioning of AWS -550 nos.
- Commissioning of ARGs - 1350 nos.
- Development and supply of Hand Held data logger for Automation of Surface Observatory.
- Modernization of manufacturing capabilities of Surface meteorological instruments in workshop at Pune

b. Upper Air observatories

In IMD, upper air observations are taken at 39 Radiosonde/Radiowind stations including 2 stations for radiosonde data only, twice a day on operational basis. These observations provide Met data i.e. pressure, temperature, humidity & wind at various levels in the atmosphere up to an altitude of 30-35 km.

There are 62 Pilot Balloon observatories spread all over the country conducting upper air wind measurements 2- 4 times a day providing wind speed and direction up to a maximum altitude of 10 kms employing optical theodolites.

1. Cyclone Detection Radars (CDRs) :

At present there are 10 Nos of S-Band Radars which are operational. Out of these, 6 are Doppler Weather Radars(DWRs) operational at Chennai, Kolkata, Machilipatnam, Visakhapatnam, Sriharikota (SHAR) and Mumbai. 3 conventional CDRs are working at Kochi, Karaikal and Paradip. SHAR Sriharikota has indigenous DWR developed by ISRO.

1.2 Storm Detection Radars (SDRs):-

There are at present 5 SDR working at Nagpur, Agartala, Ranchi, Kolkata and Guwahati for the purpose of storm detection. Two S-band radars are also working one each at Sriganganagar and Jaisalmer for monitoring development of convective clouds and thunderstorm formation. Radars at Nagpur and Agartala are under replacement with DWR in phase -I of Modernization.

3. Wind Finding Radars:-

There are 3 X-band wind finding radars working at Bhubaneswar, Ahmedabad and Bangalore.

4. Weather cum Wind Finding Radars:-

There are 2 X-Band radars used for weather cum wind finding purpose. These are installed at Machilipatnam and Karaikal. Two radars at Mohanbari and Srinagar have been dismantled. DWR is being installed at Mohanbari, under Modernization phase-I & likely to be commissioned by 2011.

Under modernization, on-going schemes, their present status and future plans are as follows:-

On-going schemes and their present status

(A) Procurement of 2 Nos. of DWRs from M/s BEL Bangalore

IMD is 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. These radars are under installation at Mumbai and Bhuj and are likely to be commissioned by First Quarter of 2012.

(B) 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 to be installed at Delhi (Palam), Hyderabad, Agartala, Nagpur, Patna, Mohanbari, Patiala, Lucknow, Bhopal, Goa, Paradip, and Karaikal. Radars at Mumbai, Bhuj and Goa are dismantled.

(C) 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. Radar at Mausam Bhawan Delhi has been installed and will be commissioned by the end of December 2011 while the radar at Jaipur is being installed and commissioned by January 2012.

(D) Procurement of Disdrometers for calibration of rain rate at DWRs stations:-

IMD has inducted 7 DWRs in its observational network and 14 more will be added by the end of first phase of modernization. With the aim to calibrate / validate rainfall data of these DWRs, RFP for 9 Nos of Disdrometers have been finalized and approved by the competent authority. Out of 9 Nos of Disdrometers, 5 Nos will be purchased under FDP scheme which is also approved and 4 Nos will be procured under Atmospheric Observational System and this scheme has also been approved. Indent for these Disdrometers have already been submitted.

(E) Procurement of Mobile Radar:-

Under FDP project, IMD is planning to procure two nos. of Mobile radars.

Future Plans*:-*

(i) Modernisation phase II & Phase III :-

On completion of the modernization phase I, IMD will have 21 DWRs in its observational network. In the II and III phase of modernization, 34 more DWRs will be procured and inducted in the total radar network of 55 DWRs to bring entire country under radar coverage. Locations for 20 DWR installations have already been identified. The program of installation of 20 out of 34 DWRs is expected to be completed by December, 2014.

(ii) Establishment of National Weather Radar Operation Centre (NWROC) at New Delhi (HQ)

Action for setting up National Weather Radar Operation Centre (NWROC) has already been initiated. The committee constituted by DGM to give recommendations for establishment of NWROC has submitted its report. Detailed project report has also been prepared. The scheme has been included in the II^{nd} phase of modernization under networking of radars.

(iii) Establishment of National Radar Data Centre (ENRDC) at New Delhi (HQ) :-

Action for setting up National Radar Data Centre (ENRDC) has already been initiated. The committee is being constituted for the same.

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/Indian Air Force (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.

c) Meteorological Satellite

(i) Current status:

At present IMD is receiving and processing meteorological data from two Indian satellites namely Kalpana-1 and INSAT-3A. Kalpana-1 was launched on 12^{th} September, 2002 and is located at 74^0 E. INSAT-3A was launched on 10 April, 2003 and is located at 93.5^0 E. Kalpana-1 and INSAT-3A both have three channel Very High Resolution Radiometer (VHRR) for imaging the Earth in Visible (0.55-0.75 µm), Infra-Red (10.5-12.5µm) and Water vapour (5.7-7.1µm) channels having resolution of 2X2 km in visible and 8X8 km in Water Vapour (WV) and Infra red (IR) channels. In addition, the INSAT-3A has a three channel Charge Coupled Device (CCD) payload for imaging the earth in Visible (0.62-0.69um), Near IR (0.77-0.86µm) and Short Wave IR (1.55-1.77µm) bands of Spectrum. The Resolution of CCD payload in all the three channels is 1kmX 1 km. At Present about 48 numbers of satellite images are taken daily from Kalpana-1 which is the main operational satellite and 9 images are taken from INSAT-3A. Imaging from CCD is done 5 times during daytime only. All the received data from the satellite are processed and archived in National Satellite Data Centre (NSDC), New Delhi.

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

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

- Cloud Motion Vectors (CMV) are derived using three consecutive half hourly images from the operational Kalpana-I Satellite. WVWs are generated at 00, 03, 06, 09, 12, 15 & 18 UTC using IR imagery daily.
- Water Vapour Winds (WVWs) are derived using three consecutive half hourly images from the operational Kalpana-I Satellite. CMV are generated at 00, 03, 06, 09, 12, 15 & 18 UTC using water vapour imageries data.
- Sea Surface Temperatures (SST) are computed at 1^0 x 1^0 grid intervals from all Kalpana-I data on half hourly /daily /weekly/monthly basis.
- Outgoing Long wave Radiation (OLR) are computed at 0.25^0 x 0.25^0 grid intervals from all Kalpana-I data on half hourly /daily /weekly/monthly basis.
- Quantitative Precipitation Estimation (QPE) is generated at 1^0 x 1^0 Grid from Kalpana-1 imagery on half hourly/daily/weekly/monthly basis.

At present Dvorak technique is widely used but manually applied. Recently efforts have been made for automation of this technique. Automated Dvorak technique is running in experimental mode at Synoptic Application Unit, Satellite Meteorology Division.

Satellite Application Unit issues three hourly bulletins in general and hourly and half hourly bulletins in case of tropical cyclones. The unit has modified these bulletins and included the forecast part also since 2009.

The Satellite Meteorology Division updates twelve images on the IMD website every half hour from the VHRR payload. It also updates images of various geophysical products as and when available.

With the Web Archival System developed at IMD KALPANA/INSAT3A data products and imageries are being archived since January 2009. The automatic script is being used to keep and update the images/products on the website upto 2 months. These are available to all users.

On 23rd Sept 09, polar orbiting satellite OCEANSAT–II has been launched by ISRO which carries a ku-Band pencil beam scatterometer to provide ocean surface winds at 10 m ht for early detection of tropical cyclones.

Recently three-ground stations have been installed in New Delhi, Guwahati and Chennai for receiving real time MODIS and NOAA data. The following products are being received regularly:

A) Geophysical Products derived from NOAA

1. Atmospheric temperature profile
2. Atmospheric water vapour profile
3. Surface emissivity
4. Surface Temperature

5. Fractional cloud cover
6. Cloud Top Temperature
7. Cloud Top Pressure
8. Tropopause height
9. Cloud Liquid Water Content
10. Total Column Precipitable Water
11. Cloud Type (including Fog)
12. Total Ozone from GOME
13. Total Ozone from HIRS
14. Ozone Profiles
15. Land Surface Temperature
16. Sea Surface Temperature
17. Normalized Difference Vegetation Index (NDVI)
18. Fog detection

B) Geophysical Products derived from MODIS

MODIS Level 2 geophysical products (Terra and Aqua)

1. MODIS cloud mask (MOD35)
2. MODIS cloud top properties (MOD06CT)
3. MODIS atmospheric profiles, precipitable water and stability indices (MOD07)
4. MODIS aerosol product (MOD04)
5. MODIS Sea Surface Temperatures (IMAPP product)
6. Normalized Difference Vegetation Index (NDVI)
7. Enhance Vegetation Index (EVI)
8. Land Surface Temperature (LST)

IPWV measurements by GPS Satellites:

At present five GPS receiving stations are installed at New Delhi, Kolkata, Guwahati, Chennai, and Mumbai for measurements of Integrated Precipitable Water Vapour.

(ii) Digital Meteorological Data Dissemination:

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

Processed satellite imagery, analyzed weather charts and conventional synoptic data are up-linked to the satellite in C-band. Satellite broadcasts these data to DMDD receiving stations in S-band. DMDD receiving stations analyze weather imagery and other data to generate required forecast. There are 37 Nos. of DMDD stations installed in India. Three DMDD receiving stations are also operating in neighbouring SAARC countries at Sri Lanka, Nepal and Maldives. These stations are receiving direct broadcast of cloud imagery, weather facsimile charts and meteorological data on an operational basis. The frequency of transmission from ground to satellite (uplink) is 5886 MHz and that of downlink is 2586 MHz.

Future Plan:

Under INSAT-3D programme, a new Geostationary Meteorological Satellite INSAT-3D is being designed by ISRO. It will have an advanced imager with six imagery channels (VIS, SWIR, MIR, TIR-1, TIR-2, & WV) and a nineteen channel sounder (18 IR &1 Visible) for derivation of atmospheric temperature and moisture profiles. It will provide 1 km. resolution imagery in visible band, 4 km resolution in IR band and 8 km in water vapour channel. This new satellite is scheduled for launch in 2010 and will provide much improved capabilities to the meteorological community and users. In preparation for the reception and processing of this data, SAC-ISRO has installed a data reception and processing system to process the data from the INSAT 3A and Kalpana 1 satellites. After full commissioning, the system will be able to receive and process the data from all the above three satellites on real time mode and produce the following products with respect to cyclone monitoring:

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

(iii) Analysis and Prediction

Cloud imageries from Geostationary Meteorological Satellites INSAT-3A and METSAT (KALPANA-1) are the main sources of information for the analysis of tropical cyclones over the data-sparse region of north Indian Ocean. Data from Ocean buoys also provide vital information. Ship observations are also used critically during the cyclonic disturbance period.

The analysis of synoptic observations is performed four times daily at 00, 06, 12, and 18 UTC. During cyclonic disturbance (depression and above intensity), synoptic charts are prepared and analysed every three hour to monitor the tropical cyclones over the north Indian Ocean.

The direction and speed of the movement of a tropical cyclone are determined primarily from the three hourly displacement vectors of the centre of the system and by analyzing satellite imageries. When the system comes closer to the coastline, the system location and intensity are determined based on hourly observations from Radar as well as from coastal observatories. The AWS stations along coast are also very useful as they provide hourly observations on real time basis. The WVWV and

CMV in addition to the conventional wind vectors observed by Radio Wind (RW) instruments are very useful for monitoring and prediction of cyclonic disturbance, especially over the Sea region.

(d) Prediction Models in operational use during the year 2011

NWP Division of IMD operationally runs three regional models WRF (ARW), WRF (NMM) and Quasi-Lagrangian Model (QLM) for short-range prediction and one Global model (T382L64) 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 NIO. IMD also makes use of NWP products prepared by some other operational NWP Centres like, ECMWF, GFS NCEP, JMA, UK Met Office Meteo France 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.

Models in the experimental mode

i. TC Ensemble Forecast Project in the PTC region

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.

(iv) HWRF for Indian Seas

Under NOAA-MoES Tropical Cyclone Program, 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 80^0x80^0 and inner domain 6^0x6^0 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 during the post-monsoon cyclone season 2011.

(e) Telecommunication Network in IMD

i) IMD maintains a very Extensive Telecommunication Network with Central Hub in its National Meteorological Telecommunication Centre (NMTC) at New Delhi, which is connected with five State of the art Regional Automatic Messages Switching Systems (AMSS) at Delhi, Kolkata, Chennai, Mumbai and Guwahati. AMSS at RTH New Delhi is upgraded with state of the art AMSS (Transmet) supplied by the M/s MFI, under the Modernization Project of IMD. For collection of Meteorological Data from the entire country and the neighboring Region/ Countries at NMTC, various modes of communication viz., dedicated leased line circuits, fax, internet, high speed data terminals, VPN connectivity, have been installed at various locations dispersed throughout the country & neighborhood.

ii) A new Transmet (RTH) System & Central Information and Processing System (CIPS) have been installed and are operational. These Systems were inaugurated by the Honorable Minister, Science & Technology & Ocean Sciences on 23-9-2010.

iii) For public weather information, Interactive Voice Response Systems (IVRS), popularly known as 'Weather on Telephone' has been installed at 26 stations (mainly state capitals) throughout the country. One can access current weather and forecasts for major Indian cities by dialing a toll free number 1800 180 1717.

iv) 52 (44 commissioned + 8 under commissioning) Stations have been provided VPN Connectivity, and are functioning for operational purpose.

v) 27 Stations have been equipped with 64 kbps High Speed Data Terminals (HSDT) connecting all important Forecasting stations.

vi) A network of 26 VSATs is being installed at selected seismological Observatories, Cyclone Detection Radar stations, Cyclone Warning Centers for reception of observational data utilizing communication Transponder of INSAT. Out of 26 stations, 24 stations have been installed and commissioned.

vii) A Satellite Data Dissemination System (SADIS-2G) (receive only) is in operation at New Delhi to receive Aeronautical Meteorological Information from International Civil Aviation Organization (ICAO) Centers which are routed to four International Airports of India for National and International Flight briefing and for providing data in GRIB/BUFR format for Wind/Temperature and Sig. Wx. Charts.

viii) Video Wall was commissioned in National Weather Forecast Centre (NWFC) with three years comprehensive Warranty w.e.f 30-8-2010.

ix) Video Conferencing Facility with H.Q.NWFC to 8- Forecasting offices at RMCs & Pune is nearly completed.

x) All the MFI System like Transmet, CIPS, Synergies, Clysis, PWS etc. were maintained by the MFI India team support till 22-7-2011 and these are being attended by the ISSD Officers w.e.f 22-7-2011.

xi) The Intra IMD Portal popularly called METNET was launched on 27th July, 2008, by the Information Technology (IT) Unit functioning under the Information System and Service Division, IMD 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.

xii) Training activities of Telecom Training Centre(TTC) during 2011

1) 51 Nos trainees were imparted training during 2011 for various courses conducted in TTC as per details given below:

S.No.	Course	No. of Trainees
i	Intermediate Training Course in Met Information System (Level-II)	08
ii	Familiarization Training Course in IT & Telecom Techniques	24
iii	Advance Term Course in Fundamental of IT & PC Applications	19

2) Revision of Syllabus of Telecom Courses by TTC was done for the following:

(i) Elementary Training Course in Met. Information Systems (Level-I).
(ii) Intermediate Training Course in Met. Information System (Level-II).
(iii) Advance Training Course in Met Information System (Level-III)
(iv) Familiarization Training Course in IT & Met. Telecom Techniques.

3) Revision of Syllabus for Intermediate Training Course in Met. Information System (Level-II) including E-learning /Self Study material of one month duration & three months regular course at HQ including one month On Job Training(OJT) has been done.

4) Revision of Syllabus for Intermediate Training Course IT & Met. Telecom Techniques including E- learning/Self Study material of one week & three weeks regular course at HQ is in progress.

5) WMO expert team from Education & Training Division of WMO visited TTC during 21st -22nd March, 2011 to have external assessment of trainings imparted in IMD for the IT System by TTC. The team appreciated the training courses.

xiii) Forecast of 100 Indian cities is made available on WMO website.

xiv) WMO Data Monitoring (Statistics) Percentage reception of Indian Synops is 98.64 %, Indian Temp is 53.63 % and that of Indian Pilot is 39.56 %.

xv) Traffic volume exchanged 125 GB per day approx.

xvi) Type of Date received at RTH and disseminated to Various IMD and Non-IMD Offices: ASCII & Binary

xvii) National Knowledge Network (NKN) Portability for Tele presence System of Ministry & Video Conference. NKN on all three services (i) Close user group (ii) Internet (iii) Telepresence operation at IMD HQ. Video Conference is also being done through the NKN.

xviii) Nodes LAN nodes LAN or nodes approx 500 at IMD HQ working are being maintained by ISSD LAN team round the clock 24 X 7 X 365 days.

xix) Up gradation of the Internet Service Provider (ISP) Bandwidth to 100 Mbps for IMD New Delhi (45 Airtel+45 Tata + 10 MTNL) completed. Already done & addition 1 GBPS link of NKN also implemented.

xx) Upgradation of ISP IMD Pune Office of fives ISP upgraded from 1 MBPS 1 LL to 20 MBPS 1LL.

xxi) Action is in progress for shifting AMSS Delhi to New ATS Building at IGI Delhi Proposal has been obtained from CMC and it is in process.

- Shifting of Synergies and Other MFI equipment at Nagpur Airport to DWR Nagpur Building. Instructions have already been issued to RMC Nagpur for shifting of all M.O. operations except Metar/Display to DWR Radar.
- Site Preparation for AMSS Guwahati & New AMSS at Nagpur is in Progress.
- Site at Nagpur & Guwahati is ready.
- CIPS handled 15 GB data daily on the average and about one year all data is archived on line on CIPS data base 15x365=5475.

12th Five Year Plan (2012-2017) Ongoing Schemes and New initiatives Taken up in ISSD

On Going Scheme

Name of Scheme
Replacement of AMSS at Guwahati & New Installation of AMSS at Nagpur and Mirror RTH for DRC Pune and operation & Maintenance.
Modernization of Communication facilities at field stations/Observatories.
Maintenance of new Website, Up gradation etc.
Spectrum Charges
Operation of MFI System like Transmet, CIPS, Synergies, CLISYS, PWS etc.
AMC for AMSS/HSDT/IVRS/PCs/LAN &other IT Infrastructure at H.Q. and at Field Stations.

VPN Circuits installation, Commissioning& Up gradation
Information System at HQ Video Conferencing
WMO Information System (WIS) Compliance with RTH New Delhi

New Initiatives

Name of Scheme
Up gradation of LAN, UPS, Back Up Power, PCs Adequate Bandwidth etc. for communication with all IMD Offices.
IT Security(Antivirus & IT Service, ISO Certification, Up gradation of LAN,UPS, Back Up Power, PCs Adequate Bandwidth etc. for communication with all IMD Offices.
Extension of Video Conferencing facility with 15MCs/AMOs
Augmentation of Data Base for CIPS to 100 TB or More & Procurement of other Hardware and Software.
Data Management and Supply System
WMO Information System (WIS) Compliance RTH New Delhi.
Procurement of IP based Cameras PCs/Data Terminals/Mobile/GSM Internet for all RMCs /MCs /AMOs/ AMSS/ DWRs/Coastal Observatories/Islands etc.
Replacement of 4 AMSS at Delhi, Chennai, Mumbai and Kolkata.

Maldives

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.

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

Total of 23 AWS have been installed and are in operation.

Upper Air Observation

Radio-Sonde observations at the Meteorological Office, Gan (WMO # 43599) were launched in 2011 with some discontinuity due to software problem in the system and hardware issues with the Hydrogen Generator. Beginning from 1st October 2011, 8 observations were made at Gan within the scope of ongoing

DYNAMO project. Additionally, 4 radio-sonde observations were made at Male' (WMO # 43555) under the same project from 1 October till 15 December 2011.

However, still there is no upper air sounding equipment in Male' and as the location of Maldives in the Indian Ocean happens to be a data sparse area in which shifting of ITCZ and phases of MJO takes place.Therefore,upper air observations from Male' 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.

Rainfall Stations

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

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

Meteorological Satellites.

Digital Meteorological Data Dissemination (DMDD) system donated by India Meteorological Department (IMD) receives WMO coded GTS data, half hourly cloud imagery from Kalpana and Fax charts in LRIT/HRIT format transmitted by IMD and display on a high resolution color monitor. Images can be further enhanced using different image processing functions and can be focused more on the area of interest. This system has the capability to plot the received met data by values or contours on a specific image. With all these features it helps forecasters to do more precise predictions. However, this system has been malfunctioning and assistance from IMD is required for full functioning of the system.

The High Resolution Satellite Image Receiving System GEOSAT 500 made by Australians did not function during 2011. It is required to pay a considerably high amount to the manufacturer to renew its service agreement.

The CMACast system has been generously donated by CMA, China in late 2011 and hopefully the installation would take place during 2012.**MICAPS** (meteorological data analyzing) System donated by CMA is to be upgraded to its latest version too during their next visit.

DWR

DWR received as part of Multi-hazard Early Warning Systemhas been repaired in 2011. However, it needs further calibration of equipment by a professional and local technicians are unable to do the job.

NWP

The system which runs WRF model had problem most of 2011. However, the issue has been resolved now. Maldives Meteorological Service continues to use NWP output provided by RIMES, ECMWF, IMD and other web based NWP products.

Telecommunications

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

Global Telecommunications System (GTS) and Message Switching System (MSS)

MESSIR-COMM message switching system developed by COROBOR is a TCP/IP based multi-channel communication link that is capable of handling vast amount of data. Although this GTS is in operation throughout 2011, Maldives received many complaints from other countries of not receiving our radio-sonde observation (TEMP) message through GTS. Likewise, the monthly CLIMAT report sent via GTS also reported non receipt of data by users. I would like to take note on some efforts that have been made in late 2011 by RTH New Delhi, in this regard and still we have to look into this matter thoroughly and work closely to arrive at a sustainable solution.

Meteorological information through internet

The official website of the Maldives Meteorological Service http://www.met.gov.mv has served its users with current weather updates, forecasts, warnings, met reports and aviation weather charts.

Myanmar

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 highly accurate digital barometer, technical guidance methods were provided under the Japan International Cooperation Program's Improvement of Storm Forecasting Project (2010-2012). Meteorological services of Department of Meteorology.and Hydrology (DMH) were very supported by these tools, on job training to the daily weather forecast and severe weather analysis and forecasting. Meteorological instruments such as Automated Weather Observing System (AWOS) and thermometer were supported by CMA. Thailand International Cooperation Agency (TICA) provided meteorological instruments such as thermometers, Upper Air Radiosonde with one year consumerable ballons to DMH.

Oman

Surface Observation

There are a total of 39 meteorological stations out of which 23 are listed in the WMO's Regional Basic Synoptic Network (RBSN) including 2 radiosonde stations and 12 Regional Basic Climatological Network (RBCN) stations out of which 3 are listed in Global Climate Observing System Surface Network.

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.

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.

Wave Measurements

One wave radar measurement station was installed offshore of Qalhat (Sur)-Oman liquid Gas Company-. Another 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. One more station will be added at Muscat.

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 centers such as New Delhi and Abu Dhabi. A bilateral Internet Circuit, which was established between these centers and the 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 has 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.

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 operated by NOAA as well as from geostationary satellites operated by EUMETSAT. Also meteorological data are being received through Satellite distribution (SADIS) receiver.

Data Visualization

The DGMAN is using a visual weather application for visualizing the meteorological data and GRIB and BUFR format coded data. It is proved to be a useful tool for visualization, analyzing and forecasting the weather.

Computer Workstations

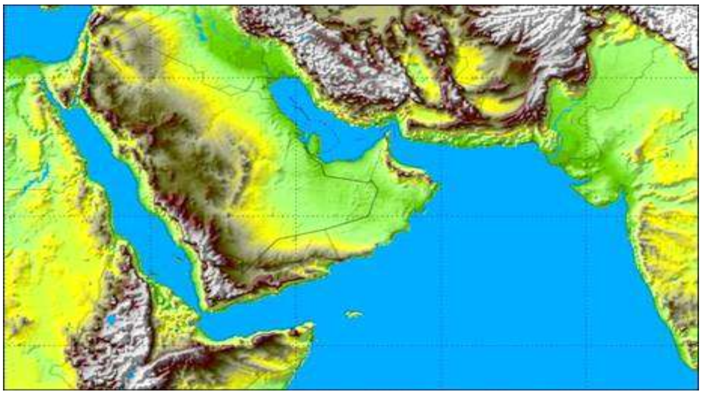
Data Processing System

Global 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 makes 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.

NWP

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 NWP 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 the following 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 NWP 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 runs an 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 Sea. WAM model has 14km resolution 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 inundation.

Model Output Statistics (MOS)

The 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.

Verification Package

The 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 used 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.

Aeronautical Services

In order to meet ICAO recommended practices and to fulfill the requirements for Aviation the DGMAN installed a SADIS workstation as early as 1996. Being effective for a few years, 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 through 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.

Future Plans

There are several goals that we plan to achieve in the near future. A network of 5 DWRs is expected to be installed by the end of 2012. In addition, more land weather stations are planed to be installed across the Sultanate. Moreover, recruitment of new staff is going on to overcome the shortage of forecasters and observers in the department. DGMAN also plans to implement a Quality Management System (QMS) in the near future in order to comply with ICAO aviation requirements. Progress is also going on in establishing a multi-hazard early warning center that will be responsible to issue warnings for natural disasters such as Tsunamis and Tropical Cyclone.

Pakistan

Establishment of Highest Glacier Monitoring Stations in Pakistan

Pakistan Meteorological Department (PMD) installed two AWSs for Glacier Monitoring in 2011. The first AWS was erected on 16th June, 2011 for recording ground based observation at an elevation of 4500m above mean sea level (a.m.s.l.) on the top of Passu and Batura Glaciers. The second AWS was installed in August, 2011 by PMD in collaboration with Italian research organization EV-K2-CNR near Concordia at Baltoro glacier. Baltoro glacier is located in Shigar basin. It has mean

length of 62 km and an area of around 640 square kilometers. It is the third largest glacier outside the polar region and many renowned peaks around 8000 meters high lie in its outskirts. The elevation of the Concordia is 4700 a.m.s.l and it is junction of many glaciers at Baltoro Glacier Complex. These AWSs continuously record the measurements of various parameters including precipitation, snow depth, wind speed and direction, temperature, relative humidity, incoming solar radiation (long and short wave) out-going terrestrial radiation (long and short wave) and net radiation etc. These monitoring stations together will help to compute the gradient flow of glacier mass, surface velocity and the rate at which glacier accumulates and loses its mass. Such monitoring mechanism will be replicated in other glaciated valleys of the Hunza Basin. . This is a step forward for the systematic assessment of the impact of the global warming on glaciers of Pakistan and resultantly assessment of the potential hydrological resources from glaciers of Pakistan.

Installation of CMACast System at PMD

CMA has presented the Integrated CMACast System to PMD in 2011. The CMACast System includes the following components:

- CMACast Reception Station;
- CMACast Geo-system (Satellite Data Quick Viewing Program and Automatically Processing Program); and
- MICAPS (Meteorological Information Comprehensive Analysis and Process System)
- Three engineers from CMA, visited Pakistan Meteorological Department (PMD) from 9 to 14 January 2012 to carry out the system installation and on-site technical training to PMD scientists and technicians.

NWP at PMD

PMD has been using High resolution Regional Model (HRM) of DWD (the National Meteorological Service of Germany) as an operational model for NWP since January, 2007. The model output (prognostic charts) are also 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. Now, PMD is planning to implement COSMO model (a non-hydrostatic model) with higher resolution. In this regard, PMD has sought support of DWD (Germany) and WMO for capacity building in NWP based on COSMO model (Consortium for Small-scale Modelling). In 2011, two scientists of PMD attended a training workshop on NWP using HRM and COSMO models.

Sri Lanka

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 of 35 AWSs has been mostly settled with the supplier.

Upper Air Observations

Radar wind observations in Colombo (43466) were carried out at 0600 and 1200 UTC until the end of March. Radiosonde observations were conducted three times a week at 1200 UTC with Indian and GPS sondes and later using GPS equipment alone as the Indian equipment was unserviceable. Pilot balloon observations were conducted at Puttalam (43424), Hambantota (43497) and at Polonnaruwa (new station) at 0000,0600 and 1200 UTC and at Colombo at 0000UTC and at 0600 and 1200 UTC to supplement the radar wind observations (to fill the gaps of any failures of the equipment) . Four radar-radiosonde observations were done daily during October-November with the support of CINDY project using GPS radar.

In addition, pilot observations were also conducted at Pottuvil (43475) during November and December to monitor the cyclonic conditions developing in the Bay of Bengal.

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.

Meteorological Satellites

The satellite imageries through internet were utilized throughout the year and the FENYUNGCast system was operational. Digital Meteorological Data Dissemination system (DMDD) donated by the Government of India through IMD encountered interference problems and request has been made to clear from telecommunication regulatory Commission. FENGYUNGCast is going to be upgraded with CMACast with kind gesture of CMA in 2012.

Telecommunications

Data and information exchange with RTH New Delhi internet lease line operated throughout. The system is integrated with SADIS and there are three visualizing terminals.

It also provides the warning with alarm in case of information provided by PTWC, JMA and RTSP, INCOIS with regard to potential tsunami situation.
Storm surge model, as per WMO/ESCAP training received, is operational as a routine at the National Meteorological Centre (NMC).

Improvement of facilities/Technical Advancement

Civil constructions with regard to Doppler Weather Radar was 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 a radar. The equipments have been received and installation is expected to complete in 2012. Construction of new buildings for Jaffna Meteorological office (where the condition of the buildings were very poor conditions) was commenced. A block of land has been acquired for construction of Trincomalee (43418) Meteorological office at a new site and construction of new buildings is scheduled in 2012.

An expert committee has been formed taking the leading role of Department of Meteorology to investigate and to minimize the damages due to lightning.

Under a bilateral agreement with Korea International Cooperation Agency (KOICA), a project to install a receiving system of Communication, Ocean and Meteorological Satellites (COMS) at Colombo has been commenced and the training prior to installation system has been completed. The installation of the system is expected to complete in May 2012. Arrangement has been made to receive CMACast from China and also expected to complete installation in 2012.

A link with RIMES was established for Reducing Risks of Tsunami, storm surges, Large Waves and other natural hazards in low elevation coastal zone. Under this programme, to improve the forecasting capability of the department, activities with regard to training and utilizing WRF model has also been commenced.

Thailand

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 tabled below.

No.	Region	Station	Types of Observatory		
			Pilot	*Rawinsonde (403 MHz)*	*Radiosonde (1680 MHz)*
1	North	Chiang Mai (Center)	•	NA	•
2		Phitsanulok	•	NA	NA
3	Northeast	Ubon Ratchathani (Center)	•	NA	•
4		Udon Thani	•	NA	NA
5		Nakhon Ratchasima	•	NA	NA

6	Central	Bangkok (Headquarters)	•	NA	•
7	East	Chanthaburi	•	•	NA
8	South and east-coast	Songkhla (Center)	•	NA	•
9		Prachuap Khiri Khan	•	NA	NA
10		Surat Thani	•	•	NA
11	South and west-coast	Phuket (Center)	•	NA	•

Before last October, the NMCs including the headquarters had disruption of TEMP message due to problem in Radiosonde and Radiosonde RS92 remained unserviceable. Thus, Pilot observation was replaced the Radiosonde observation.

For enhancement of upper-air observation, in spite of financial constraints, Thailand Meteorological Department (TMD) this year is being in the process of purchasing Radiosonde. After buying last year two sets of Rawinsonde, we are now considering proper places for installation.

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.

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.

Activities of WMO

The representative of WMO reported that, according to the Integrated WWW Monitoring (IWM) carried out on a quarterly basis from July 2010 to April 2011, the average availability of SYNOP reports ranged from 9% to 96% during this period in the Panel region The availability of SYNOP reports continued to be more than 70% for all countries, except for the Maldives, which continued to show a negative trend decreasing further to 9% of availability. Overall, the total availability of reports increased to 88% during this period from 86% in the previous year.

Average availability of TEMP reports ranged from zero to 49% with decreased availability in most countries. As during the previous period, the availability is around 11% for the Maldives with Myanmar not reporting TEMP. 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 45% in the previous year to 38% during this period.

In reference to the results of IWM, the representative of Myanmar advised WMO that there should be no upper-air station registered as a RBSN station.

Regarding the space-based observing system, the Panel was informed that 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-CNES Jason-1 mission; NASA-JAXA's TRMMM (with precipitation radar, microwave imager and lightning mapper); ESA's Envisat mission (namely with SAR and radar altimeter), 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). Missions planned for launch in 2012 include: the ISRO-CNES SARAL (with an altimeter) and JAXA's GCOM-W1 missions (with microwave imager providing all-weather sea surface temperature measurements). As concerns the Global Precipitation Measurement (GPM) programme, the launch of its core satellite is now planned for early 2014.

The Panel noted that WIS has been operational from January 2012, with an initial three GISCs (Beijing, Offenbach and Tokyo) offering the initial service. More GISCs are planned, including one in New Delhi. These are supported by Data Collection or Production Centres. 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) 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 representative of WMO stressed the usefulness of Common Alerting Protocol (CAP), International Telecommunication Union (ITU) Recommendation X.1303 as 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. The Panel Members were encouraged to consider early implementation of CAP for their warning services.

The WMO Secretariat briefed the meeting on the Severe Weather Forecast Demonstration Project (SWFDP), including its overall framework, the experience of developing other SWFDP regional projects.

The Panel was informed of the WMO SWFDP framework, including guidance from the Commission for Basic Systems (CBS) which is described in the basic documents: “SWFDP Overall Project Plan (2010)”, and “SWFDP Guidebook for Planning Regional Subprojects (2010)” that have been developed by the CBS Steering Group on the SWFDP.

The Panel noted that SWFDP aims to contribute to capacity-building and to help developing countries in particular to have available existing NWP products and make the best possible use of those products for improving warnings of hazardous weather conditions and weather-related hazards. Global-scale products, as well as data and information provided by other regional centres, are integrated and synthesized by a designated Regional Specialized Meteorological Centre (RSMC), which, in turn, provides daily guidance for short-range (days 1 and 2) and medium-range (out to day-5) on specified hazardous meteorological phenomena (e.g. heavy rain, strong winds, etc) to participating National Meteorological Centres (NMCs) of the region. This is a “Cascading” concept of the forecasting process, which is further discussed under item 7.

The meeting recalled that the SWFDP had been implemented successfully in Southern Africa and other three projects are in progress for the South Pacific Islands, Eastern Africa and for the Southeast Asia.

The meeting noted that the “SWFDP Overall Project Plan (2010)” is a high-level document targeting senior managers, which describes the SWFDP technical aspects related to weather forecasting (GDPFS) and public weather services (PWS) programmes; and general principles and conceptual framework for guiding project planning; while the “SWFDP Guidebook for Planning Regional Subprojects (2010)” provides a “template” and procedures for developing a Regional Subproject Implementation Plan (RSIP). The meeting noted that the development of an Implementation Plan for an SWFDP for the Bay of Bengal (South Asia) should follow the procedures as described in the Guidebook, with the required adjustments to address particular aspects of the region. The meeting further noted that the Implementation Plan, when developed, is required to be reviewed by the Steering Group for the SWFDP, and approved by the Regional Association, prior to its implementation to ensure that the required procedures had been properly addressed.

The Panel was pleased to note that a WMO/RIMES joint regional project for “Reducing risks of tsunami, storm surges, large waves and other natural hazards in low elevation coastal zones” has been implemented within the UNESCAP Tsunami Regional Trust Fund. Within this project, the Technical-Planning Workshop on SWFDP for the Bay of Bengal (South Asia) was held in New Delhi, India, from 23 to 27 January 2012. Participants included representatives (forecasters) of Bangladesh, India, Maldives, Myanmar, Sri Lanka and Thailand, representatives from global products centres (JMA, NOAA/NCEP and IMD/NCMRWF), and the WMO Secretariat within this project. The objective of the workshop was to develop a series of conclusions and recommendations on how the SWFDP-Bay of Bengal should be designed and developed for its first demonstration period, including the following aspects:

- which participating centres (global, regional, national)
- what geographical window (latitude-longitudes) should be adopted for the project
- which hazards, i.e. where warnings are issued by the NMHSs, and are the most important in this region (should at least include heavy rainfall and strong winds)
- what RSMC daily guidance hazard thresholds should be adopted (e.g. heavy precipitation at 100 mm/24-hr)
- what is the period of the season for each of the hazards
- what products should be requested from the global and regional centres (including locations for EPS grams to be supplied
- what forecasting guidance products from other RA II related projects could be included or linked to the SWFDP
- timetable and milestones

The Panel believed that the SWFDP had a vital role to contribute to the visibility and credibility of the NMHSs of the region as the authoritative sources for the provision and delivery of reliable, timely, accurate and useful severe weather warnings and forecasts. WMO expends considerable resources and effort to highlight the role of NMHSs in this regard and assists them with the delivery of user focused and relevant services.

The Panel welcomed the initiation of the SWFDP for the Bay of Bengal and some Members currently not included in the SWFDP expressed its interest to be associated with the project when the target countries will be increased. In this regard, the Panel requested WMO to explore the possibility to mobilize resources by contacting donors. The Panel felt that it would be worthwhile to consider developing a link with SWFDP as an AOP for 2012.

1.3 HYDROLOGICAL ACTIVITIES

Bangladesh

BMD provides all sorts of data, information and weather forecast to the Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB). A Metropolitan Area Network (MAN) between Storm Warning Centre (SWC), Dhaka and FFWC was established in 1998 through which FFWC receives meteorological and hydrological data (including rainfall and water discharge data of up stream) along with Radar and Satellite images.

Through the completion of the establishment of Meteorological and Hydrological Doppler Radar at the north-eastern part of Bangladesh under JICA Grant Assistance, FFWC is being connected by VSAT link to get all the radar information for flood and flash flood monitoring and forecasting. Also during execution of JICA's Technical Cooperation on the Human Capacity Development training will be imparted to FFWC for radar data calibration and its utilization.

Flood Forecasting and Warning Centre under BWDB for Flood Forecast in Bangladesh.

A. Data collection

- Voice data (HF Wireless network, 67 stations)
- Mobile telephone (3 stations)
- Telemetry System (14 stations)
- Satellite Imagery (GMS, NOAA-12 & NOAA-14)
- On-line data from Bangladesh Meteorological Department, including satellite and rainfall radar data

B. Satellite Imagery:

- Reception of NOAA-12 and NOAA-14 images via direct acquisition facilities
- Monitoring of cloud & depression movements, precipitation estimation from cloud temperature analysis
- Cyclone monitoring

C. Real Time Data Management

- GIS based map display showing water level and rainfall status (Flood Watch)
- Data entry & processing
- Automatic data exchange to and from forecasting model
- Display of forecast water levels and discharges
- Automatic generation of flood forecast bulletins
- Generation of flood status at local administrative unit (thana) level
- Automatic statistics generation

D. Flood Forecast Model

Basis: - One dimensional fully hydrodynamic model (MIKE 11 HD) incorporating all major rivers and floodplains. This is linked to a lumped conceptual rainfall-runoff model (MIKE 11 RR) which generates inflows from catchments within the country.

India

IMD is providing 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 district-wise rainfall summary has been modified to get outputs in Excel Format.

Preparation of weekly sub-divisionwise/ district-wise/state-wise rainfall reports including the statistics are carried out 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 2011 daily sub-division rainfall report (169 reports) were prepared and supplied to the Cabinet Secretary and other users. District-wise reports for last 5 years were put up on IMD Website and creation of sub-divisional rainfall maps was automated.

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. For this Mahanadi Basin is taken as pilot project for the flood seasons 2011 by using IMD's MME forecast. IMD's WRF (9 km × 9 km) model was also partly utilized in the flood season 2011 with 48 hours lead time. During the Flood 2011, 15495 QPFs were issued by FMO's and supplied to Central Water Commission for flood forecasting purposes.

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 carryied 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 report 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, survey 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 which affect any i 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.

Maldives

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

Myanmar

Occurrences of Floods in 2011

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 2011, there were floods at downstream of Ayeyarwady river, Chindwin river, Thanlwin river, Sittoung river, Dokhtawady river, Bago river, Shwegyin river and Ngawun river. Among these floods, the floods at downstream of Ayeyarwady, Chindwin, Dokehtawady and Shwegyin rivers were normal flood, with 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 Bago of Bago river and this flood was the highest record during last 47 years. This flood caused the inundation about 3-7 feet at 9 wards of Bago and also flooded 2-3 feet depth on highway road between milepost No. 48/7 and 49/2, milepost No. 49/6, and 49/4. Similarly, the flood occurred six times at Hpaan of Thanlwin in 2011 and the third flood wave exceeded the danger level by 6 feet and stayed about 26 days. This flood was the second highest flood by historical record (1966-2011). This flood affected the 610 households, 3132 people from 5 wards and 32786 acres of paddy field by inundation. At the Sittoung River, the flood at Toungoo occurred five times and the third flood wave exceeded the danger level by 2½ feet and the flood duration stayed 26 days and this flood duration was the longest duration by historical record (1966-2011). The flood affected 7501 households, 33754 people from 14 wards. Similarly, the noteworthy amount of rainfall was 225 mm at Ngathainggyaung of Ngawun river on 20-7-2011 and due to this heavy rainfall, the landslide was caused and the torrent left 3 people dead, destroyed the 22 houses and affected (830) household and 3307 people. This flood exceeded the danger level by 2 feet and stayed 51 days above danger level. During the year 2011, DMH has issued (34) flood warnings and (136) flood bulletins during 2011 flood season.

Apart from river flood, flash flood and severe landslide occurred at Pakokku district of Magway Region, due to the continuous heavy rain which amounted (6.65) inches at Pakokku, (5.95) inches at Gangaw and (9.34) inches at Nyaung Oo during 18-20 October 2011. It caused (161) death toll, lost 3384 livestock , affected (102) wards and villages, 9523 houses, 29751 population, and damaged 2535 houses, 15 government building, 33 religious building, 7 bridges, 5378 acres croplands in Pakokku District.

The peculiar urban floods were also encountered in Central Myanmar during the first week of October, due to the locally heavy fall in the areas for (2) to (3) days. The rain enhanced overflowing of the small streams and inundated about (400) houses and affected 4622 households in low land areas of Kyaukse township. Similarly, due to heavy rain during 1st to 3rd October 2011, the torrent flows was caused and it inundated about 2 days on the highway road and the crop fields at Yamethin township.

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 DMH 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 seven to ten 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.

Discharge Measurement

In order to provide runoff data, discharge and sediment discharge measurements are carried out every year at three sites in the selected three rivers by Hydrological Division, Upper Myanmar Division and Lower Myanmar Division. At the year 2011, measurements of discharge, sediment discharge and bed profile were implemented at Nyaung U and Thabeikkyin for Ayeyarwady river and Mawlaik for Chindwin River.

Acid Deposition Monitoring

As a national monitoring center 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. In November 2011, the sampling instruments for air concentration monitoring by Filter Pack method that supported ACAP has been installed at (Kaba-Aye) Yangon (Urban Site). The Laboratory of DMH has been able to analyze 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 2011, the two experts from Asia Center 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 such as QA/QC activities, quality management, quality system and so on; to setup the sampling instruments for air concentration monitoring by Filter Pack method and initial training for the implementation of the dry deposition monitoring; to setup the high efficiency distilled water generator in the laboratory and others.

GIS application in Hydrology

GIS application in meteorology and hydrology is initial stage at the present. The government has invested about 100 million Kyats for establishment of GIS application in DMH. During 2011, DMH has developed flood hazard analysis and flood simulation by using IFAS for small catchments and ungauged catchments. DMH is also implementing geomorphological parameters of Myanmar river systems.

Oman

The Ministry of Regional Municipalities and Water Resources is responsible for the hydrological measurements and the management of the water resources for the Country. During the year 2011, a measurement of all hydrological parameters was measured through a network of 4681 monitoring stations. This network includes rain gauges, wadi gauges, flow peaks, aflaj, springs and water level in addition to 36 dams distributed all over the Sultanate.

Rainfall

There are 362 rain gauges, of which 277 Automatic and 85 of standard type. About 47 of these rainfall stations are fitted with telemetry using GSM modems.

During the year 2011, the coastal areas of the country were exposed with exceptional rainfall as a result of Tropical depressions that affected Oman during the second tropical cyclone season in October and November. The maximum annual accumulated rainfall was 378 mm in Dhofar while in the east (Sharqiyah) 124 mm. The highest recorded in Muscat was176 mm and in the Interior region 256 mm was recorded at Nizwa.

Wadi flow and floods

There are 167 wadi gauge stations to measure wadi flow and to compute flood volumes. In addition, there are 25 stations to measure the peak height of the wadi flows. The year 2011 is considered one of the years where low discharge rates were recorded. The total flood volumes during 2011was estimated (190 Mm^3) which is below the annual average (220 Mm^3). The highest recorded was (284Mm^3) in Dhofar region in the southern part of the country.

Groundwater level measurements:

The Ministry of Regional Municipalities & Water resources operate a network of 2107 groundwater wells measured for water levels, 1644 of them are measured every month and the rest are measured every three months. Analysis of data showed that as a result of the decrease in the recharge, there is a gradual decrease in water levels in most areas of the Sultanate, except Muscat and South Sharqiyah regions where recharge as a result of Cyclone Phet is still in progress.

Dams

There are 3 types of Dams in Oman: 70 surface retention dams, 32 recharge dams and 12 Flood protection dams. On the 32 recharge dams stations for measuring flow and sedimentation, a total of 42 Mm^3 was retained by recharge dams during 2011. In addition, the Wadi Dayqah sdam in Muscat regions stored a total of 14.6 Mm^3.

Events

The Ministry arranged 3 main water resources related workshops and conferences during 2011:

- International Workshop on Hydrology, Nature and Engineering at the Sultan Qaboos University on 20th to 21st March 2011.
- World Water Day Seminar, 20-22 March, 2011 at the Sultan Qaboos University.

- International Conference on Drought Management Strategies in Arid and Semi-Arid Regions 11-14 December, 2011 at Muscat.

Achievements:

Some of the main Ministry achievements are listed below:

- The Ministry has completed 9 dams for groundwater recharge, flood protection and storage. In addition to that, there are 7 other dams under construction during this year.
- Several studies have been completed during last year that include the topics of dams construction, study of the increase groundwater level in some part of the country, study of water situation, drilling of exploration wells, rehabilitation of monitoring wells at Muscat area , wadi gauges and rain gauges affected by cyclone.

Pakistan

Flooding in Southern Pakistan

The extraordinary heavy monsoon rainfall and cloud bursts in southern Pakistan (an unusual location for heavy monsoon rains) caused severe flooding in Sindh province and some adjoining area of the Balochistan province. The seasonal rainfall over Sindh province was exceptionally above normal (+248%). The distribution of total rainfall during monsoon 2011 over Pakistan is shown in Fig.1.

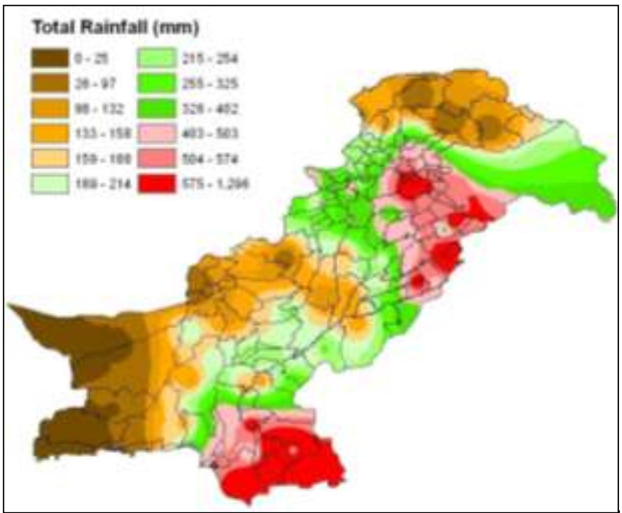


Fig.1: Distribution of rainfall over Pakistan during Monsoon 2011

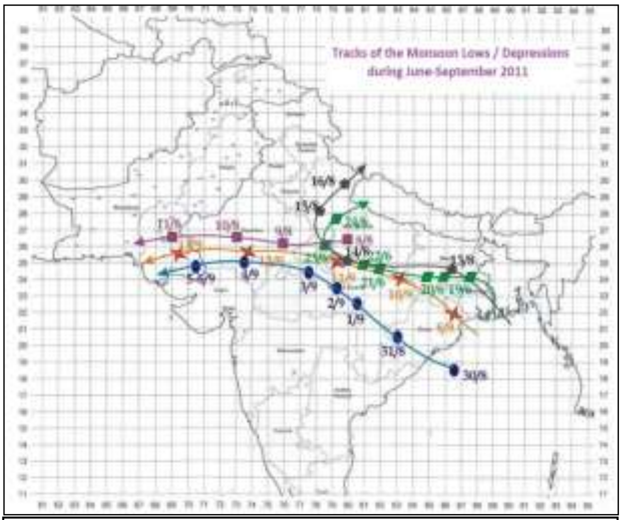


Fig.2: Tracks of the Monsoon lows and depressions during June-September, 2011

The significance of the 2011 monsoon rainfall in Sindh province is that most of the rainfall is received in just around four weeks period in August / September due to the three monsoon weather systems that approached this region successively during this period (Fig.2). The total volume of water fallen over Sindh province during this four weeks period is estimated to be above 49 million acre feet which is unimaginable.

Met. Stations in Sindh province	Normal Rainfall Monsoon Season (July-September)	Total Rainfall received during 2011 Monsoon Season (July-September)	Rainfall received during just around four weeks period (mid August to mid September)
Mithi*	288 mm	1348 mm**	1300 mm
Nagar Parker*	-	-	990 mm
Mir Pur Khas*	196 mm	866 mm**	866 mm
Diplo*	-	-	779 mm
Chachro*	-	-	735 mm
Nawabshah	113 mm	650 mm**	650 mm
Badin	187 mm	647 mm	643 mm
Chhor	186 mm	552 mm**	549 mm
Dadu*	68 mm	485 mm**	482 mm
Padidan	94 mm	423 mm	423 mm
Hyderabad	121 mm	409 mm	402 mm
Karachi Airport	136 mm	281 mm	270 mm
* observation record less than 30 years ** new record for the monsoon season			

The rainfall was predicted well in advance by PMD and the disaster management agencies were well prepared and responded appropriately. However, the scale of this natural calamity combined with the topography of the area having very poor natural drainage, was very large. Owing to low lying area, most of the rain water stagnated and breaches in Left-Bank Outfall Drain and irrigation channels further aggravated the situation causing complication in the scale of flooding.

According to the National Disaster Management Authority (NDMA) of Pakistan, the extraordinary heavy rains and floods took 520 lives and affected 9.619 million of population. The detail of damage is given in the following Table.

Table: Impact of 2011 Floods (Source: NDMA, Pakistan)

Impact	Losses in Figure
Deaths	520 (497 in Sindh & 23 in Balochistan)
Injured	1180 (753 in Sindh & 427 in Balochistan)
Area Affected	6,763,454 (6,674,859 Sindh & 88,595 in Balochistan)
Total Population Affected	9.619 Million (9.27 in Sindh & 0.349 in Balochistan)
Houses Damaged	1,604,406 (1,596,807 in Sindh & 7,599 in Balochistan)
Cropped Areas Lost	2.18 Million Acres (in Sindh)
Cattle Head Perished	116,529 (in Sindh)

3.2 Flash Flood Guidance System (FFGS): initial version implemented at PMD

An initial version of Flash Flood Guidance System (FFGS) has been installed at PMD to help provide warnings about the imminence of potential flash-flooding. The development of FFGS for Pakistan was conceived during WMO fact-finding and needs- assessment Expert Mission that visited Pakistan in early November, 2010 in wake of 2010 super floods during Monsoon season.

The FFGS for Pakistan has been developed by Hydrologic Research Center (HRC), USA with the assistance by USAID through joint collaboration between the WMO, U.S. NOAA National Weather Service, and the PMD at a cost of US $ 99,000. For the implementation of the initial version of FFGS at PMD, two scientists from HRC, USA visited PMD, Islamabad in August 2011. A training workshop for this purpose was also held at PMD during 15th – 18th August, 2011.

The main objective of the FFGS is to provide near real-time guidance products pertaining to the imminence of potential small-scale flash flooding throughout Pakistan. The system will provide the necessary products to support the development of warnings for flash floods from intense rainfall events through the use of satellite-based rainfall estimates. The FFGS outputs will be a diagnostic tool for the meteorologists to analyze weather-related events that can initiate flash floods and then to make a rapid evaluation of the potential for a flash flood at a location.

3.3 UNESCO Project to Improve Flood Alerts in Pakistan

UNESCO, the Government of Pakistan and the JICA have launched a US$3.5 million project funded by the Japanese government to upgrade early flood warning in Pakistan. The project is part of UNESCO's wider effort to help Pakistan to tackle natural disasters in wake of 2010 floods. The project aims to address the following three inter-related focus areas:

- Strategic Augmenting of Flood Forecasting and Hazard Mapping Capacity
- Knowledge Platforms for Sharing Transboundary and Community Data
- Capacity Development for Flood Forecasting and Hazard Mapping

The project will benefit from the technical expertise of the International Centre for Water Hazard and Risk Management (ICHARM), Japan under the auspices of UNESCO. ICHARM 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.

UNESCO is also playing a leading role in the Friends of Democratic Pakistan Water Sector Task Force which is preparing a national water sector strategy coordinated by the Asian Development Bank, in consultation with the Government of Pakistan.

Sri Lanka

The main responsible organisation of Hydrology and flood forecasting in Sri Lanka is the Department of Irrigation (DOI). In addition, Mahaweli Authority and Ceylon Electricity Board also involved in managing water in case of disaster situation – either floods or drought. The Department of Irrigation worked very hard to minimise the disasters due to very heavy down pour during January and early February, 2011 in Eastern, Northcentral and Northern provinces where, majority of major and minor reservoirs and irrigation schemes are established.

34 river gauges and raingauges are maintained by the DOI to provide 24 hour rainfall, 3 hourly rainfall at three times during the day and hourly river water levels round the clock to the Head office, Colombo. There also two stations for hourly river water levels monitoring during the day time mannualy. 44 rural community river gauges stations recording water levels twice a day by non-irrigation department staff sending the data at the end of the month to the head quarters. Further 27 rural community rainfall stations, manned by non-irrigation paersoonels to measure 24 hour rainfall and to send at the end of the month.

Flood warnings are issued by Hydrology Division of Department of Irrigation for all wet zone rivers, specially Kelani, Kalu, Gin, Niwala, Attanagalu Oya and Maha Oya. For this purpose Hourly Water Level variations & Rainfall occured during last hours are monitored by the hydrology division office at colombo and during bad weather periods 24 hours control room is established for continous receiving of data & if neccessary, issue warnings. Normally warnings are issued to DMC and electronic media. Advice of Met department is reveived for the next hours rainfall variations to make effective early warning.

There is an on going project funded by World Bank (DSWRPP Component iii HMIS) to upgrade Present Hydromet Stations and to establish new Stations with Automatic Sensers and on time communication capacity to transfer data to Colombo office. Under this project new 28 QLPs, 12 Ps and 10 QLPWTs are to be established and existing 20 QLPs and 2 QLPWTs are to be upgraded. (Q-Discharge, L: Water Level, P: Rainfall, WT: Weather Station)

Thailand

1. Enhancement of Facility

Water management in Thailand comes under the care of two government agencies: the Royal Irrigation Department (RID) and the Water Resource Department (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 24hours. 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, 13 of 25 main river basins have 208-telemetric systems installed for water resources management and flood prevention and mitigation.

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 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 12 telemetric systems installed in 12 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.

2. 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

Flood Forecasting Initiative

With regard to the WMO Flood Forecasting Initiative (FFI), progress was achieved with regard to establishing Flash Flood Guidance Systems as outlined below.

With the aim to make best use of meteorological forecasting products for hydrological purposes it is generally recognized in RA-II that QPE/QPF products are very important to improve hydrological service delivery. However, QPE/QPF has not been extensively used in real-time hydrological modeling maybe because: its uncertainty issues and because QPE/QPF products were developed for meteorological, not hydrologic purposes. QPE and QPF could be strengthened through enhanced coupled modeling and an end-to-end evaluation on QPE/QPF quality and impacts on flood and streamflow products for basins of diverse size and topography. To improve QPE and QPF, hydrologists could be encouraged to work with QPE/QPF groups to ensure that hydrological requirements for precipitation (QPE/QPF) can be considered.

The Associated Programme on Flood Management (APFM) that promotes the concept of Integrated Flood Management practices has progressed largely and in particular the development of Tools on a wide variety of flood management issues and the Helpdesk established under the programme since June 2009. A regional training workshops had been held in Hanoi in April 2011 in cooperation with the Mekong River Commission Secretariat; workshops to establish a National Integrated Flood Management Strategy has been held in January 2011 in Pakistan and tow of these national workshops are scheduled for 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.floodmanagement.info

Efforts are underway to establish an Integrated Drought Management Programme which was seen as highly relevant for the region.

Further activities under WMO-FFI implemented in 2011 include:

- Workshop on the Intercomparison of flood forecasting models currently in use in the various WMO Regions, to help the countries in identifying the most suitable models to serve their requirements (Koblenz, Germany September 2011);
- Workshop on the development of a framework for the assessment of service delivery capabilities of hydrological services in flood forecasting (Geneva, October 2011);
- Regional workshop cum training in flood forecasting in Nanjing, China in October 2011

Commission for Hydrology (CHy)

With regard to activities of the Commission for Hydrology, the following achievements and on-going activities of the Commission are reported:

- ***Quality Management Framework (QMF)***

  The QMF – Hydrology aims at improving all aspects of operations and activities of NHSs/NMHSs. The WMO Quality Management Framework guidance will be finalized as a draft by March 2012 put up for review on the e-Board to have ready for CHy-XIV.

Two stages of activities are envisaged:

- Produce Guides and Manuals to improve operations of NHSs/NMHSs;
- Encourage NHSs/NMHSs to adopt and implement Quality Management Systems (QMS) and finally obtain ISO certification.

- ***Publications***

  The Manual on Flood Forecasting and Warning has been published in 2011 and currently being distributed. Likewise, under the guidance of JCOMM, the Guide to Storm Surge Forecasting has been published in 2011.

- ***Capacity Building***

  In Capacity Building the following achievements have been made and a number of activities are on-going including:

- ***Distance Learning (DL)***

  In accordance to the recommendation of the Strategy on Education and Training in HWR to promote distance learning activities, WMO, in collaboration with COMET and NOAA, delivered a first International Basic Hydrological Sciences Distance Learning Course in 2009. In 2011 two regional courses were held: an advanced one for Eastern Europe in March and a basic one for RA V in October. In July 2011, an invitation to interested institutions to participate in this DL initiative was issued, and a Training of Trainers Workshop on Distance Learning Delivery of Hydrology Courses was held in COMET's headquarters in Boulder, USA, from 29 November to 9 December 2011, with participants covering all WMO regions.

- ***Roving Seminars on Manuals of Stream Gauging and Flood Forecasting***

  In cooperation with International Association for Hydro-Environment Engineering and Research (IAHR), two versions of a course on stream gauging based on the second edition of the WMO Manual have been designed: a short one (3 class days plus one field day) for the IAHR audience and a two-week one for WMO's audience (staff of NMHSs). The first course in the IAHR version was held in Brescia, Italy in September 2011, while the first course in the WMO version is tentatively scheduled in the second quarter of 2012 in Ghana. A first version of training material on Flood Forecasting and Warning has also been prepared and used in the training course on the subject, held in Nanjing, China in October 2011.

Regional activities

Progress has been made in the implementation of WHYCOS projects and in particular the Mekong-HYCOS that will end by November 2012 and the Hindu Kush Himalayan (HKH) HYCOS projects that is currently being implemented. The objective of both HYCOS projects is the establishment of regional flood information systems.

Together with NOAA/National Weather Service, the Hydrologic Research Center (HRC), San Diego, USA as technical partner, and funding from USAID, elements of the Flash Flood Guidance System with Global Coverage have been established in the region: The Mekong FFGS is being operational and likewise, an advanced proto-type FFGS has been established in Pakistan. With further funding become available from USAID, a kick-off meeting will be held later in 2012 in Kathmandu, Nepal for the establishment of a FFGS in the Hindu Kush Himalayan region and – in extension to the system existing at the Mekong River Commission (MRC), an FFGS is planned to be established in Myanmar, starting in 2012.

Current and proposed Theme Areas of the RA-II Working Group on Hydrology (WGH)

With regard to achieving the objectives of the RA-II WGH, the following theme areas are currently under implementation and advanced draft reports for each of these areas are expected by end of April 2012. The active theme areas are:

- Improving Institutional Capacity including the implementation of the RA II Strategic Plan for NHSs
- Disaster Mitigation – Implementation of the WMO Flood Forecasting Initiative including Flash Flood Forecasting Capabilities
- Hydrological responses to climate variability and change and promotion of the use of climate information by water managers,

The priority activities suggested for consideration from the RA II- WGH session in November 2010 were:

- Flood forecasting and warning;
- Hydrological aspects of drought;
- Hydrological response to climate variability and change;
- Hydrological observations, including from satellites;
- Water resources assessment.

These will be discussed during the upcoming RA-II session in December 2012.

Regional Cooperation

As a major step forward, the WGH during its session in November 2010 had decided to establish close links to the WGH of the Typhoon Committee. It was agreed that the RA-II WGH would nominate its chair to represent activities of the WGH and likewise that the results of the proposed joint working areas be communicated during the 43rd session of the TC in January 2011. The four areas where joint activities are envisaged are documented below.

- Urban Flood Risk Management (UFRM)
- Flash Flood/Debris Flow/landslide Forecasting/Warning
- Assessment of the Variability of Water Resources in a Changing Climate
- Drought Monitoring and Forecasting based on Space-based Information

Cooperation between the RA-II WGH, the WGH of the Typhoon Committee and the Hydrology and Water Resources Branch of the Department on Climate and Water (CLW) at WMO Secretariat are in full swing, especially – at this moment - in the areas of urban flood risk management and flash flood warnings. The TC-WGH had also noted with interest regional activities related to the intercomparison of flood forecasting models and training courses in flood forecasting envisaged for RA-II, probably in close cooperation with the Bureau of hydrology, Ministry of Water resources P.R China.

Recommendations

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

- Considers the establishment of a WGH in analogy to the highly successful WGH of the ESCAP/WMO Typhoon Committee (TC) with active involvement of hydrologists and seeks to enhance full collaboration with the TC;
- 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

1.3 DISASTER PREVENTION AND PREPAREDNESS

Bangladesh

Historical statistics would suggest that Bangladesh is one of the most disaster-prone countries in the world, with great negative consequences being associated with various natural and human-induced hazards. Bangladesh is extremely vulnerable to natural disasters originating from its unique geographical location, topography and relatively low capacity of its society and institutions to cope with such extreme events. As such, and with increasing population and infrastructure at risk, Bangladesh is globally recognized as the country most vulnerable to tropical cyclones.

The complete Cyclone Warming Programme in the country is supervised by the storm warning centre (SWC) of BMD. It monitors the cyclonic disturbances in the Bay of Bengal and advises the Government of Bangladesh at the Apex level.

The cyclone warnings are issued in two stages

Alert Stage

a) Issue as soon as possible the alert warning signals of cyclone, at least 36 hours ahead of formation of depression in the Bay of Bengal.

b) Supply information through Website/Fax/telephone/Tele-printer to Cyclone Preparedness Programme (CPP) about the formation of depression in Bay of Bengal so as to allow CPP to take appropriate actions including dissemination of information to all concerned. Issue warning signals code 'Whirlwind' to all concerned officials through telephone, Tele-printer, telegram, fax, email etc.

c) Prepare and submit Special Weather Bulletin and broadcast/publicize the same through national news media such as the all stations of Radio and 'Television and in national newspapers for the benefit of the general people. In case of Local Cautionary Signal no.3, arrange for adequate and full time coordination between SWC of the BMD, Bangladesh Betar, and Bangladesh Television for publicity beyond normal broadcasting hours.

d) Send Special Weather Bulletins to EOC at the DMRD, DMB the DRR, the CPP and BDRCS for undertaking adequate arrangements.

Warning State

Publicize warning signals at each of the following specified stages.

(a)	Warning	24 hours before
(b)	Danger	At least 18 hours before
(c)	Great Danger	At least 10 hours before

The same warning signals are to be repeated to the EOC at the DMRD, Control Room of the DMB, the DRR, the CPP and the BDRCS.

The following information should be mentioned in the signals to be disseminated.

a) Position of the storm centre.
b) Velocity and direction of the storm.
c) Mention of the Upazilas of the Districts likely to be affected, if possible.
d) Appropriate time of commencement of gale wind at different places (velocity above 32 miles/hour or 51.84 km/hour).

BMD is implementing a project "Strengthening Bangladesh Meteorological Departments (BMD) Early Warning Capacity funded by the Comprehensive Disaster Management Programme 2010-2014 (CDMP-II), Disaster Management and Relief division, Ministry of Food and Disaster Management, Government of the people's Republic of Bangladesh. The project has components such as Develop methodology and converting forecast to understandable bi-lingual text, Meteorological Training, Training on WRF model, Training on forecast product visualization (GIS Training), Procurement and installation of computational hardware, Weather prediction and visualization software procurement, Up gradation of existing H/W, Establishment of automatic communication system/high speed

Internet, redundant power back up system, Installation of weather studio, existing climate data homogenization.

BMD is the sole authorized government agency to deliver routine weather forecasts & warning for all extreme events, aviation forecasts, agricultural advisory to farmers and policy makers, climate data and information, earthquake information and tsunami warning to relevant public and private stakeholders for overall risk reduction, social and economic activities.

The main test for BMD now is to improve its services delivery while keeping up with the increasing demands. BMD is also to effectively serving the government and relevant actors with data and information on the probable impacts of climate change enabling appropriate adaptation and mitigation measures.

The revised Standing Orders on Disaster (SOD) 2010 have been prepared with the avowed objective of making the concerned persons understand their duties and responsibilities regarding disaster management at all levels, and accomplishing them. All Ministries, Divisions/Departments and Agencies shall prepare their own Action Plans in respect of their responsibilities under the Standing Orders for efficient implementation. The National Disaster Management Council (NDMC), Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) and Cabinet Committee on Disaster Responses (CCDR) will ensure the coordination of disaster-related activities at the National level. Coordination at District, Upazila and Union levels will be done by the respective District, Upazila and Union Disaster Management Committees. The Disaster Management Bureau will render all assistance to them by facilitating the process. Revised and updated SOD indicate additional duties to the BMD for risk reduction, emergency response and rehabilitation. The detailed responsibilities are clearly spelt out in the section 4.2.4.1 of the SOD. The National Plan for Disaster Management has set key targets to strengthen and improve all Hazard Early Warning Systems through technical, technological and physical capacity strengthening of BMD. The action agenda for 2010-2015 includes technical and technological capacity building of BMD to improve the accuracy of early warning information. During CDMP Phase-I an MOU was signed to strengthen BMD and sharing data with the limited resources. During this phase 35 met-observatory stations were computerized, installed web-based data acquisition system for fetching and dissemination met-data and information, installed LAN with internet connection and static website for BMD was developed.

India

Cyclone Warning Services for disaster management

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 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.

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 throughIndian 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 MeteorologicalOffices).
(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 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 National Television (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.

(b) Organisational structure of disaster management in India

It is a three tier system:

- National Level
  - NDMA (National Disaster Management Authority)
  - NDM (MHA)
  - NIDM (National Institute of Disaster Management)
- State level
- District Level

(i) Role & Responsibilities of NDMA

NDMA as the apex body is mandated to lay down the policies, plans and guidelines for Disaster Management to ensure timely and effective response to disasters.

Towards this, it has the following responsibilities:

- Lay down policies on disaster management;
- Approve the National Plan;
- Approve plans prepared by the Ministries or Departments of the Government of India in accordance with the National Plan;
- Lay down guidelines to be followed by the State Authorities in drawing up the State Plan;

- Lay down guidelines to be followed by the different Ministries or Departments of the Government of India for the Purpose of integrating the measures for prevention of disaster or the mitigation of its effects in their development plans and projects;
- Coordinate the enforcement and implementation of the policy and plan for disaster management;
- Recommend provision of funds for the purpose of mitigation;
- Provide such support to other countries affected by major disasters as may be determined by the Central Government;
- Take such other measures for the prevention of disaster, or the mitigation, or preparedness and capacity building for dealing with the threatening disaster situation or disaster as it may consider necessary;

Lay down broad policies and guidelines for the functioning of the National Institute of Disaster Management

(ii) Role & Responsibilities of NIDM

- To undertake quality research covering both natural and human induced disasters, with a multi-hazard approach
- To work as a National Resource Center for the central and state governments in the country through effective knowledge management and sharing of best practices.
- To professionalize disaster risk reduction and emergency management in India and other neighboring countries by developing an independent cadre of professionally trained emergency and mitigation managers.
- To promote formal training and education for disaster management in India and in the region
- To build working partnerships with the Government, universities, NGOs, corporate bodies and other national and international Institutes of eminence.
- To link learning and action by building a synergy between institutions and professionals in the sector.

(iii) National Disaster Management

- National Crisis Management Committee (NCMC)
  - NCMC will issue guidelines from time to time as required for effective response to natural disasters. All Ministries/Departments/Agencies at the national level shall comply with the instructions of NCMC.
- Ministry of Home Affairs (MHA)
  - The Ministry of Home Affairs is the nodal agency at the National level for coordination of response and relief in the wake of natural disasters(except drought, pest attack & hailstorm). MHA will provide financial and logistic support to the State Governments, keeping in view, their resources, the severity of the natural disaster and the capacity of the State Governments to respond in a particular situation.
- National Executive Committee (NEC)
  - The Disaster Management Act stipulates that the NEC under the Union Home Secretary will 'coordinate response in the event of any threatening disaster situation or disaster". NEC may give directions to the concerned Ministries/Departments of the Govt. of India, the State Governments and the State Authorities regarding

measures to be taken by them in response to any specific threatening disaster situation or disaster.

- Other Central Ministries/Departments
  - o The other concerned Central Ministries/Departments/Organisations will render Emergency Support Functions (ESF) wherever Central intervention and support are needed by the State Governments.

(c) National Cyclone Risk Mitigation Project (NCRMP) -

The National Cyclone Risk Mitigation Project (NCRMP) is to be implementation in all the 13 cyclone affected coastal states and Union Territories (UTs) of the country, with financial assistance from the World Bank. It has four major components.

Component A: This component is aimed at improvement of early warning dissemination system by strengthening the last mile connectivity (LMC) of Cyclone warning and advisories from the authority to communities and to interact with the communities by the authority in the event of a cyclone affecting an area.

Component B: This component will have several sub-components like construction of cyclone shelters, connecting roads & bridges, saline embankments, coastal canals and plantation/re-generation of mangroves forests, shelter belt plantation etc.

Component C: This component includes Technical Assistance for hazard risk management and capacity building.

Component D: This component is related to project management and monitoring. The project will be implemented in a phased manner beginning with two highly cyclone vulnerable states like Andhra Pradesh and Orissa for which World Bank appraisal has already been completed. Implementation of the Project will lead to reduction of cyclone vulnerability of coastal States and UTs further. The Project will be implemented in a phased manner with the first phase beginning in 2010 and planned to be completed in 2015.

(d) National Disaster Management Guidelines — Management of Cyclones

National Disaster Management Guidelines — Management of Cyclones (hereafter called cyclone guidelines), has been formulated taking the concerned Central Ministries, Departments, States and UTs on board. The process also included wide consultations with scientific technical institutions, academics, technocrats and humanitarian organizations.

The formulation of these guidelines is an important step towards the development of plans for the management of cyclones and their attendant disasters. These have been prepared to provide guidance to the central Ministries, Departments and State authorities for the preparation of their disaster management plans. These guidelines call for a proactive, participatory, well structured, fail safe multidisciplinary and multi-sector approach at various levels. Information in detail can be obtained from NDMA website, http://www.ndma.gov.in

(e) National Disaster Response Force (NDRF)

As mandated by The Disaster Management Act, 2005 the National Disaster Management Authority, Govt. of India has constituted the National Disaster Response Force (NDRF), for the purpose of specialized response to a threatening disaster situation or disaster. Presently NDRF comprises eight battalions with further expansion to be considered in due course. Seven of these battalions have been positioned at nine different locations in the country based on the vulnerability profile. This force is being trained and equipped as a multi-skilled, high tech. force with state-of-the-art equipments.

(f) Public Awareness

In its endeavour to spread awareness amongst the masses, NDMA has launched Public Awareness campaigns through electronic and print media since November 2006. The focus was on building appropriate environment for disaster management and creating a high level of impact on the target audience. NDMA's awareness campaign is aimed at building individual capacity on the levels of risk perception, preparedness, self reliance and self confidence. Mode used are popular T.V. Channels, All India Radio and popular private FM Channels and Print Media.

(g) Mock Exercise

To facilitate the State Governments in reviewing the adequacy and efficacy of the State and Disaster Management Plans and to identify gaps in resources and systems, NDMA, in co-ordination with the vulnerable states, has embarked on conducting Mock Exercises on various natural (including cyclone) and man-made disaster. This will also help in inculcating culture of preparedness.

(h) Disaster Awareness in School Curriculum

Disaster management as a subject in Social Sciences has been introduced in the school curriculum for **Class VIII** & **IX.** The Central Board of Secondary Education (CBSE) which has introduced the curriculum runs a very large number of schools throughout the country and the course curriculum is invariably followed by the State Boards of Secondary Education.

Important Events

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.

On-going Projects

1. FDP on landfalling cyclones over the Bay of Bengal

As the Field Operational Centre (FOC) of the project, CWRC, RMC Chennai is 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.

A *Weather Summary* of observations / analysis, regarding the lone IOP declared during FDP 2010 in connection with the formation of Severe Cyclonic Storm ***Jal*** over the Bay of Bengal, was prepared.

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.

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 will continue during 2012 and special observational and forecast demonstration campaign will be conducted during 15 April- 31May 2012.

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

IMD is collaborating 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.

5. Supply of *Cyclone eAtlas-IMD* CD

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. During the year 2011, 20 CDs were supplied to Indian buyers and one to a foreigner (Nepal).

Maldives

Maldives Meteorological Service is the authoritative organization in the country for issuing advisories and warnings related to meteorological, hydrological, tectonic and oceanographic disasters. To accomplish these tasks, MMS has prepared the Standard Operating Procedures (SOP) to act upon any likely event of meteorological, hydrological, tectonic and oceanographic disasters. MMS acquired a High Resolution Satellite Image Receiving System, DWR, number of AWSs, broadband and short-period seismometers within the framework of establishing a National Early Warning System.Maldives'sea level network comprises of three tide gauges in *Hanimaadhoo*, *Male'* and *Gan*to monitor low frequency changes in sea level associated with global sea level rise or decadal climate variations like other gauges in GLOSS network. After the 26 December 2004 Tsunami, these 3 tide gaugeshave been upgraded by multi-national aid facilitated by IOC/UNESCO with more sensors such as radar/ pressure/ float based water level sensors, and the reference level float switch sensors.With these improvements, it shall even detect any slight variations in sea level due to a tsunami wave**.**

Warnings and advisories

The National Meteorological Centre issued timely and accurate severe weather warnings and advisories, disseminated them to the public through mass media and through its website.

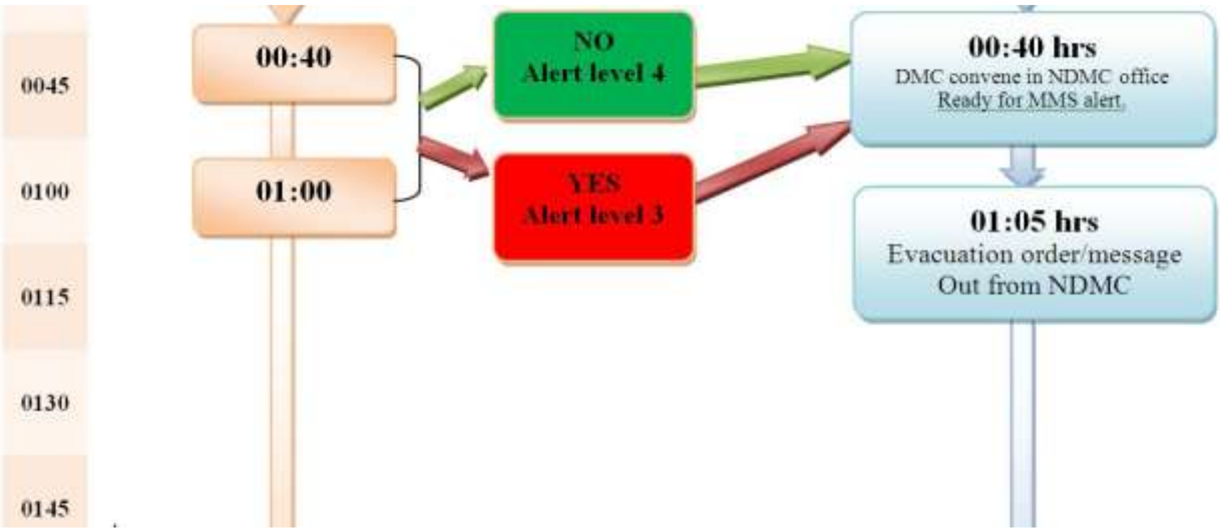
Apart from severe weather or tropical cyclone warnings, earthquake or tsunami warning reports received from Pacific Tsunami Warning Centre, Japan Meteorological Agency, Regional Tsunami Service Provider (RTSP)India, Indonesia, Australia and the Regional Integrated Multi-hazard Early Warning System (RIMES), through internet and GTS were also disseminated to public satisfactorily in time.

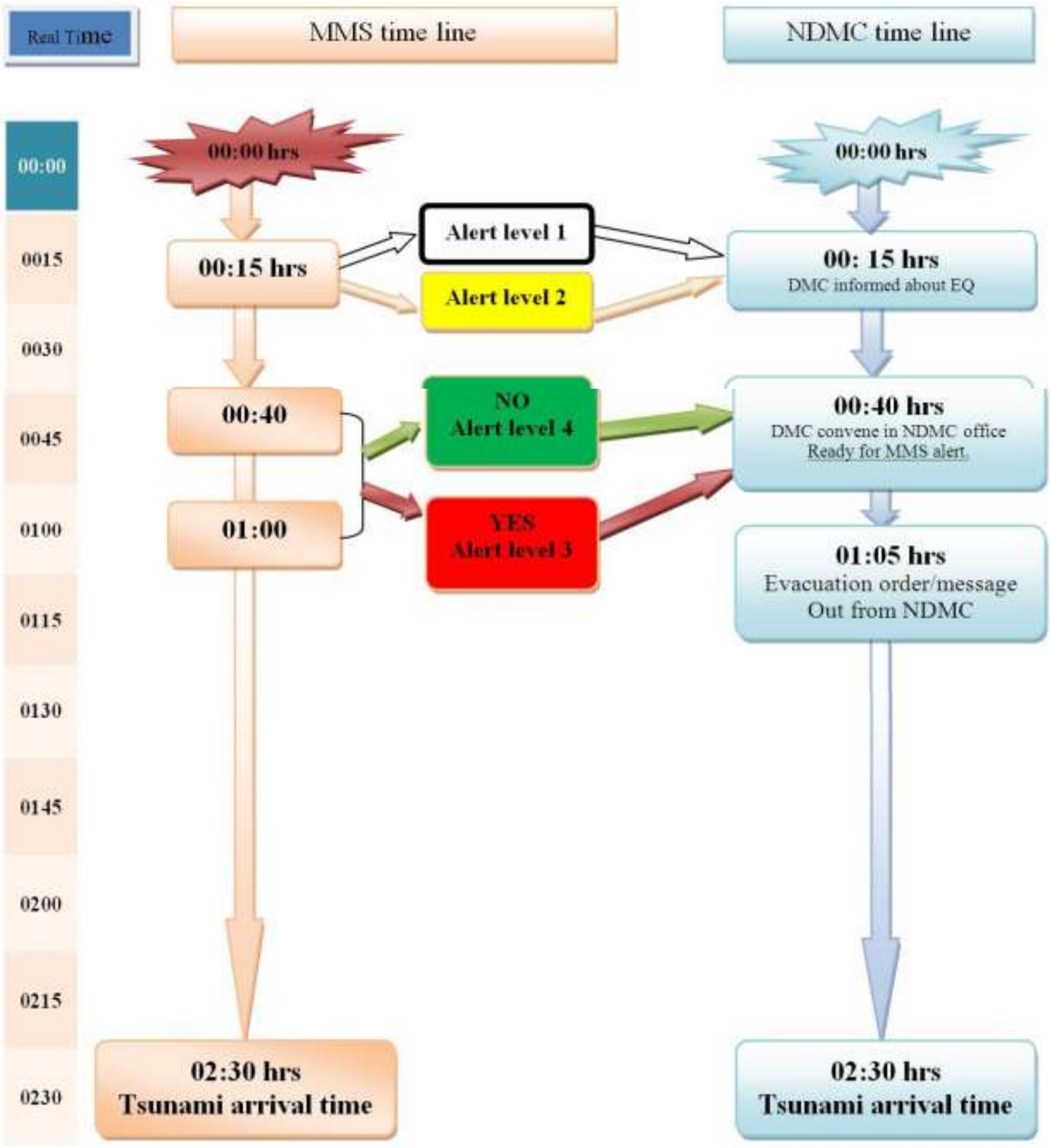
MMS conducts awareness programs targeting at public and students in different atolls periodically.

As National Tsunami Warning Centre (NTWC), MMS also participated in IOC's IOTWS Indian Ocean Tsunami Exercises conducted during 2011.

Under the SOP of the Department, the warnings were additionally dispatched through cooperate SMS and Hotlines to designated authorities.

Earthquake and Tsunami Message Timeline





Myanmar

Main responsibility of DMH is to provide early warning to the higher authorities, local government, and disaster risk reduction relevant agencies, media, International Non Governmental Organisations (INGOs), Myanmar NGOs and general public. DMH officials actively cooperate with Local INGOs representative to implement community awareness, public education programme and officials interviewed with State run TV about disaster risk reduction and role of early warning, adverse weather phenomenon in Myanmar and necessary actions to reduce socio economic losses. National Monsoon Forum jointly organized twice annually with the collaboration with regional partner agencies and stakeholders for climate outlook and disaster risk reduction. Director General of DMH is a member of National Advisory Committee of Disaster Prevention and Preparedness. Public education approach meteorological articles about current weather events, significant weather, update information of La Nina, cyclone emergency colour coding scheme were published in State Newspapers, Ministry of Transport Journal and other private Journal. DMH established a link first time in 2011 with Myanmar RADIO for live radio broadcasting about early warning and advisories while depression approaching Myanmar Coastal areas. Latest position, expected weather, suggested actions were informed to general public effectively. DMH owned weather studio for effective communication with clear, understandable weather information and DMH official website www.moezala.gov.mm and (2) automatic weather answering phones fulfil early warning system with updated warning and news. Disaster reduction activities of DMH was not accomplished without valuable support and close cooperation with WMO and its Regional office, RSMC, New Delhi, RTHs for the early warning, training and other support for Myanmar.

Ongoing Projects and Plans

Myanmar belongs to long coastal areas and one of the vulnerable areas for cyclone, storm surge, Tsunami, high wave and strong wind. A project entitled 'Reducing risks of tsunamis, storm surges, large waves, and other natural hazards in low elevation coastal zones" supported by the UNESCAP and jointly implemented by WMO and RIMES is carrying out within 2011-2013 period for the effective communication and link with early warning and local community and disaster managers. DMH will continue to promote cooperation with regional and international centre and institutions for the development of meteorological, hydrological, disaster risk reduction, climate change, water resources, earthquake and tsunami related technical cooperation programme.

Oman

Regional Cooperation in DPP policies and strategies

Oman is an active member on the recently inaugurated Gulf Cooperation Council Emergency Management Center (GCCEMC). As part of enhancing its national search and rescue capacity, Oman National Search and Rescue team is preparing to undergo INSARAG IEC this March and thus strongly encourages fellow PTC members to enhance their search and rescue capacities by adopting INSARAG methodology by which a common preparedness, mobilization, and operational standards are adopted by respective countries. Oman Search and Rescue Team (SRT) is now ready for international deployment. Thus, member countries are

encouraged to contact National Committee of Civil Defence (NCCD) for any search and rescue response during disasters.
During 2011, NCCD has participated in various training programs pertaining to emergency and disaster risk reduction.

Information Sharing

NCCD is conducting a national Emergency Management Information system (SOEMIS) which is dedicated to enhance decision making for Disaster management and risk reduction. The system complies all GIS data and integrate it with an intelligent user friendly program that provide valid up to date information of about 90 layers of data covering all infrastructure, emergency services and other data that might be used during emergencies by all responding agencies/sectors. One product of such system is risk mapping. In cooperation with the hydrology and metrology authorities in Oman, risk maps are now being developed utilizing academic institutions capabilities.

Public Awareness

A dedicated working group was established that is tasked with develpoing a national disaster risk reduction awareness strategy. The PAWG is chaired by OESCC with members representing government, non government, and private sector in collaboration with international organizations. A national emergency simulation center is under study. The center is going to be a public awareness tool that will contribute to Disaster risk reduction activities.

Improve National Coordination

NCCD established a sector that is dedicated to enhancing cooperation and coordination between early warning stakeholders. The Early Warning System (EWS) is tasked with improving coordination between NCCD and metrology, hydrology, seismic, and other early warning organization in the country. Meetings are held regularly and an action plan is the basis for their activities and programs.
NCCD is working closely with the national EWS project in a joint technical committee that aims at enhancing coordination and communication during emergencies. The development of SOPs is one outcome of this program.

Multi Hazard Management System

NCCD has adopted a national functional multi-hazard emergency management system. The system is based on the following principles:

- Disaster Risk Reduction is an integral component of the Emergency management system.
- Risk analysis is the basis for all emergency management activities.
- NGOs and Private Sector should be involved in emergency management from planning stage.
- Enhancing community capabilities in risk reduction and effective response.

- According to this system, eight sectors were established. Each sector was tasked of carrying a cretin function as follows:

1. Risk Analysis and Early warning Sector
2. Information and public awareness Sector
3. Search and Rescue Sector
4. Medical response and Public health Sector
5. Relief operations and shelter management Sector
6. Utilities and infrastructure Sector
7. CBRN Response Sector
8. DVI and victim affairs Sector

Emergency Response Activities

NCCD responded to tropical storms that affected parts of the country during November 2011. Effective early warning systems along with saturated public awareness activities were some of the most effect tools that resulted in reducing losses.

Recommendations

- The importance of enhancing search and rescue capacities in member countries according to INSARAG methodology.
- The importance of enhancing communications and coordination during disaster between member countries.
- The importance of enhancing cooperation between country members in the field of training and joint exercises.
- Annual meeting followed by a workshop, training course, or exercise in emergency preparedness and response should be organized by the PTC Disaster Prevention and Preparedness Working Group (DPPWG).

Pakistan

Establishment of new Ministry of National Disaster Management (NDM) in 2011

The National Disaster Management Authority (NDMA), formally established in 2007 in the aftermath of infamous December-2004 tsunami and October-2005 Kashmir earthquake, is the executive arm of the National Disaster Management Commission which is headed by the Prime Minister of Pakistan. At provincial level, Provincial Disaster Management Authorities (PDMAs) have been established. NDMA coordinates with all the government (federal/provincial/district) and non-government organizations to undertake disaster management and DRR activities in the country. NDMA in consultation with various stake holders has also prepared National Disaster Management Framework, Contingency Plans for various disasters. A Contingency Plan for the monsoon season has also been prepared. The finalization of draft National Disaster Management Plan 2012-2022 is also in progress.

The Government of Pakistan has also established a new Ministry of National Disaster Management (NDM) in 2011 and NDMA has come under the umbrella of this new Ministry.
NDMA has played a pivotal role in disaster management, relief and rehabilitation activities during floods in southern Pakistan due to exceptionally heavy monsoon rainfall in the Sindh province in 2011.

National Disaster Management Plan

NDMA of Pakistan with assistance by the Japanese government through JICA has prepared a draft 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 EWS 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)

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

PMD with support by the China Earthquake Network Center (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.

Sri Lanka

The Disaster Management Centre (DMC) under the Ministry of Disaster Management is the State organization for Disaster Prevention and Preparedness in Sri Lanka. National Centre for Disaster Relief Services which is also under the Ministry of Disaster Management mainly involve in relief services. In accordance with the Disaster Management Act and as one of its main tasks, the Preparedness Planning Division undertook to develop Disaster Preparedness and Response Plans for all districts, DS Divisions, vulnerable Grama Niladhari Divisions, and for other organizations. The main activities of the preparedness planning as follows,

- National Disaster Management Policy, National Disaster Management Plan, National Emergency Response Plan, review , update and co-ordination.
- Preparation of preparedness plans for natural and manmade disaster and co-ordination.
- Assist to technical guidance to preparation of preparedness plan for entire government institution according to Natural Disaster Management Plan.
- The school Disaster Safety Programs are implemented by the Ministry of education in collaboration with the Disaster management centre and national institute of education
- Strengthening of Disaster Response capacities of local authorities /purchase of equipment and distribution to local authorize.
- Preparedness activities for disaster related to large dams.
- Develop preparedness and response plans for vulnerable DS & GN divisions in downstream of major dams.
- Capacity building of Local Authorities for emergency response.
- Coordinate preparedness and response plans for hospital.

The Disaster Management Plan is an instrumental document that illustrates the district mechanism established for responding to disasters. District Disaster Management Coordination Committees (DDMCC) were established to study disaster management issues in the district in the pre disaster phase and to coordinate emergency response activities during disasters. The Committee consists of all key stakeholders, representatives from INGOs/NGOs, and others. These members are given different tasks such as early warning dissemination, search and rescue, camp management, etc. Sub committees have appointed for different tasks. The plan clearly lists out the roles and responsibilities of all sub committees.

Disaster preparedness plan is a useful document which provides the framework to the district mechanism for responding to disasters if and when a disaster occurs. The District Disaster Management Coordination Committee is the main management body in the district. The members of the committee, the sub committees and their roles and responsibilities are listed in the plan. These plans contain base line data of the administrative area, risk and vulnerability assessment for the hazards prevailing in the area, contact details of focal points, resources available in the area and responsibilities of different stakeholders involved in disaster response and other details.

Preparedness activities have been conducted in most vulnerable Grama Niladhari Divisions, by the District Disaster Management Coordination Units. These activities are:

- Awareness on hazards, identification of risk, early warning, etc.
- Formation of disaster management committees and sub committees
- Preparation of the community level hazard map showing risk areas, evacuation routes to safe locations, etc.
- Providing training on search and rescue, first aid, camp management etc.
- Provide early warning dissemination equipment such as megaphones, public address systems, sirens, rain gauges
- Conducting mock drills (simulation exercise) for Tsunami, landslide and cyclone.

Preparedness activities for disasters related to large dams

Considering the possibility of dam related disasters during a cyclone period or due to an earth tremor, the Disaster Management Centre has initiated preparedness activities for the communities in downstream of large dams for their safety. This is one of the activity in the ongoing Dam Safety &Water Resource Planning Project (DSWRP) implemented by the Ministry of Irrigation and Water Management.

School Disaster Safety Programme

The school disaster safety programme is coordinated by the District Disaster Management assistant directors in all districts. They conducted School Awareness Programme, School Tsunami and cyclone Evacuation Drills. The main activities in this programme are preparing the school hazard map, forming disaster management school committees and sub committees, conducting mock drills, providing first aid training for selected student groups, providing equipment such as fire extinguishers, rain gauges etc.

Strengthening of disaster response capacities of disaster prone areas/purchase of equipment

During past disaster it has been observed that local authorities were not sufficiently equipped with suitable machinery and equipment to respond to different emergency situation. Even sharing viable resources with other LAs was not possible due to very limited resources available. In the context the DMC took initiatives to provide local authorities with equip such as water bowers, backhoes for landslide prone areas.

Strengthening of disaster response capacities of highly vulnerable GN division/ purchase of equipment and distribution to camp management sub committees

In order to fulfill the needs of the sub committees involved in the disaster responses equipment's provided. As a symbol kitchen utensils were purchase by the ministry of disaster management.

Sri Lanka National Disaster Management Plan (2009-2014)

National Disaster Management Plan, developed as a for the period of five years from 2009 to 2013 conforming to the DM Act and the draft Sri Lanka National Disaster Management Policy. It describes management arrangements, relationships, mechanisms, strategies and corresponding timeframes for action to establish the DRM framework and implement related programmes in the country with multiple-stakeholder participation covering all phases of the DM cycle.

Corporate Plan of Disaster Management Centre (DMC) (2010-2014)

DMC has prepared the Corporate Plan to elucidate development efforts and programmes of the DMC in a single strategic document. The objective of this integrated corporate plan is to facilitate DMC for performance excellence by facilitating the management of DMC in defining what the environment holds and how to navigate through that environment in order to achieve the changes that are desirable for long-term success of DMC. DMC will be able to plan out the annual programme for each year based on this well thought-out long term plan. The Corporate Plan also briefly summarizes the work done by DMC since its inception.

Thailand

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.

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 centers by the manual siren device.

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.

Mr Disaster Warning

Flashflood 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.

Disaster Prevention and Mitigation Academy (DPMA)

As a national training center, 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.

One Tambon One 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.

Capacity-Building of Civil Defense Volunteer

Recruited from local residents aged over 18 years, the civil defence 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.

1.4 TRAINING

Bangladesh

i. Under the grant aid assistances of the Government of Japan in the project “Development of Human Capacity on Operation of Weather Analysis and Forecasting - July 2010-December 2012” training activities are on going for BMD personnel. The overall goal of the Project is to improve the capacity of Meteorological Service through improving the weather analysis and forecasting by Numerical Weather Prediction technique. It will also improve the capacity of BMD in climate data management and its application in climate change impact assessment and scenario development, management of climate data and running of climate model through calibration of all the radar, the issuance of the quantitative rainfall forecast BMD will be improved.

ii. A memorandum of understanding (MOU) have been signed between Bangladesh Meteorological Department and Norwegian Meteorological Institute for capacity building of meteorological personnel in the project "Institutional support and capacity building for mitigation of weather and climate hazards in Bangladesh"

iii. Other Workshops, Seminars and Training Courses attended by the Met personnel during the year 2011 were as follows:-

Workshop/Seminar/Training Course	Duration	Country	No. of Persons
Improvement of weather Services for the Societal Development in Nepal	10-11 February 2011	Kathmandu, Nepal	1
NTWC Training Workshop and WG2/RTT Intersessional Meeting	07-11 February 2011	Hyderabad, India	1
Abu Dhabi Dialogue Knowledge Forum Small Grants Program(SGP)	02-03 March 2011	Kathmandu, Nepal	1
Operational Tropical Cyclone Forecast at RSMC Tropical Cyclone.	28 February’11-March 2011	New Delhi, India	1
Training Seminar on Application of Seasonal Forecast GPV Data to Seasonal Forecast Products.	18-21 January 2011	Tokyo, Japan	1
2nd Advisory Workshop on Enhancing Forecasting Capabilities for North Indian Ocean Storm Surges.	11-15 February 2011	New Delhi, India	1
Workshop/Seminar/Training Course	**Duration**	**Country**	**No. of Persons**
16th Session of the World Meteorological Congress.	16 May-03 June, 2011	Geneva, Switzerland	1
Aviation Meteorology Service in Asia.	11-15 April, 2011	Beijing, China	1
Training Course on Meteorological Hazards Early Warning for Developing Countries.	11-31 May, 2011	Nanjing, China	1
BIMSTEC Workshop on Seasonal Prediction and Application to Society.	22-23 June, 2011	New Delhi, India	1
Meteorology for Meteorological Official from Developing Countries.	15 June-05 July, 2011	Nanjing, China	1
Regional Training Seminar on WMO Information System (WIS)	11-14 April,2011	Beijing, China	1
HKH-HYCOS Second Regional Steering Committee.	04-06 May,2011	Kathmandu, Nepal	1
BIMSTEC Workshop on seasonal	22-23 June,2011	New Delhi, India	1

Prediction and Application to Society			
Meteorology from Meteorological Official from developing countries	15 June-05 July 2011	Nanjing, China.	1
Training Workshop and SASCOF-2 Meeting	08-12 April, and 13-15 April,2011	Pune, India	1
NK-Storm Surge Modeling	13-17 June,2011	Bangkok, Thailand	1
Training course on Meteorological Hazards Early Warning for Developing countries.	11-13 May,2011	Nanjing, China.	1
Asian Climate Change Trends and Policy	20-22 July,2011	Bangalore India	1
Reducing Risk of Tsunami Storm Surges, Large Waves and other Natural Hazards in Low Elevation Coastal Zones.	28-30 September,2011	Bangkok ,Thailand	1
Application of NWP Models in Mountain Weather and Forecasting and Extreme Weather Warming over the SAARC Region.	26-27 July, 2011	Delhi India	1
Regional Workshop on Slandered Operating Procedures for Tsunami Warning and Emergency Response for Indian Ocean Countries	19-23 September, 2011	Jakarta, Indonesia	1
APSCO Third International Symposium on Earthquake Monitoring and Early Warning by using Space Technology	26-27 July, 2011	Beijing, China	1
Application of NWP Models in Mountain Weather and Forecasting and Extreme Weather Warning Over the SAARC Region.	13-15 September,2011	Delhi India	1
MASTA 2011 Master Program on Space Technology Applications (Satellite Communications)	13 September to 30 June,2012	Beijing, China	1

Workshop/Seminar/Training Course	**Duration**	**Country**	**No. of Persons**
Group on Earth Observations (Geo- VII) Plenary Session.	16-17, November,2011	Istanbul Turkey	1
Workshop on Climate Change and Sustainable Management of Water Resources in the Asia-Pacific Region.	22-34 November,2011	Islamabad Pakistan	1
Expert Group Meeting on Development of regional Protocol on Early Warning System on Cyclones and Tsunami in South Asia	19-20 December,2011	New Delhi India	1
Workshop on Human Resources Development for NMHSs in Asia (RA-II) and South- West Pacific (RA –V) Countries	17-21 October,2011	Quizon city, Philippines	1
Training Seminar on One Month Forecast Products and Meeting on Twelfth Joint Meeting for the Seasonal Prediction of the East Asian Winter Monsoon	07-11November,2011	Tokyo, Japan	1
SAARC Expert Group Meeting on Regional Drought Monitoring and Early Warning System.	27-28 December,2011	Hyderabad, India	1
HYCOS Project- Regional 3rd Steering Committee Meeting	1-2 December,2011	Kathmandu, Nepal	1
Workshop on Results and Review on SAARC STORM Pilot Field Experiments.	21-23 December,2011	Kathmandu, Nepal	1

India

The training activities at RMTC Pune are as follows:

I) Current Status:

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

i) Advanced Meteorological Training Course in General Meteorology with one foreign candidate from Maldives.
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.

II) On going projects:

Under World Bank aided Hydrology Project Phase II, the following regular courses are running:

i) Basic Hydromet Observer Course
ii) Hydromet Supervisor's Course
ii) Senior Level refresher course

III) Future Plans:

i) 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.
ii) To design and organise advanced refresher training course of 10 weeks duration for the forecasters of Rwanda Met. Agency.
iii) To introduce e-learning in training programme.
iv) To upgrade the infrastructure of training institute & Trainees Hostel.
v) 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

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.

Eight IMD officers were sent abroad for various components of forecasting system, for technical training in software Code, operation and maintenance of C-Band DWRs system under IMDs modernizing its observational facilities and infrastructure during 2011.

Familiarization training on tropical cyclones monitoring at RSMC New Delhi

One official each from Myanmar, Bangladesh and two from Oman are undergoing attachment/training on Operational Tropical Cyclone Forecasting at RSMC, New Delhi from 28 February to 11 March, 2011.

Future Plan:

1. Attachment of cyclone forecasters training in RSMC, New Delhi has been completed for the year 2011 and same will be conducted in 2012.
2. The seminars/workshops will be conducted for the cyclone forecasters in India during March and September 2012 as pre-cyclone exercise.
3. National Conference on FDP- Cyclone (pilot phase) was conducted during 1-2 November, 2011.

Maldives

Ongoing Graduate level and Post-Graduate level programs and Advance level courses funded by MMS's regular budget.

Name of Training Program	Country	Duration	Participants
Bachelor in Information Technology	Maldives	2008-2011	1
Bachelor in Information Technology	Sri Lanka	2010-2012	1
Master's in Meteorology	India	2010-2012	1
Advanced Met. Course	India	2010-2011	1

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

#	COURSE NAME	LEVEL	Overall Priority	YEAR			No. Trained and in Service	No. Being Trained	Funds Confirmed	Sources of Funds		Estimated Costs (MVR)	Section / Unit	Training Required	
				2012	2013	2014				Budget	Overseas Project			Local	Overseas
1	Software Engineering	B.SC	2	-	1	1	0	-	-	-	-		TSU		✓
2	Climatology	B.SC	1	1	-	-	1	0	-	-	-		CLIMATE		✓
3	Advanced Meteorology	Advanced Certificate	6	2	2	2	6	0	-	-	-	85,000.00	MET		✓
4	Climatology Advanced	Certificate	1	1	-	-	0	-	-	-	-		CLIMATE		✓
5	Electronic Engineering	B.SC	2	1	-	-	0	1	-	-	-		TSU		✓
6	Climatology Intermediate	Certificate	1	1	-	-	1	0	-	-	-		CLIMATE		✓
7	Electric & Electronic Engineering	Diploma	2	1	1	-	0	-	-	-	-		TSU		✓
8	Accounting Course	Certificate	2	1	1	-	0	1	-	-	-	8,000.00	FINANCE	✓	
9	Multi - Media	B.Sc	1	1	-	-	0	-	-	-	-	105,000.00	TSU	✓	
10	Meterology	B.SC	2	1	1	-	0	-	-	-	-	250,000.00	MET		✓
11	Seismology	Diploma	2	1	1	-	0	-	-	-	-		SEISMO		✓
12	Intermediate meteorology	Certificate	2	1	1	-	7	-	-	-	-		MET		✓

At present, one staff is undertaking a long-term training on operating management of earthquake, tsunami and volcano eruption observation system in Japan and also one candidate is now undertaking Master programme on Remote and Geographic Information System(RS-GIS) under TICA programmes.

During the year, one staff got Master Degree for Seismology Earthquake Engineering and Disaster Management Policy from Japan by JICA, one staff got Diploma for operating management of earthquake, tsunami and volcano eruption observation system in Japan and another one staff got also M.Sc Meteorology from University of Philippine.

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 III Course and for Navy and Air Force as their request.

Oman

The Ministry of Regional Municipalities and Water Resources is very keen in training the staff. During the year 2011, the Ministry arranged for both local and overseas training and workshops as follows:

Training Program	No. of Trainees
Analysis of Rainfall gauge Data	15
Monitoring , processing and analysis of water Resource Data	18
Study and account of Floods and its impacts Direct & indirect Method measurements	16
Engineering and Technology of wells drilling	16
Geology of Oman	15

Future Plans

The Ministry of Regional Municipalities and Water Resources is working on implementation of the five years plan starting from last year. The plan includes exploration of new water resources in the country through drilling. In addition, the plan includes construction of more dams to store water and recharge the groundwater aquifers. Moreover, the plan includes expansion of hydrological network and upgrade of automatic stations including the telemetry systems. The other Ministry plans include but not limited:

- Secure clean and safe drinking water.
- Reduce the water balance deficit.
- Implement water management policy, particularly in agriculture sector.

- Implement the Integrated Water Resources Management principles for sustainable water use.
- Protect water quality as a part of sustainable environmental approach.
- Encourage the investments in Non-Conventional water projects (Desalination and Wastewater treatment plants).

Pakistan

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. So far, nineteen (19) officers have joined back to PMD after completion of their higher studies from United Kingdom, Canada, Norway, China and Thailand.

In 2011, eleven (11) scientists joined back to PMD after completion of their higher studies in Meteorology from abroad. One scientist has completed his PhD (Meteorology) from Stockholm University, Sweden on scholarship award by Higher Education Commission of Pakistan, while the other ten scientists have done their MS (Meteorology) from Nanjing University of Science and Information Technology (NUIST), China with partial financial support by the China Meteorological Administration (CMA) and NUIST and remaining support by the government of Pakistan. In addition, two (02) scientists have also completed their JICA sponsored postgraduate studies in seismology and tsunamis from Japan during 2010-2011. Three (3) scientists are also expected to join PMD during 2012 after completion of their PhD studies. Two of these scientists have been doing their PhD (Meteorology) in China since October, 2009 with main scholarships by the Chinese Academy of Sciences and the remaining cost of their studies by the Government of Pakistan. The third scientist has been doing his PhD (Meteorology) in Germany since May, 2008 with scholarship by the university.

During 2011, two (2) more scientists have proceeded abroad for their PhD studies. One scientist has gone to South Korea, while the other scientist has proceeded to China on scholarships by the Korean University and Chinese Academy of Sciences respectively. In addition, during 2011, one scientist has also been awarded scholarship by the WMO for doing 3-years MSc (Hydrology) at St. Petersburg, Russian Federation. Four (4) scientists have also proceeded to Japan for doing MS in Hydrology and Flood-related Disaster Mitigation at International Centre for Water Hazard and Risk Management (ICHARM), Japan. Two of these scientists have gone under the auspices of JICA and the remaining two under the auspices of UNESCO with Japanese support under a UNESCO project which aim to improve flood alerts in Pakistan.

During 2011, around 45 fellowships were availed by PMD scientists for attending short-term trainings/ workshops/ seminars abroad. These fellowships have been offered mainly by WMO, CEA, UNESCAP, ICIMOD, UNESCO-IOC, CMA, JICA, etc. and the foreign governments including those of China, Norway etc.

Training of Met. Personnel at IMG, Karachi

During 2011-2012, 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.

Training at COMSATS Institute of Information Technology, Islamabad

Around nine (09) officers of PMD have completed their MS (Meteorology) from Department of Meteorology, COMSATS Institute of Information Technology (CIIT), Islamabad during 2011-2012. PMD has also been providing teaching faculty support to CIIT.

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, the fourth such course was scheduled in 2011 but it could not be materialized due to financial constraints.

Sri Lanka

Two meteorologists are currently receiving post graduate training at University of Phillipines under the sponsorship of WMO. Upon request of WMO, Scientific staff received the training in the following programmes

- Forecast capabilities of Indian Ocean Storm surge, India 11-15 February
- WMO Information & public Affairs Focal point meeting Poland, 07-13 March
- Capacity building workshop on seasonal prediction – SASCOF – 2 India, 08-15th April
- IOC/WMO 2nd capacity building, Mauritius, 2-6 May
- Monsoon heavy rainfall, china 12-14 October
- Human resources Development for NMHS in RA II and RA V
- Competency Standard for aero nautical Personnel, India 31st October – 4th November.

In addition, scientific & engineering staff members also participated for short period training programmes arranged by JICA, KOICA, JMA, RIMES, SMRC and Government of Sri Lanka .

Two residential training programmes were conducted for the meteorological technicians under continual education & training scheme. New recruits of training grade of meteorological technicians underwent there training throughout the year.

Thailand

In 2011, only 2 TMD staff were involved in 2 oversea trainings co-sponsored by WMO. One attended the training on Super Ensemble Techniques, Nanjing, China during 5-16 December; another attended Storm Surge Attachment, Delhi, India during 12-23 December.

For local training, QPE/QPF was formed during 29 August to 2 September with 35 local staff, and Satellite Software began during 26-29 September with 22 local staff.

Activities of WMO

The Panel noted the training events and workshops which were organized in 2011 for the benefit of its Members. Since its last session, the Panel had benefited from WMO's education and training activities 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 2012, 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 the available training resources produced by the Cooperative Program for Operational Meteorology, Education and Training (COMET). The Members were encouraged to make maximum benefit of the available training resources in English and Spanish languages, especially the online Tropical Textbook – a comprehensive guide to understanding tropical weather.

The Panel noted that WMO fellowships for long-term and short-term training continued to be granted to the Member countries of the Panel under the various WMO programmes. More information on WMO Fellowship programme is available on the ETRP Website.

The Panel also noted that the WMO Reginal Training Centres (RTCs) and national training institutions offer training courses time-to-time and they are made available on ERTP Website.

The training activities offered by the Members are extremely valuable. To assist WMO better support the education and training needs of ESCAP members it was recommended that ESCAP develop and refine their training needs over the intersessional period. ESCAP were encouraged to consider reviewing and adapting the competency approach being used by Tropical Cyclone centres outside of ESCAP (for example the Bureau of Meteorology in Australia) and then identifying regional and national training requirements based around the competencies. The Panel were encouraged to develop a prioritized list of training needs and opportunities and advise WMO for reporting, planning and implementation purposes.

1.5 RESEARCH

Bangladesh

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

- ✓ Analysis of extreme rainfall events
- ✓ Analysis of significant Nor'wester events
- ✓ Bangladesh contribute information on significant weather and new developments in the meteorological service to BMD's newsletters

India

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:

(a) Web based version of *Cyclone eAtlas – IMD*

IMD had digitised the tracks of cyclones and depressions over the North Indian Ocean since 1891 and brought out a CD, *Cyclone eAtlas-IMD,* during 2008, for deriving several statistical and climatological parameters of tropical cyclones of the North Indian Ocean. A project on software development for web hosting of the *Cyclone eAtlas-IMD* has now been undertaken and completed successfully. The web based *Cyclone eAtlas-IMD* was declared open to users by the DGM, IMD in January 2012. The software can be accessed freely by all users at the URL: www.rmcchennaieatlas.tn.nic.in. Feedbacks from users are quite encouraging.

(b)* Met. Monograph on *Climatology and Forecasting based on climatology of Tropical Cyclones of Indian Seas

A Met. Monograph (No. Cyclone Warning – 9/2011) on *Climatology and Forecasting based on climatology of Tropical Cyclones of Indian Seas* by *Y.E.A. Raj* was brought out by IMD during January 2012. All climatological aspects of Tropical

Cyclones of the North Indian Ocean, viz., formation, movement, coastal crossing, dissipation and rainfall as well as forecasting based on climatology have been covered in detail aided by large number of tables and figures.

(c) Statistical prediction of seasonal cyclonic activity over the North Indian Ocean

A research work for prediction of number of days of cyclonic activity over the North Indian Ocean during the chief cyclone period of October-December was undertaken recently. The results of the study have been published in a paper entitled *Statistical prediction of seasonal cyclonic activity over the North Indian Ocean* by *S.Balachandran and B.Geetha* in *Mausam*, 2012, Vol.63, No.1. Experimental outlook on the seasonal cyclonic activity over the North Indian Ocean for the year 2011 was prepared on real-time basis and validated. Efforts are on for improving the prediction model as well.

(**d) A study on '*Weakening of the TC Khai-muk before crossing coast*' was undertaken and completed.**

(e) 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 Very Severe Cyclonic Storm *Thane* over the Bay of Bengal during 25-31 December 2011.

On-going projects

1. Generation of rainfall maps for landfalling Tropical Cyclones of the North Indian Ocean

A software for generation of isohyetal maps for Tropical Cyclones of the North Indian Ocean using gauge rainfall data for the period from 1971 to 2010, namely, *Cyclone Rainfall Atlas (CYRAAT*) was developed in-house by Shri RM.A.N.Ramanathan. Daily and cumulative rainfall maps can be generated for any cyclone as per user's choice. Based on the products generated, a Met. Monograph is being prepared.

2. Generation of rainfall characteristics of Tropical Cyclones of the North Indian Ocean using TRMM data

A 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 each stage of intensity of the system viz., Depression, Cyclonic Storm and Severe Cyclonic Storm, during its growth as well as decay for all Tropical Cyclones of the North Indian Ocean during 2000-2010.

A CD containing the output products would be brought out for the benefit of cyclone researchers.

Future Plans

1. A project on development of user friendly, fully automated software for generation of rainfall maps for different resolution options is proposed to be undertaken by outsourcing to a software developer.

2. 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.

Papers published in Mausam

(i) Relation between pressure defect and maximum wind in the field of a Tropical Cyclone – Theoretical derivation of proportionality constant based on an idealised surface pressure model in Mausam, 2010, Vol. 61, No. 3 by Y.E.A.Raj.

(ii) Simulation of monsoon depression over India using high resolution WRF Model – Sensitivity to convective parameterization schemes in MAUSAM Vol. 62, Number 3, July 2011, by D. R. Pattanaik, Anupam Kumar, Y. V. Rama Rao and B. Mukhopadhyay.

(iii) Modulation of cyclonic disturbances over the north Indian Ocean by Madden - Julian oscillation in MAUSAM Vol. 62, Number 3, July 2011, by M. Mohapatra and S. Adhikary

(iv) Technical and operational characteristics of GPS radiosounding system in the upper air network of IMD, MAUSAM Vol. 62, Number 3, July 2011 by Gajendra Kumar, Ranju Madan, K. C. Saikrishnan, S. K. Kundu and P. K. Jain

(v) Statistical prediction of seasonal cyclonic activity over North Indian Ocean MAUSAM Vol. 63, Number 1, January 2012 by S. Balachandran and B. Geetha

(vi) Satellite derived sea surface temperature variability in the Bay of Bengal by O. P. Singh

(vii) 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

Workshop/Seminar/lectures organised in India

a. A study on *Statistical prediction of movement of cyclonic storms using LOESS technique* was undertaken by RM.A.N.Ramanathan and Y.E.A.Raj. The results of the study were presented by Shri RM.A.N.Ramanathan in the seminar on Indian Northeast Monsoon – Recent Advances and Evolving Concepts (INEMREC-2011) conducted by the Indian Meteorological Society, Chennai Chapter during February 2011.

b. Dr. Medha Khole, Scientist `E' participated in the Sixteenth World Meteorological Congress in Geneva, Switzerland from 18th to 23rd May 2011.

c. Dr.S.Balachandran, Scientist-E participated in the international seminar on Application of NWP models in mountain weather forecasting and extreme weather warning over the SAARC region organised by SAARC Meteorological Research Centre, Dhaka at New Delhi during 26-27 July 2011 and presented a paper entitled *A numerical study of salient features of tropical cyclone Khai-muk using WRF model* by S.Balachandran and B.Geetha.

d. Dr. Medha Khole, Sci. E attended a National Workshop on, "Weather Forecasting" on 11th Aug. 2011 organised by Modern College of Arts, Science & Commerce, Pune and delivered a lecture on, `Monsoon Forecasting'.

e. Shri RM.A.N.Ramanathan, AM-II participated in the National seminar on 'Disaster Management and Law – Issues and Challenges' held at Chennai during 12-13 October 2011.

f. Dr.S. Balachandran, Scientist-E, participated in the National Conference on FDP (Cyclones) – BOBTEX-2011 during 01-02 November 2011 and presented a paper entitled *Barotropic energetics associated with genesis of Tropical Cyclone Khai-muk*.

g. Mrs Sunitha Devi, Sci. D delivered a talk on `National Disasters and Organisational Structure of IMD for Disaster Warning' to Class I & Class II Officers from Revenue Department, Zilla Parishad, Police & Public Work Departments from all Districts in Maharashtra, who were undergoing a program titled `Cyclone Disaster Management' organised by YASHADA (Yashwantrao Chavan Academy of Development Administration).

h. A paper entitled "Mapping of Socio-Economic benefits of Meteorological Services" by Dr. Medha Khole, Scientist E at Tropmet – 2011.

i. Dr.Y.E.A.Raj, DDGM and Dr.S.Balachandran, Scientist-E, participated in the Second WMO International Conference on Indian Ocean Tropical Cyclones and Climate Change held at New Delhi during 14-17 February 2012 and delivered invited talk / presented a research paper as under:

(i) Dr.Y.E.A.Raj delivered an invited talk on *Climatological characteristics of Tropical Cyclones of North Indian Ocean*

(ii) Dr.S.Balachandran presented a paper entitled *ENSO related Energetics of Tropical Cyclones over the North Indian Ocean* by S.Balachandran and B.Geetha.

Workshop/Seminar/lectures attended outside India

- Dr. M. Mohapatra, Scientist F participated in the 4th trilateral meeting of experts of India-Russia China in the field of disaster management in Saint Petersburg, Russia from 7 to 9 September, 2011.
- Dr. Y.V. Rama Rao, Scientist E, NWP, IMD, New Delhi participated in the UN-ESCAP supported WMO and RIMES joint regional project on reducing risks of Tsunami storm surge, large waves and other natural hazards in low elevation coastal zones.
- Dr. N. Chattopadhyay, Scientist E ,IMD, Pune participated in the WMO workshop on Severe Weather Forecasting Demonstration Project (SWFDP)-Eastern Regional Training Workshop on Severe Weather Forecasting (GDPFS) and warning Services(PWS) in Arusha, Tanzania from 28 Nov. to 2 Dec. 2011.

- Dr. O. P. Singh, Scientist F, IMD, New Delhi was deputed to Kathmandu, Nepal to attend HYCOS project Regional Steering Committee Meeting by ICIMOD from 1to2 December, 2011.
- Sh. G. Suresh, Scientist E, IMD, New Delhi was deputed to Bangkok, Thailand to participate in the workshop on Managing Waveform Metadata from Seismic Networks. from 8 to 13 January, 2012.

Maldives

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

Annual Climate Report

Maldives Meteorological Service publishes *Annual Climate Report* every year.

Myanmar

Department of Meteorology and Hydrology reorganized "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 2011. For example;

- Research studies on SW Monsoon and NE Monsoon have been carried out with the emphasis on changing of onset/withdrawal phase, duration, intensity, monsoon rain, storm frequency and shiftment of their seasonal tracks, dry spell and wetspell, 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). DMH had established a laboratory to monitor the air and water quality of Myanmar. Since then, regular monitoring works and research on acid rain are carrying out on the quality of water and air, on the trans-boundary pollution, etc..
- 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 April, 2012 on the Improvement of Tropical Storm Forecasting and Warning to DMH. After completion of Expert Dispatch program, DMH is expected to have its own capacity for more precise cyclone and storm surge forecasting and warning by using advanced technology and sophisticated equipments and to promote research activities.

- DMH has run the Model for Assessment of Greenhousegas Induced Climate Change/SCENario GENerator (MAGICC/ SCENGEN) for climate scenarios of Myanmar for the year 2020, 2050 and 2100.

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.

Oman

Oman hosts WMO 7th center of excellence for satellite training in cooperation with EUMETSAT. Panel members are welcome to participate in satellite training courses that will be held in the future. Other workshops, Seminars, Research and Training Courses attended by the Met personnel during the year 2011 were as follows:-

Workshop/Seminar/Training Course	Country	No. of Persons
PhD. In Climate change	UK	1
PhD. In wind power	Oman	1
PhD. In Network	Oman	1
Master in Statistics	Oman	1
Master in environment	Oman	1
Masters in networking and programming	Oman	2
EUMETSAT Satellite Application Course	Oman	6
Met. Technician course (Class IV)	Oman	22
Climate change seminar	Turkey	2
Aviation course	UK	2
TV graphics production	Germany/ South Africa	3
Satellite application	China	1
Satellite expert training	Europe	1
database systems CLDB	Slovakia	2
numerical weather forecasts	Germany	3
programming languages	Oman	4
Total		53

Pakistan

Scientists of PMD also contributed (both as lead authors and co authors) in around ten (10) research papers which have been published in various international journals like *Climate Dynamics, Science International, Atmospheric and Climate Sciences, Atmospheric Ocean* and/or presented at international scientific conferences and have been published in the proceedings of the these conferences/ seminars.

A number of small projects related to research work in forecasting techniques, climate change, climate modeling, downscaling for seasonal and monthly prediction and verification of High resolution Regional Model (HRM) were also carried out by the scientists of PMD. These projects aimed at improving the services of PMD. The scientists also presented their research work at various conferences/ symposia / workshops at national and international level during 2011.

PMD started publication of its biennial research journal namely “Pakistan Journal of Meteorology” in 2004. During 2011, PMD published two issues (No. 14 & 15) of “Pakistan Journal of Meteorology”. These issues contain 15 research papers which were mainly contributed by the scientists of PMD in addition to some foreign researchers.

Sri Lanka

The following research studies have been completed.

- Analysis of Indian Ocean Dipole on the weather of Sri Lanka.
- Analysis of rainfall change with the onset of Southwest monsoon and Northeast monsoon
- Extremes of rainfall in Sri Lanka on decadal basis.
- Extremes of maximum and minimum temperatures in Sri Lanka on decadal basis
- Analysis of aerial rainfalls of Sri Lanka
- Utilizing WRF model (ongoing)
- Preparation of Cyclone risk profiles for Sri Lanka (ongoing)

Activities of WMO

The Panel was informed of the activities of the WMO World Weather Research Programme (WWRP) in 2011 and its plan for the future. It noted with pleasure that the International Workshop on Rapid Change of Tropical Cyclone Intensity and Movement was successfully held in Xiamen, China from 18 to 20 October 2011. The workshop was attended by 53 tropical cyclone researchers and forecasters. The workshop highlighted recent advances in the theory and practice of forecasting rapid changes in tropical cyclone intensity and track.

The 3-day training session on Tropical Cyclone Ensemble Forecast was conducted from 14 to 16 December 2011 at the WMO Regional Training Centre in Nanjing, China. It was held in conjunction with the 2-week International Training Course on Tropical Cyclones organized by CMA (5-16 December 2011). The training session was co-sponsored by CMA, Typhoon Committee, WWRP (including THORPEX) and TCP and was targeted mainly at forecasters of the Typhoon Committee Member countries. It focused on the use of up-to-date ensemble forecast of tropical cyclones such as on maximum wind speeds, rainfall, and landfall timing and location.

The Panel noted that WWRP and TCP are jointly organizing the Second International Conference on Indian Ocean Tropical Cyclones and Climate Change (New Delhi, India, 14-17 February 2012). Major objectives of the Conference are to i) review and discuss current status of the operational tropical cyclone forecasting and warning system, ii) progress on the understanding of tropical cyclone genesis, iii) climate change and tropical cyclone activity, tropical cyclone risk and iv) vulnerability assessment and tropical cyclone disaster preparedness, management and reduction.

To be held in succession by WWRP in India is International Conference on "Opportunities and Challenges in Monsoon Prediction in a Changing Climate" (OCHAMP-2012) to be held from 21 to 25 February 2012 in Pune. The Conference will be dedicated to Monsoon prediction in a changing climate. Its aim is to give impetus to basic research and development and also to spread the salient features of the research pursuits in force throughout the world. It would bring together a panel of highly-accomplished and leading experts in the field of monsoon prediction coming from different research and operational meteorological environments.

WWRP and TCP also plan to organize the International Workshop on Unusual Tropical Cyclone Behaviour tentatively in Guangzhou, China in November 2012. The workshop will focus on unusual behaviour of tropical cyclones, especially on motion, evolution, intensity, precipitation patterns and structure. A better understanding of such tropical cyclone behavior will lead to more accurate forecast and better guidance for disaster risk managers and thus contribute to mitigation of impacts of storms.

1.6 PUBLICATION

India

RSMC Report on Cyclonic Disturbances during 2011:

2. Details of the systems

2.1 Depression over the Bay of Bengal (2 February 2011)

2.1.1 Brief history

Under the influence of the trough of low at sea level, a low pressure formed over the southwest Bay of Bengal. It concentrated into a **Depression** at 0900 UTC of 2 and lay centered near Lat. 6.5° N/Long. 82.5° E, about 550 kms southeast of Kanyakumari. It remained practically stationary and weakened into a well marked low pressure area at 0000 UTC of 3 over southwest Bay of Bengal.

2.1.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 1002 hPa. The maximum estimated mean wind speed was 25 kts. The salient feature of the system includes its formation close to equator, short life (about 15 hours) and practically no movement.

2.1.3 Weather and damage caused

As the system was far south of the Indian coast and dissipated over the Ocean, it did not affect the weather over India.

2.1.4 Satellite and RADAR observations

The system was tracked with the help of satellite cloud imageries from 0900 UTC of 2 to 0000 UTC of 3. The maximum intensity of the T No 1.5 was reported from 0900 UTC of 2 to 0000 UTC of 3.

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 T1.0 in the evening of 1st Feb. 2011. The meso-scale convective clusters in association with the system merged gradually along with increase in deep convection. Associated moderate to intense convection was seen over southwest Bay of Bengal, adjoining Sri Lanka, Comorin, Gulf of Mannar, Palk Strait and coastal Tamil Nadu. The lowest cloud top temperature was – 55° C.

2.2 Depression over the Arabian Sea (11 – 12 June 2011)

2.1.1 Brief history

A low pressure area formed over the east central Arabian Sea off north Maharashtra coast on 6. It persisted there on 7 and lay as a well marked low pressure area over the east central Arabian Sea and neighbourhood from 8 to 10 and over the east central Arabian Sea off north Maharashtra-south Gujarat coasts on 11 morning. Subsequently, it concentrated into a **Depression** and lay centered over the northeast Arabian Sea off Maharashtra-Gujarat coasts at 1200 UTC of 11 near Lat.20.0°N/Long.71.5°E, about 180 km northwest of Mumbai. It moved north northwestwards and crossed Saurashtra (Gujarat) coast near Lat.20.8°N/Long.71.2°E, about 25 km to the east of Diu around 2200 UTC of 11 and lay centered at 0300 UTC of 12 over Saurashtra and neighbourhood, about 70 km south southwest of Amreli, near Lat.21.0°N/Long.70.5°E and remained practically stationary over the same area till 0600 UTC. Gradually moving northwestwards, it weakened into a well marked low pressure area over Saurashtra and adjoining northeast Arabian Sea by 1200 UTC of 12. It further weakened into a low pressure area over the same region on 13 and became less marked on 14.

2.2.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 996 hPa from 1200 UTC of 11 to 0200 UTC of 12. The maximum estimated mean wind speed was 25 kts. Maximum sustained wind of 40-50 kmph was reported along Saurashtra and Diu coasts. The system moved initially in north northwestwards before crossing and then northwestwards over land.

The pressure values of the stations (Gujarat State and Rajasthan) to the north of the system were less than that of the system, hence, those parts did not come under the influence of the system.

2.2.3 Weather and damage caused

No damage was reported due to this system. However, under the influence of the system, widespread rainfall with isolated heavy to very heavy falls occurred over Saurashtra & Kutch and Diu. A trough was seen along & off the west coast from this system, which also gave significant weather over the coast. The significant amount of 24 hours cumulative rainfall (>7 cm) recorded at 0300 UTC of date are follows:

12-6-2011

Saurashtra, Kutch& Diu :

Sutarapada 27, Veraval 17, Kodinar 9, Talala and Upleta 8 each.

Konkan & Goa:

Murud 25, Roha 22, Tala 19, Mumbai (Santacruz) 18, Sudhagad 17, Mhasla 15, Thane, Malvan, Alibagh, Uran, Mumbai (Colaba) and Mangaon 11 each, Kalyan and Dodamarg 10 each; Pen, Khalapur, Kankavli and Sawantwadi 9 each; Khed, Matheran, Ambernath, and Mahad 8 each; Ulhasnagar, Karjat, Kudal, Bhiwandi, Panvel, Canacona, Sangameshwar, Poladpur and Dapoli 7 each.

13-6-2011

Saurashtra, Kutch& Diu:

Mangrol 14, Sutrapada 8,

Konkan & Goa;

Vaibhavwadi 12, Thane Belapur 11, Dabolim, Canacona and Poladpur 9 each; Kankavli and Sangameshwar 8 each; Guhagar 7.

2.2.4 Satellite and RADAR observations

According to INSAT imagery, a vortex formed over east central Arabian Sea with T1.0 and lay centered at 0000 UTC of 8 June near lat. 17.0^0N/ 70.0^0E and near lat. 19.0^0N / 71.0^0E at 0300 UTC of 11 June. The broken intense convection in association with the system became slowly organised.

The maximum intensity of the system according to Dvorak's classification was T1.5 from 1200 to 2100 UTC of 11 June 2011. The associated broken intense to very intense convection (with cloud top temperature of -77^0C) lay over Arabian Sea between lat 16.5^0N & 21.0^0N and to the east of long 65.5^0E.

2.3 Deep Depression over the Bay of Bengal (16 – 22 June 2011)

2.3.1 *Brief history*

A low pressure area formed over the northwest Bay of Bengal and neighbourhood on 14. It lay as a well marked low pressure area over the same region on 15. It concentrated into a **Depression** and lay centered at 0300 UTC of 16 over the northwest Bay of Bengal, near Lat. 21.5° N / Long. 89.0° E, about 150 kms southeast of Kolkata and further intensified into a **Deep Depression** at 0600 UTC of 16 over the same region. It further moved north northwestwards and crossed West Bengal-Bangla Desh coasts, near Lat. 21.8° N/Long. 89.0° E, about 100 km to the east of Sagar Islands, between 1100 & 1200 UTC of 16 and lay over Gangetic West Bengal and adjoining Bangla Desh, near Lat. 22.0° N/Long. 89.0° E, about 100 kms southeast of Kolkata at 1200 UTC of 16. Moving slightly northwards, it lay centered near Lat. 22.5° N / Long. 89.0° E, about 80 km east of Kolkata at 0300 UTC of 17. Subsequently moving westwards, it lay over Gangetic West Bengal, near Lat. 23.0°N / Long. 88.0°E, close to Burdwan at 1200 UTC of 17. Further moving westwards, it lay over Gangetic West Bengal and adjoining areas of Jharkhand, centered near Lat. 23.0° N / Long. 87.0° E, about 25 km south of Bankura at 0300 UTC of 18. It remained practically stationary over the same region at 1200 UTC of 18. Thereafter, it further moved northwards and lay over Jharkhand and adjoining Gangetic West Bengal, centered near Lat. 23.5° N / Long. 85.5° E, about 50 km. southeast of Ranchi at 0300 UTC of 19. Moving slightly westwards, it lay centered near Lat. 23.5° N / Long. 85.0° E, about 25 km. northnorthwest of Ranchi at 1200 UTC of 19. It further moved west northwestwards and lay over Chattisgarh and adjoining areas of Jharkhand, about 50 km northeast of Ambikapur (23.7/83.5) at 0300 UTC of 20 and further weakened into a **Depression** over the same area at 0600 UTC of 20. Moving slightly northwestwards, it lay centered at 1200 UTC of 20 over southeast Uttar Pradesh and neighbourhood, about 150 km south of Varanasi (24.0/83.0). Subsequently moving west northwestwards, it lay centered at 0300 UTC of 21, over east Madhya Pradesh and adjoining south Uttar Pradesh, about 100 km. east of Rewa (24.5/82.0). Then it moved westwards and lay centered at 1200 UTC of 21, over the same area close to Satna (24.5/81.0). Continuing the westward movement, it lay centered at 0300 UTC of 22, over east Madhya Pradesh, close to and to the west of Panna (24.5/80.5) and over the central parts of Madhya Pradesh and adjoining south Uttar Pradesh, about 50 km northeast of Sagar at 1200 UTC of 22 (24.5/79.1) and at 1800 UTC near Lat. 24.5° N / Long. 78.5°E. It moved further northwestwards and weakened into well marked low pressure area over west Madhya Pradesh and neighbourhood in the early morning of 23.

2.3.2 Other features observed

The lowest estimated central pressure (ECP) was 978 hPa at 0600 UTC of 17. The lowest observed pressure was 983.4 hPa at 1200 UTC of 18 at Bankura. The maximum estimated mean wind speed was 35 knots. The maximum sustained surface wind (MSW) was reported as 35 knots by an AWS to the northeast of Kolkata around 0600 UTC of 17th June.

As per the DWR Kolkata observations, the maximum radial wind as observed from PPI (V) was 25 mps at a height of 0.5 km above ground level at 1806 UTC of 17 June at a distance 60-65 km west-southwest of DWR Kolkata. The maximum horizontal wind estimated from VVP_2 product is 40 knots at height 1.2, 2.4, 2.7 & 3.0 km within 50 km radius of Kolkata at 1836 UTC of 17th June 2011.

An important feature of the system was abnormal pressure drop at the centre of the system (max 12 hPa) over the land, even though the maximum surface wind speed was reported as 30-35 knots over Gangetic West Bengal.

The system moved initially in a northerly direction and crossed west Bengal-Bangladesh coast. It continued to move in northerly direction for some more time after crossing and then moved west-northwestwards across Gangetic West Bengal, Jharkhand, north Chhattisgarh and west Madhya Pradesh during 17-23 June.

2.3.3 Weather and damage caused

Heavy rainfall and landslides took a toll of 9 persons in West Bengal and 3 in Chattisgarh. In west Midnapore 200 mud walled house totally collapsed due heavy rain. Many villages inundated due collapsing of River-embankment in North 24 Parganas and Kansabati Area. In Jharkhand, trees were uprooted, power supply disrupted and heavy damage was caused to houses and crops.

Under the influence of the system, widespread rainfall with isolated heavy to very heavy falls occurred over Orissa, Gangetic West Bengal Jharkhand, Chattisgarh, Madhya Pradesh, Bihar and Uttar Pradesh. The significant amount of 24 hours cumulative rainfall (>7 cm) recorded at 0300 UTC of date are as follows:

15-6-2011:

Gangetic West Bengal:

Berhampur 12.

16-6-2011:

Orissa:

Chandbali and Hindol 12 each; Chendipada, Champua, Rajkanika, Keonjhargarh and Kakatpur 9 each; Jaleswar and Jaipur 8 each; Naktideul, Paradip, Rajghat, Thakurmunda and Bhubaneswar 7 each.

Gangetic West Bengal:

Digha11; Kharagpur 7.

17-6-2011

Gangetic West Bengal:

Canning 10; Digha; Durgachak and Uluberia 7 each.

Orissa:

Sukinda 25; Tensa 18; Jenapur 12; Bhograi 11; Pallahara, Pattamundai, Akhuapada and Jaleswar 9 each; Joshipur , Kendrapara and Rajkanika 8 each; Dhenkanal, Jaipur, Madanpur Rampur Chandbali 7 each.

18-6-2011:

Gangetic West Bengal:

Mohanpur 27; Kalakunda 21; Bankura 19; Purihansa 17; Barackpur and D.P. Chat 16 each; Kolkata Alipur, Kolkata Dumdum, Midnapore (PT) and Midnapore (CWC)15 each; Contai Kharidwar and Tusuma 14 each; Asansol, Bagati, Burdwan, Kansabati dam and Panagarh 13 each; Durgapur 12; Harinkhola, Simulia, and Digha 10 each; Uluberia and Gheropara 9 each; Durgachak 8; Diamond Harbour and Sriniketan 7 each.

Orissa:

Baripada, Jamsolaghat and Bhograi 14 each; Rairangpur and Bangiriposi 13 each; Tining, Jaleswar and Chandanpur 11 each; Sukinda 10; Rajghat 9; Rairakhol, Joshipur, Rajkishorenagar and Athmalik 7 each.

Jharkhand:

Ghatsila 13; Kuru and Panchet 10 each; Maithon 9; Ranchi 8; Lohar-daga, Gumla, Dhanbad, and Jamshedpur 7 each.

19-6-2011:

Gangetic West Bengal:

Berhampore and Bankura 13 each; Phulberia, Tusuma Kharidwar and Kansabati dam 11 each; Asansol 10, Purihansa and Tantloi 9 each; Durgapur and Suri 8 each; Panagarh IAF, simulia and DP Ghat 7 each.

Jharkhand:

Ramgarh and Putki 17 each; Ranchi AP and Jamshedpur aero 16 each; Tenughat and Jamshedpur 15 each; Jamtara 14; Papunki 13; Balumath and Hindgir 11 each; Nandagih, Moharo, Hariharganj and Messenjore 9 each; Barkisuriya and Daltonganj 7 each.

Bihar:

Sherghati 15; Gaya 9; Arwal 7.

20-6-2011:

Orissa :

Tensa 8; Rajkishorenagar 7.

Jharkhand:

Lohar-daga and Raidih 17 each; Kuru 16; Nandadih 13; Gumla, Daltonganj and Balumath 10 each; Ranch AP 8; Hindgir 7.

Chhattisgarh:

Ambikapur 13; Ramanujganj 11; Baikunthpur 9.

Bihar:

Arwal 10; Bihar and Palmerganj 9 each; Bhabhua 8; Indrapuri, Patna, Chenari, Kursela and Dehri 7 each.

East Uttar Pradesh:

Robertsganj 12; Chunar 11; Churk and Muhammadbad 10 each; Dudhi and Jaunpur 9 each; Rajghat, Deogaon Lalganj, Ghazipur, Gonda and Zamania 7 each.

21-6-2011

Gangetic West Bengal: Basirhat 12.

East Uttar Pradesh:

Ankinghat 11; Gyanpur, Karwi, Sultanpur, Muhammadabad 9 each; Patti, and Bikpur 8 each; Mahul Phulpur, Haidargarh and Chhatnag 7 each.

Chhattisgarh:

Janakpur 17; Manendragarh 10; Baikunthpur 8.

East Madhya Pradesh:

Rewa and Sidhi 16 each; Satna 15; Singrauli 13; Khurai 11; Kotma and Dindori 10 each; Umaria 9; Anuppur 8; Jabalpur Ajaigarh and Khajuraho aero 7 each.

22-6-2011

East Madhya Pradesh:

Damoh 28; Buxwaha 21; Hatta 20; Garhakota 18; Sagar 16; Ghamspre 14; Rehli and Gotegaon 13 each; Kaneli 12; Khurai 11; Rajnagar 10; Narsinghpur and Jabalpur 9 each; Khajuraho and Amarwara 8 each; Panna, Tikamgarh, Keolari and Lakhnadon 7 each.

West Madhya Pradesh:

Mungaoli 16; Chanderi 13; Kuwai 11; Lateri and Benumganj 9 each; Pichhore 8; Ganjbasoda, Vidisa, Datia, Pachmarhi and Sironj 7 each.

23-6-2011:

East Madhya Pradesh:

Sagar 17; Khurai 14; Garhakota 12.

West Madhya Pradesh:

Guna 34; Ashoknagar 29; Ganjbasoda 20; Mungaoli 19; Sironj 18; Begumganj 17; Chanderi 16; Isagarh and Lateri 15 each; Biaora 13; Narsingarh 11; Bhanpur, Rajgarh, Pichhore, Kolaras, Udaipura, Salwani 9 each; Vidisha, Khilchipur and Garoth 8 each; Sheopur, Sailana, Manasa, Shivpuri, sarangpur and Ratlam 7 each.

East Rajasthan:

Baran 29; Kanwas 22; Kishanganj and Sangod 21 each; Atru and Anta 19 each; Chhabara 18; Chipaboard 17; Mangrol 15; Khanpur and Shahbad 14 each; Jhalawar, Asnawar and Jhalawar 13 each; Iklera,and Manoharthana 11 each; Bakani and Pratapgarh 10 each; Patan keshorai, Degod, Ramganjmandi, Mandana, Begu and Kota Airport 9 each; Jhalarapatan, Ladpura, Kota, Deoli, Kekri, Jhazpur, Newai and Bhainjsroadgarh 8 each; Kotri Nimbahera, vanasthali, Mandalgarh, Pirawa, Telera, Pachpahar, Malpura and Chechat 7 each.

2.3.4 Satellite and RADAR observations

Doppler Weather Radar (DWR), Kolkata was observing the system since 0300 UTC of 15 June 2011 at every 10 minutes interval. As per the observations, the front part of the system hit the coast at about 1106 UTC of 16 June at 108 km SSE of Kolkata. The system got better organised with two spiral bands by 1206 UTC of 16 June. It intensified further at 0558 UTC of 17 June.

The maximum radial wind as observed from PPI(V) was 25 mps at a height of 0.5 km above ground level at 1806 UTC of 17 June at a distance 60-65 km WSW of DWR Kolkata.

2.4 Land Depression over Jharkhand (22 – 23 July 2011)

2.4.1 Brief history

Under the influence of the low pressure area formed over Gangetic West Bengal and neighbourhood, a **Depression** formed over northwest Jharkhand and neighbourhood, about 50 km southeast of Daltonganj (23.5/84.5) at 0300 UTC of 22. Moving in a west northwesterly direction, it lay over southeast Uttar Pradesh and neighbourhood, about 100 km east of Sidhi (24.0/83.0) at 1200 of 22. Thereafter, it moved westwards and lay centered over east Madhya Pradesh, about 100 km northeast of Sagar at 0000 UTC of 23 (24.5/80.5). Continuing the westward movement, it weakened into a well marked low pressure area and lay over north Madhya Pradesh and neighbourhood on 23 morning and became less marked on 24.

2.4.2 Other features observed

The lowest estimated central pressure (ECP) was 990 hPa from 0300 to 1200 UTC of 22. The maximum estimated mean wind speed was 20 knots. The maximum sustained surface wind (MSW) was reported as 30 knots by Umaria at 0300 UTC of 22 July. The lowest central pressure of 989.4 hPa was reported by SRO (Singrouli, east Madhya Pradesh), an AWS station.

It moved west-northwestwards along the monsoon trough and lay centered at 0000 UTC of 23rd July 2011 over east Madhya Pradesh, about 100 Km northeast of Sagar. It further moved west-northeastwards and weakened into a well marked low pressure area over north Madhya Pradesh and neighbourhood at 0300 UTC of 23rd July 2011.

2.4.3 Weather and damage caused

No damage was reported due to this system. Under the influence of the system, widespread rainfall with isolated heavy to very heavy falls occurred over Madhya Pradesh, Madhya Maharashtra, Konkan & Goa and Rajasthan. The significant amount of rainfall (>7 cm) are follows:

23 July, 2011

East Madhya Pradesh:

Kurwai 12, Dewas 11, Ganjbasoda, Guna and Begumganj 10 Each; Salwani/Silvani and Ashoknagar 9 each; Mungaoli 8; Narsingarh, Kolaras, Udaipura, Lateri, Sirinj and Puchhore 7 each.

West Madhya Pradesh:

Narsinghpur 16; Tendukheda 15; Gotegaon 13; Deori, Rehli Jabalpur (New) 11 each; Kaneli Sagar and Khurai 10 each; Bichhia and Umaria 9 each; Nowgoan 8 Sidhi; Buxwaga, Patan and Garhakota 7 each.

Madhya Maharashtra:

Gaganbavada 9; Mahabaleshwar 7.

Konkan & Goa:

Lanja 7.

24 July, 2011

East Rajasthan:

Tadaraisingh 10; Anta 9; Bakani, Manohar Thana and Gangapur 8 each; Nagrarfort, Bagidora, Kotri and Arnod 7 each.

West Madhya Pradesh:

Tarana 11; Bhanpura and Shujalpur 7 each.

Konkan & Goa:

Sawantwadi, Vaibhavwadi and Lanja 11 each; Jawahar 10, Kudal 9; Sangamneshwar and Rajapur 8 each; Kankavli, Khed, Bhira 7 each.

Madhya Maharashtra:

Radhanagari 15; Chandgad and Gargoti and Bhudargad 12 each; Mahabaleshwar 7.

2.5 Depression over the Bay of Bengal (22 – 23 September 2011)

2.5.1 Brief history

A low pressure area formed over the northwest Bay of Bengal and adjoining coastal areas of West Bengal on 20. It became well marked low pressure area over the northwest Bay of Bengal and adjoining West Bengal - Orissa coasts on 21. Subsequently, it concentrated into a **Depression** over the northwest Bay of Bengal off north Orissa-West Bengal coasts and lay centered at 0300 UTC 22 near Lat. 21.5° N/Long. 87.5° E, about 50 km east southeast of Balasore. It moved slightly westwards and lay centered near Lat. 21.7° N/Long. 87.2° E at 1200 UTC and then moving west northwestwards, crossed north Orissa coast, close to Balasore between 1700 & 1800 UTC of 22. Subsequently moving northwestwards, it lay over Jharkhand and neighbourhood, centered close to Jamshedpur (22.5/86.5) at 0300 UTC of 23. It remained practically stationary over the region, close to Jamshedpur till 0600 UTC and weakened into a low pressure area by 0900 UTC.

2.5.2 Other features observed

The lowest estimated central pressure (ECP) was 995 hPa at 1200 UTC of 22. The maximum estimated mean wind speed was 25 knots. The lowest central pressure of 995.7 hPa was reported by Balasore at 0900 UTC of 22 which was very close to the estimated value.

It moved westwards when it was over the sea area and then northwestwards, along the monsoon trough after crossing the coast. After weakening into a well marked low pressure area, it moved northeastwards across Jharkhand, Bihar and Sub-Himalayan West Bengal & Sikkim.

2.5.3 Weather and damage caused

Heavy rains associated with the system over the upper catchment areas caused floods over Orissa and Bihar.

Under the influence of the system, widespread/fairly widespread rainfall with isolated heavy to very heavy falls occurred over Orissa, Gangetic West Bengal, Jharkhand and Bihar during 22-24 September. The system; as a low pressure area also gave widespread/fairly widespread rainfall with heavy to very heavy falls during 25-27 over Sub-Himalayan West Bengal & Sikkim and Bihar. The significant amount of 24 hours cumulative rainfall (>7 cm) recorded at 0300 UTC of date are as follows:

22-09-2011

Orissa

Ghatagaon 18, Nawana, Udala 16, Soro 15, Thakurmunda 14, Balimundali, Tensa 13, Champua, Swampatna 12, Joshipur, Jhumpura, Telkoi, Bangiriposi 11, Karanjia 10, Keonjhargarh, Jaipur, Rairakhol, Akhuapada, Pallahara, Harbhanga, Chandbali, Baripada, Binjharpur, Chandanpur, Lahunipara, Sukinda, Bonth 9, Patmundai, Rajkanika, Anandpur, Jamsolaghat, Tihidi, Nilgiri, Batagaon 8, Rengali, Baudhgarh, Tikarpara, NH-5 Gobindpur, Jajpur 7.

Gangetic West Bengal

Sabong 11, Kharagpur 10, Kalaikunda 9.

Bihar

Lakhisarai 12, Barhiya, Benibag 11, Phulparas, Dengraghat 7.

23-09-2011

Orissa

Keonjhargarh, Tensa 19, Telkoi 15, Jhumpura, Panposh 14, Rajgangpur, Lahunipara, Mandira Dam 13, Nawana 12, Ghatagaon 11, Swampatna, Bargaon 10, Pallahara 9, Bonth 8, Keiri, Jenapur, Rajkishore Nagar, Joshipur, Laikera, Kuchinda, Tairing, Chiplima, Kankadahad 7.

Gangetic West Bengal

Jhalda 7.

Bihar

Indrapuri 15, Aurangabad, Dehri 8, Palmerganj 7.

Jharkhand

Kuru, Lohardaga 13, Ranchi 9.

24-09-2011

Orissa

Pallahara 7.

Jharkhand

Garhwa 9.

25-09-2011

Gangetic West Bengal

Tantloi 7.

Sub-Himalayan West Bengal & Sikkim

Hasimara 15, Bagrakote, Tadong, Chengmari/Diana 11, Tadong 9, Kalimpong, Buxaduar, Garubathan, Islampur, Jalpaiguri, Gangtok 8, Darjeeling 7.

Bihar

Dehri 9.

26-09-2011

Sub-Himalayan West Bengal & Sikkim

Islampur 9, Haldibari 8.

Bihar

Rewaghat 32, Mahedi/Mehashi, Sheohar 28, Meenapur 27, Ahirwalia, Chakia, Dhengbridge 26, Belsand 23, Chapra 22, Sahebganj, Marsrakh 18, Muzaffarpur, Vaishali 17, Ladegiaghat 15, Benibag 14, Motihari 13, Jandhaha 12, Arwal, Balan, Phulparas, Patna, Sripalpur, 9, Mohania, Hayaghat, Jhanjharpur 8, Chargharia, Rosera 7.

27-09-2011

Sub-Himalayan West Bengal & Sikkim

Haldibari 13, Jalpaiguri 9, NH-31 Bridge, Dinhata 8, Domohani, Mohitnagar 7.

Bihar

Taibpur 17, Galgalia 12, Dhengraghat 10, Araria, Saulighat, Jandaha 7.

2.6 Deep Depression over the Bay of Bengal (19 – 20 October 2011)

2.6.1 Brief history

A low pressure area formed under the influence of a cyclonic circulation over southeast & adjoining southwest Bay of Bengal over the same area on 17 morning. It lay as a well marked low pressure area over east central & adjoining northwest and west central Bay of Bengal on 18. Then, it lay over north and adjoining east central Bay of Bengal in the evening and subsequently concentrated into a **Depression** at 0000 UTC of 19 near Lat. 20.0° N/Long. 90.5° E, about 350 Kms east-southeast of Digha. It further moved northeastwards and lay centered at 0300 UTC of 19 near Lat. 20.2° N/Long. 91.0° E and intensified into a **Deep Depression** at 0600 UTC near Lat. 20.5° N/Long. 91.5° E. It lay over northeast Bay of Bengal, near Lat. 21.0° N / Long. 92.0° E, very close to Bangladesh coast at 1200 UTC of 19. It crossed Bangladesh coast, close to south of Cox's Bazar around 1300 UTC and subsequently weakened into a **Depression** at 0000 UTC of 20 and lay centered near Lat. 21.5° N / Long. 93.5° E. It further weakened into a low pressure area and lay over Myanmar and adjoining Bangladesh and Mizoram and northeast Bay of Bengal on 20 and became less marked on 21.

2.6.2 Other features observed

The maximum estimated mean wind speed was 30 knots. The lowest central pressure of 1001.5 hPa was reported by Cox's Bazar (Bangladesh) at 1200 UTC of 19. It generally moved northeastwards.

2.6.3 Weather and damage caused

As the system was far away from the Indian coast, no adverse weather/damage occurred over the Indian region.

2.6.4 Satellite and RADAR observations

The maximum intensity of the T No 2.0 was reported from 0600 UTC to 1800 UTC of 19.

2.7 Cyclonic Storm 'Keila' over the Arabian Sea (29 Oct. – 4 Nov. 2011)

2.7.1 Brief history

The trough of low from south Arabian Sea to south Gujarat coast on 27 Oct. organised into a low pressure area over the central parts of south Arabian Sea and adjoining central Arabian Sea on 28. It lay as a well marked low pressure area over the central and adjoining south Arabian Sea on 29. It concentrated into a **Depression** over the west central and adjoining southwest Arabian Sea and lay centred at 0600 UTC of 29, near Lat. 13.0°N / Long. 62.0°E, about 1400 kms west of Mangalore. Moving westwards, it lay centred at 1200 UTC of 29 near Lat. 13.0°N / Long. 61.0°E and at 0300 UTC of 30 near Lat. 13.0°N / Long. 60.0°E. Subsequently moving northwestwards, it lay centred near Lat. 13.5°N / Long. 59.5°E at 1200 UTC of 30; near Lat. 15.0°N / Long. 58.5°E at 0300 UTC of 31 October and near Lat. 16.0°N / Long. 57.5°E at 1200 UTC of 31 October. Moving westwards, it intensified into a **Deep Depression** and lay centered near Lat. 16.0°N / Long. 56.0°E at 0300 UTC of 1 November and near Lat. 16.0°N / Long. 55.5°E at 1200 UTC. Continuing the westward movement, it further intensified into **Cyclonic Storm 'Keila'** and lay centered at 0300 UTC of 2, near Lat. 16.0°N / Long. 55.0°E. Subsequently, it moved north northwestwards and lay centered near Lat. 16.5°N / Long. 54.5°E, about 30 kms south southeast of Salalah (Oman) at 1200 UTC of 2. It further moved northwestwards and crossed Oman coast, close to north of Salalah (17.1/54.3) between 1600 – 1700 UTC and weakened into a **Deep Depression** and lay centered at 1800 UTC of 2, over coastal Oman, close to Salalah (17.1/54.2). It remained practically stationary over the same area at 0300 UTC of 3. Moving eastwards, it lay at 1200 UTC of 3, over Oman coast centered near Lat. 17.0° N/ Long. 54.5° E. It meandered over the same region and then moving slightly southwestwards, weakened into a **Depression** and lay centered at 0300 UTC of 4 near Lat. 16.5° N/ Long. 55.0° E. It subsequently weakened into a low pressure area at 0600 UTC of 4 and became less marked in the evening.

2.7.2 Other features observed

The lowest estimated central pressure (ECP) was 996 hPa from 0600 UTC of 2 Nov. till the time the system crossed the coast. The maximum estimated mean wind speed was 35 knots. Around the time of landfall, Salalah reported maximum wind of 23 knots at 1500 UTC and 6 knots at 1800 UTC of 2nd November 2011. It indicates that the system weakened just after the landfall.

The system initially moved westwards, then northwestwards and again in westward direction. It moved further in northwestward direction before crossing the coast. After crossing, it moved in a southerly direction, re-emerged into the Arabian Sea, close to Oman coast and dissipated over the Sea area.

2.7.3 Weather and damage caused

As the system was far away from the Indian coast, no adverse weather/damage occurred.

2.7.4 Satellite and RADAR observations

As per the satellite observation, the maximum intensity of T 2.5 was reported from 0300 to 1500 UTC of 2. It meandered over the Oman coast and re-emerged into the Arabian Sea at 0300 UTC of 4 Nov. as Depression and weakened into low pressure area.

2.8 Deep Depression over the Arabian Sea (6 – 10 Nov. 2011)

2.8.1 Brief history

A low pressure area formed over the southeast and adjoining east central Arabian Sea on 2. It lay as a well marked low pressure area over the central parts of Arabian Sea on 6 morning and concentrated into a **Depression** at 0600 UTC of 6, over the central and adjoining southeast Arabian Sea, near Lat. 10.5° N/ Long. 65.5° E (about 1050 kms west southwest of Mangalore) and near Lat. 10.6° N/ Long. 65.5° E at 1200 UTC of 6. Further moving west northwestwards, it lay at 0300 UTC of 7, near Lat. 11.5° N/ Long. 63.5° E and at 1200 UTC, near Lat. 13.5° N/ Long. 60.5° E. Moving westwards, it intensified into a **Deep Depression** and lay centered at 0300 UTC of 8, over the west central Arabian Sea, near Lat. 13.5°N/ Long. 60.0°E. Then, it moved west northwestwards and lay centred at 1200 UTC of 8, near Lat. 14.0° N/ Long. 59.0° E. Further moving north northwestwards, it lay centred at 0300 UTC of 9, near Lat. 15.0° N/ Long. 58.5° E. Thereafter it moved northwards, weakened into a **Depression** and lay centered at 1200 UTC of 9, near Lat. 15.5° N/ Long. 58.5° E. It moved northwards and lay centered at 0300 UTC of 10, near Lat.16.0° N/ Long. 58.5° E. It then weakened into a well marked low pressure area and lay over the west central Arabian Sea off Oman coast in the evening of 10. It further weakened and became unimportant by 11th morning.

2.8.2 Other features observed

The lowest estimated central pressure (ECP) was 1000 hPa from 0300 UTC of 8 to 0600 UTC of 9. The maximum estimated mean wind speed was 30 knots. A ship SKWI (14.9/58.8) reported highest mean wind speed of 50 kts and PPPP 1001.2 hPa at 0300 UTC of 9.

The system moved in a northwesterly direction from 0600 UTC of 6 to 1200 UTC of and then it moved in a northerly direction for sometime before dissipating over the Sea area.

2.8.3 Weather and damage caused

As the system was far away from the Indian coast, no adverse weather/damage occurred.

2.8.4 Satellite and RADAR observations

The maximum intensity of the T No 2.0 was reported from 0000 UTC of 8 to 0600 UTC of 9.

2.9 Deep Depression over the Arabian Sea (26 Nov. – 1 Dec. 2011)

2.9.1 Brief history

A well marked low pressure area formed over Comorin area & neighborhood under the influence of a cyclonic circulation over the area on 25. It concentrated into a **Depression** and lay at 0300 UTC of 26 centered near Lat.7.5° N and Long 76.5° E, about 120 km south southwest of Thiruvananthapuram. It moved northwestwards and lay at 1200 UTC over Lakshadweep area & adjoining Maldives and Comorin area, centered near Lat. 8.5° N and Long 75.0° E. It further moved northwestwards and lay at 0300 UTC of 27 over Lakshadweep area and neighbourhood centered near Lat 10.5^0 N and Long. 73.0^0 E, about 70 km southeast of Amini Divi. It continued to move northwestwards and lay at 1200 UTC over southeast & adjoining east central Arabian Sea centered near Lat. 12.0° N and Long 71.5° E. Maintaining its northwesterly course, it intensified into a **Deep Depression** and lay at 0000 UTC of 28 over east central Arabian Sea centered near Lat. 13.5° N / Long. 70.0° E & near Lat 14.0^0 N /Long. 69.5^0 E, about 450 km northwest of Amini Divi (Lakshadweep Island) at 0300 UTC. Then, it took a west-northwesterly course and lay at 1200 UTC of over east central Arabian Sea centered near Lat 15.0^0 N / Long. 68.0^0 E and at 0300 UTC of 29 and near Lat. 15.7° N / Long. 66.8° E, about 750 kms southwest of Mumbai. It remained practically stationary and weakened into a **Depression** and lay centered near Lat. 16.0 °N/ Long. 66.5 °E at 1200 UTC of 29. Further moving northwestwards, it lay over the east central and adjoining west central Arabian Sea, near Lat. 17.0 °N/ Long. 64.5 °E at 0300 UTC of 30 and near Lat. 18.0 °N/ Long. 63.5 °E at 1200 UTC. Moving further northwestwards, it lay centered at 0300 UTC of 1 Dec. near Lat. 19.5° N / Long. 62.5° E, about 1100 kms west of Mumbai. It weakened into a well marked low pressure area at 0600 UTC of the same day over the same area and lay as a low pressure area over west central Arabian Sea in the evening. The system became less marked on 2nd morning.

2.9.2 Other features observed

The lowest estimated central pressure (ECP) was 998 hPa from 0000 UTC of 28 to 0600 UTC of 29. The maximum estimated mean wind speed was 30 knots. Amini Divi reported lowest pressure of 996.3 hPa at 0300 UTC of 27 Nov. when the system was 70 kms southeast of Amini Divi.

The system moved generally in a northwesterly direction, before dissipating over the Sea area.

2.9.3 Weather and damage caused

As the system was far away from the Indian coast, no damage occurred.

Heavy to very heavy rainfall at isolated places occurred over Kerala on 27 Nov. and Lakshadweep during 27 - 28 Nov. Though the system moved into Arabian Sea, it drew moisture from the Bay of Bengal across Tamil Nadu. So all the sub divisions covered by North east monsoon regime received excess weekly rainfall during the week ending 30.11.2011.

Some chief amounts are given below:

25-11-2011

Tamil Nadu: Tiruvadanai 20**,** Muthupet, Kollidam, Kattumannarkoil 17, Marakkanam, Pattukottai 15, Chidambaram, Parangipettai, Cuddalore, Tiruthuraipoondi 14, Peravurani 13.

26-11-2011

Tamil Nadu:

Venkatagiri Town 23, Uthiramerur 20, Maduranthagam 19, Virudhachlam 17, Vembavur, Mahabalipuram 16, Vallam, Thozudur 15, Chengalpattu, Sethiyathope 14, Nanguneri, Kodavasal, Tiruvarur, Orathanadu, Marakanam 13

27-11-2011

Tamil Nadu:

Varkala 18, Pallipattu, Coonoor 16, Papanasam, Tiruvallur, Rameshwaram 15, Poondi 14, Kodaikanal 13

Kerala

Varkala 18, Neyyattinkara 9, Kollam, Thiruvananthapuram 7

Lakshadweep

Kavaratti 11, Agathi 7

28-11-2011

Tamil Nadu:

Nellore 18, Ponneri 15, Papanasam 15

Lakshadweep

Agathi 8

2.9.4 Satellite and RADAR observations

The maximum intensity of the T No 2.0 was reported from 2100 UTC of 27 to 0300 UTC of 29.

2.10 Very Severe Cyclonic Storm (Thane) over the Bay of Bengal (25– 31 Dec. 2011)

2.10.1 Brief history

A trough of low at mean sea level organized into a low pressure area over the southeast Bay of Bengal and neighbourhood in the forenoon of 24th. It became well marked over the same area by 24th evening and persisted there on 25th morning. It concentrated into a **Depression** and lay at 1200 UTC of 25 centered near Lat.8.5° N and Long 88.5° E, about 1000 kms south east of Chennai. It moved northwestwards and intensified into a **Deep Depression** at 0000 UTC of 26 over southeast Bay of Bengal and lay centered near Lat. 9.5° N/Long. 87.5° E. It remained practically stationary during next 3 hours and lay centered at 0300 UTC of 26 near Lat. 9.5° N/Long. 87.5° E, about 900 kms southeast of Chennai. It moved further northwards and lay centred at 1200 UTC of 26 over the southeast Bay of Bengal, near Lat. 10.5° N/Long. 87.5° E. Further moving northwards, it intensified into a **Cyclonic Storm (Thane)** and lay centred at 1800 UTC 26 over the southeast Bay of Bengal, near Lat.11.0° N/Long. 87.5° E. It then moved northwestwards and lay centered at 0300 UTC of 27 over the southeast Bay of Bengal, near Lat. 12.0° N/Long. 87.0° E, about 750 kms eastsoutheast of Chennai and near Lat. 12.5° N/Long. 86.5° E at 1200 UTC. It then moved westwards and lay centred at 0300 UTC of 28 over the southwest & adjoining southeast Bay of Bengal near Lat. 12.5° N/Long. 85.5° E, about 550 kms eastsoutheast of Chennai. Continuing its westward movement, it intensified into a **Severe Cyclonic Storm** at 0900 UTC, near Lat. 12.5° N/Long. 85.0° E and further intensified into a **Very Severe Cyclonic Storm** at 1200 UTC of the same day and lay centered near Lat. 12.5° N/Long. 84.5° E. It further moved westsouthwestwards and lay centered at 0300 UTC of 29, near Lat. 12.0° N/Long. 82.5° E, about 270 kms east of Puducherry and at 1200 UTC near Lat. 12.0° N/Long. 81.3° E. Subsequently moving westwards it crossed north Tamil Nadu coast close to south of Cuddalore between 0100 - 0200 UTC of 30. It continued to move westwards and weakened into a **Severe Cyclonic Storm** and lay centered at 0300 UTC of 30, near Lat. 11.6° N/Long. 79.5° E, about 30 kms west of Cuddalore and 35 kms southwest of Puducherry. Moving further westwards, the system weakened rapidly into a **Deep Depression** at 0600 UTC, near Lat. 11.6° N/Long. 79.0° E, about 100 kms west of Cuddalore. It moved westsouthwestwards and further weakened into a **Depression** and lay centered at 1200 UTC, over north Tamil Nadu close to Salem(Lat. 11.6° N/Long. 78.2° E). Moving westwards, it further weakened into a well marked low pressure area over north Kerala and neighbourhood at 0000 UTC of 31.

2.10.2 Other features observed

As per the post cyclone survey report, the lowest observed mean sea level pressure was 969 hPa was recorded at Cuddalore. Puducherry reported maximum wind of 68 knots (125 kmph) and Cuddalore reported maximum wind of 76 knots (140 kmph) at the time of landfall. Gale wind speed reaching 120-140 kmph prevailed along and off north Tamil Nadu and Puducherry coast.

Storm surge

As per post-cyclone survey conducted by IMD, the storm surge of about 1 metre height inundated the low lying coastal areas of Cuddalore, Puducherry and Villuparam districts at the time of landfall of the cyclone, Thane.

The system moved initially in the northwesterly direction and then in a northerly direction. It again moved in a northwesterly direction and further moved in a westerly direction. After attaining the intensity of Very Severe Cyclonic Storm, it then moved generally in a west to west southwesterly direction and crossed north Tamilnadu coast between Cuddalore (43329) and Puducherry (43331) during 0100 UTC to 0200 UTC of 30 Dec.

2.10.3 Weather and damage caused

Incidents related to heavy rains claimed 35 lives in Tamil Nadu, 7 in Puducherry, and 4 in Kerala. In fishing sector, in the cyclone affected coastal areas, hundreds of boats were damaged About 73292 thatched houses were fully and 94633 houses were partially damaged by wind and rains in various districts in the Tamil Nadu. 6000 people were sent in relief camps. Standing crops of Sugarcane, Tapioca, betel nuts, banana and coconut over thousands of hectares were affected. The storm uprooted trees and electric post, disrupted power supply and transport services and standing crops. Cuddalore was the worst-hit district with roads severely damaged. The estimated damage was 1300 to 1500 crores.

Under the influence of the system, widespread/fairly widespread rainfall occurred over Andaman & Nicobar Island from 25-27 Dec. and over coastal Andhra Pradesh, Rayalaseema, Tamil Nadu and Kerala during 31 Dec.2011-1 Jan. 2012.

Heavy to Very heavy rainfall occurred at isolated places over Andaman & Nicobar Islands on 24 from 26 -27 Dec. and at a few places over Tamil Nadu and Kerala during 30 - 31 Dec. and 31 Dec. respectively.

The significant amount of 24 hours cumulative rainfall (>7 cm) recorded at 0300 UTC of date are as follows:

24-12-2011

Andaman & Nicobar Islands

Nancowry 7.

26-12-2011

Andaman & Nicobar Islands

Port Blair 11, Nancowry 10.

27-12-2011

Andaman & Nicobar Islands

Maya Bandar 19

30-12-2011

Tamil Nadu & Puducherry

Puducherry 15, Kalpakkam, Kelambakkam 10, Cuddalore, Uthiramerur, Maduranthagam 9, Chingalepet, Mahabalipuram 8, Chennai, Tiruvallur 7.

31-12-2011

Tamil Nadu

Kallakurichi 18, Gingee 16, Mylaudy, Nagarkoil, Sankarapuram 14, Kuzithurai, Uthiramerur 13, Cheyyar, Virudhachalam 12, Tozudur, Tirukoilur, Polur, Sathanur, Proj Wandiwash 11, Maduranthagam, Kancheepuram, Puducherry, Arni 10, Chengalpet, Tiruvannamalai, Ulundurpet 9, Boothapandi, Kanyakumari, Tiruvallur, Chengam, Kalavai, Sholingur 8, Chennai, Jayamkondan, Cheyyur, Kelambakkam, Sriperumbudur, Padallur, Attur, Kumbakonam, Poonamallee, R.K.Pet, Thiruvalangadu, Tiruttani, Arakkonam, Tindivanam, Viluppuram, Vellore 7.

Kerala

Haripad 22, Thiruvananthapuram 18, Nedumangad 16, Kayamkulam 15, Thiruvalla 14, Chengannur 12, Mancompu, Neyyattinkara 11, Mavelikkara 10, Alappuzha, Kottayam, Kanjirapally, Konni 9, Punalur 8, Kozha, Varkala 7.

2.10.4 Satellite and RADAR Observation:

The maximum intensity of T 4.5 was reported from 0300 UTC to 2300 UTC of 29. **EYE** was reported during this period.

DWR Chennai issued the serially numbered RADAR bulletin from 28 1200 UTC till 0600 UTC of 30 and then the hourly radar based bulletin was discontinued as the system had weakened beyond reasonable estimation of features.

Annual Review of Tropical Cyclones

The Annual Review for the year 2010 has been completed and has been sent to WMO for publication. The Annual Review for the year 2011 is under progress and will be completed soon. 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 2012.

1.7. REVIEW OF THE TROPICAL CYCLONE OPERATIONAL PLAN

Mr. B. K. Bandayopadhyay, rapporteur of Tropical Cyclone Operational Plan (TCOP), presented a comprehensive review made to produce the 2011 version of the Operational Plan. He suggested that along with the naming of cyclones, its meaning should also be given by the respective countries. Further, he made a few comments to make the Plan more effective. The Panel appreciated Mr. Bandayopadhyay for his devotion to the Operational Plan during last year, noting in particular the heavy workload of the update process. It requested Mr. Bandayopadhyay to continue to serve as the rapporteur for 2012. The 2011 Edition of TCOP is available on the WMO TCP website. For the early issuance of the 2012 Edition of TCOP as well as alleviation of the workload, the Panel urged the Members to communicate their amendments, if any, to Mr. Bandayopadhyay as early as possible and not later than 31 March 2012.

To secure the close communication between operational forecasters of the RSMC New Delhi and the Member countries, the Panel requested the rapporteur to pay special attention to reestablishment of the list of focal points of the forecast centers (ANNEX V-A-1) with the support of the PTC Secretariat.

1.8. PTC SECRETARIAT

The Panel expressed its gratitude to the Government of Pakistan for hosting the PTC Secretariat and appreciated the services being rendered by Dr Qamar uz Zaman Chaudhry, Permanent Representative of Pakistan with WMO in his capacity as Secretary of PTC and Mr. Ata Hussain, Deputy Director (Coordination and International Cooperation) PMD as the Meteorologist of PTC Secretariat.

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

The Panel was briefed by Mr. Hussain 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 Panel was informed that the new website of PTC (www.ptc.wmoescap.org) was launched in 2011. For making the website more informative and useful, the Panel urged the Members for send their views and comments to PTC Secretariat.

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 2012-2013.

1.9. SUPPORT FOR THE PANEL'S PROGRAMME

The Panel was informed that the WMO Technical Cooperation Programme (TCO) activities are being implemented with funding from the WMO Voluntary Cooperation Programme (VCP), Trust Fund (TF) arrangements and a modest Regular Budget contribution, mainly for fellowship and training purposes to ensure successful implementation of WMO programmes, as well as the WMO Programme for the Least Developed Countries (LDCs). Technical cooperation activities are also being implemented through bilateral and multilateral arrangements and through funding provided by financial institutions such as the World Bank and regional development banks and other partners.

The Panel noted that in 2011, Maldives made a cash contribution to the Voluntary Cooperation Fund (VCP(F)). A new VCP project request was submitted by Sri Lanka for the provision of upper-air consumables (radiosondes and balloons) for the CINDY/DYNAMO field experience and this request was supported by Japan and TOTEX (Japan). A TDCF Migration Expert Mission to Bangladesh was completed in 2011. An expert mission to Myanmar on the satellite data utilization was carried out in December 2011. An expert mission on feasibility investigations for the future projects of BMD took place in January 2012. Two VCP projects are under implementation 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 (September/October 2010), Factory Acceptance Tests (September/October 2010 and January 2011), a Coordination Meeting (October 2010) 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 2012.

It is recalled that the basic objective of the Technical Cooperation among Developing Countries (TCDC) (or South-South Cooperation) was to promote and strengthen collective self-reliance among developing countries through the exchange of expertise, pooling of resources, sharing of technical capabilities and development of complimentary capacities. Expert missions, familiarization visits, study tours and training were also implemented under the TCDC. The Member countries are invited to utilize such a scheme to promote the technical cooperation activities. In this regard, the Panel recognized the usefulness of the training courses organized by PMD for the Panel members and requested WMO to explore the possibility to find financial resources to support to conduct similar training courses in Pakistan.

The Panel was informed that China organized the 40th China Study Tour and the Regional Training Seminar on WMO Information System (WIS) in April 2011. Maldives, Myanmar, Pakistan, Sri Lanka and Thailand of the Panel participated in the event, which witnessed the donation of communication and information systems (CMACast and MICAPS) to all the participating countries aimed at enhancing the capabilities of NMHSs in the implementation of WIS in Asia.

The Panel noted that the WMO "Emergency Assistance Fund" (officially entitled "WMO Disaster Assistance Fund for Meteorological and Hydrological Services"), established in 1991, is an existing WMO emergency assistance mechanism to assist Members affected by disasters in the rehabilitation and restoration of observing network, data collection and processing facilities and in international data exchange, in cases where disasters have destroyed or severely disabled the meteorological and/or hydrological infrastructure. In recent years (2005-2011), Bangladesh, Myanmar, Pakistan and Sri Lanka were assisted by this scheme. Affected Members who need emergency assistance are advised to utilize this scheme, and all Members are requested to consider possible support to the affected NMHSs.

The Panel also noted in Bangladesh, some meteorological equipment was damaged by floods during the severe Cyclone Sidr in November 2007. Three SSB transceivers and two sets of Automatic Weather Stations (AWSs) were provided with the support of France, UK, VCP(F) and the WMO Emergency Assistance Fund.

The Panel was informed that following Cyclone Nargis in May 2008, a WMO emergency appeal was made for assistance to re-establish essential meteorological infrastructure and services in Myanmar. China and Japan offered to provide in-kind and cash contributions to the WMO Emergency Assistance Fund. Hydrometeorological instruments including an AWS, an electric generator, PCs for storm surge modeling as well as short-term training and a long-term fellowship, were provided in 2008-2010. More reliable Internet connectivity is to be provided to the Department of Meteorology and Hydrology (DMH), Myanmar, with the Emergency Assistance Fund and the VCP(F). India offered to provide an INSAT Digital MDD system to DMH in 2010.

The Panel was informed that following the exceptional severe floods in Pakistan in July-August 2010, a WMO fact-finding and needs-assessment mission was carried out from 4 to 8 November 2010 in collaboration with ESCAP and in coordination with UNESCO. The mission assessed the current capability of the Pakistan Meteorological Department (PMD), specifically, with regard to technical details of Pakistan floods in July-August 2010; damage to the hydrometeorological infrastructure; capability of PMD flood monitoring and warning services; responses by stakeholders; and community-level dissemination and public awareness. The mission assisted PMD in the development of a proposal for the enhancement of its meteorological and hydrological services to implement effective flood early warning systems. Based on the findings and recommendations of the mission, a WMO appeal has been made for assistance to restore essential hydrometeorological infrastructure (AWSs, conventional synoptic meteorological stations, etc.) in Pakistan. Potential donor Members are invited to consider possible in-kind and/or cash contributions to the WMO Emergency Assistance Fund to meet the immediate and medium-term requirements of PMD.

The Panel was pleased to note that a WMO/RIMES joint regional project for “Reducing risks of tsunami, storm surges, large waves and other natural hazards in low elevation coastal zones” was submitted in August 2010 to the United Nations

Economic and Social Commission for Asia and the Pacific (ESCAP) Tsunami Regional Trust Fund for its sixth round of funding. This project was approved for funding by UN ESCAP in January 2011 and a Letter of Agreement was concluded between UNESCAP and RIMES in May 2011 for the implementation of the project. WMO and RIMES concluded necessary arrangements. This project is to be implemented in six (6) Panel member countries, i.e., Bangladesh, India, Maldives, Myanmar, Sri Lanka and Thailand for the two year period from May 2011 to April 2013 aiming at reducing tsunami, storm surges, large waves and other natural 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 Panel noted that a project meeting was held at the AIT Conference Center from 28 to 30 September 2011 with the participation of the representatives of six (6) participating countries, ESCAP, WMO and RIMES to discuss and finalize country work plans. In addition, six (6) other countries, i.e., Cambodia, China, Lao PDR, Pakistan, Philippines and Viet Nam were also invited to identify approaches for replicating the project.

The Panel was informed that WMO will mainly implement the component on "Capacity building for the generation of location-specific warning information products" as well as other component related to Public Weather Services, with the close collaboration with the National Meteorological and Hydrological Services of the participating countries and RIMES. In this regard, the Panel noted that the Technical-Planning Workshop on Severe Weather Forecasting Demonstration Project (SWFDP) for the Bay of Bengal (South Asia) was held in New Delhi, India, from 23 to 27 January 2012. Participants included representatives (forecasters) of Bangladesh, India, Maldives, Myanmar, Sri Lanka and Thailand, representatives from global products centres (JMA, NOAA/NCEP and IMD/NCMRWF), and the WMO Secretariat within this project.

1.9.1 Panel on Tropical Cyclones Trust Fund (PTCTF)

The establishment of the Panel on Tropical Cyclones Trust Fund (PTCTF) indicated a step towards achieving self-reliance of the Panel. At the moment, the Trust Fund is being used not only for the provision of institutional support but also as funding support to the representatives of Panel Members attending training events and conferences.

Members were urged to continue to enhance their contributions to the Trust Fund as a substantial support for the Panel's activities.

A detailed financial report on the Trust Fund as of 31 December 2011 was submitted by WMO to the Panel (see **Appendix II**).

The Panel endorsed the use of the Trust Fund for 2012 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 to PTC Secretariat for its operating expenses including those for printing Panel News and running PTC-website. (US$ 4,000)

3 Support for participation of PTC in the 10th Session of ICG/IOTWS (US$3,000)
4 Support for participation of PTC in the ESCAP Commission (US$3,000)
5 Support for organizing a PTC Workshop in Oman (US$15,000)

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. Some of the lectures were presented in the Technical Conference which was held prior to the opening ceremony. The list of all the presentations inclusive of those in the Technical Conference is as follows:

- Global Framework for Climate Services
  - Dr Geoff Love (WMO)
- Storm Surge Inundation in Rekhine and Deltaic coast of Myanmar under climate change scenarios
  - Prof. S. K. Dube (IIT)
- Air Traffic Management applications of Tropical CycloneInformation
  - Mr. Peter Dunda (ICAO)
- Forecast Demonstration Project (FDP) on Landfalling Cyclones over the Bay of Bengal :An Overview'
  - Mr. B. K. Bandyopadhyay (IMD)
- Tropical Cyclone Forecasting Experience after NARGIS in Myanmar
  - Mr. Chit Kyaw (Myanmar)
- Bitter experience to Better resilience: Lessons learnt from Cyclone Nargis for disaster risk reduction intervention in Myanmar
  - Ms. Lat Lat Aye (UNDP)
- Response to 2011 Disasters
  - Mr. Chum Hre (Myanmar)
- WMO's Support activities for Forecasting and Warning Services in Myanmar
  - Mr Kuniyuki Shida (WMO)
- Challenging to Innovative Water-related Disaster Risk Management'
  - Dr Badri Shrestha (ICHARM)
- Improvement of cyclone and storm-surge forecasting and warning in the Department of Meteorology and Hydrology, Myanmar
  - Mr. Kunio Akatsu (JICA)
- Lessons learned from Great East Japan Earthquake, Tsunami
  - Mr. Hideomi Oi (JICA)
- Disaster Impacts and Early Warning
  - Ms Edle Tenden & Ms Mari Sawai

(ESCAP)

- Update on the status of the IOTWS and the Regional Tsunami Service Providers

  \- Mr Tony Elliott (UNESCO/IOC)

- Sensitivity of Physical Parameterization schemes in Simulating the Cyclone Nargis and other major Cyclones over the Bay of Bengal.

  \- Dr Potty Jayaraman (RIMES)

- Introduction of Typhoon Nowcasting System in CMA

  \- Mr Xu Yinglong (China)

- Coupling atmospheric, crop and econometric models for climate risk reduction in PTC member Countries

  \- Mr Sanjay Srivastava (ESCAP)

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 FOURTIETH SESSION

The representative of Sri Lanka proposed to host the next session of PTC in Sri Lanka subject to approval by the government of Sri Lanka. The dates of the 40th session in 2013 would be determined based on the consultation between Sri Lanka, WMO, ESCAP, Chairman of the Panel and Secretary of PTC.

1.12. ADOPTION OF THE REPORT

The report of the thirty-ninth session was adopted at 1145 hours on Friday, 9th March 2012.

1.13. CLOSURE OF THE SESSION

The Panel expressed its sincere appreciation to the Government of Myanmar, the host country, for providing the excellent facilities, the venue, other arrangements and its warm hospitality. The Panel also expressed its deep appreciation to Dr Hrin Nei Thiam, Chairperson of the Panel, Mr Sunil H Kariyawasam, 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 Dr Hrin Nei Thiam for their hard work in organizing the session, assistance provided to the participants and producing a session report.

The thirty-ninth session of the Panel was concluded at 1250 hours on Friday, 9th March 2012.

CHAPTER-II

(A) CYCLONIC ACTIVITIES OVER NORTH INDIAN OCEAN DURING 2011

The north Indian and adjoining land surface Ocean witnessed the formation of ten cyclonic disturbances during the year 2011. Out of ten disturbances five cyclonic disturbances formed over the Bay of Bengal, four over the Arabian Sea and one over land. Out of the five cyclonic disturbances over the Bay of Bengal, one intensified upto the stage of very severe cyclonic storm, THANE, two upto the stage of deep depression and rest two upto the stage of depression. Out of four cyclonic disturbances formed over the Arabian Sea, one intensified upto the stage of cyclonic storm, KEILA, two upto the stage of deep depression and one upto the stage of depression. Tracks of the cyclonic disturbances formed over the north Indian Ocean during the period are shown in Fig.1.

The salient features of the cyclonic disturbances during 2011 were as follows:

- The number of total cyclonic disturbances (depression and above) during the year was below normal, as only 10 cyclonic disturbances formed during 2011 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 cyclone 'Keila' made landfall over Oman, the very severe cyclonic storm, 'Thane' made landfall over Tamilnadu and Puducherry coast.
- The track of the cyclone "KEILA" was rare in nature as it made a loop after the landfall over Oman near Salalah.
- There were four 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 main monsoon month of July and August 2011. However, one land depression formed during July.

(a) Cyclonic Storm, "KEILA" over the Arabian Sea (29 October-04 November, 2011.)

A cyclonic storm 'Keila' developed over the southeast Arabian Sea with genesis of depression on 29th October, 2011. It moved initially west-northwestwards and then northwestwards and crossed Oman coast close to north of Salalah. It then emerged into Arabian Sea and dissipated gradually. It caused death of 14 people in Oman. The system was mainly monitored by the satellite. However, crucial ship and buoy observations also helped in estimation of location and intensity.

The special features of the storm are as follows:

- It was one of the rarest track in recent years, as the cyclone made a loop after Its landfall over Oman and emerged into the Arabian Sea.
- The track of the system could not be predicted accurately by most of the NWP models
- The cyclone slowed down during landfall period and gradually dissipated after emerging into Arabian Sea.

(b) Very Severe Cyclonic Storm, ‘THANE’ over the Bay of Bengal (25-31 December 2012)

A very severe cyclonic storm, ‘THANE’ developed from a low pressure area which lay over the southeast Bay of Bengal on 25th December, 2011. The low pressure area concentrated into a depression over the same region on 25th December, 2011 It moved initially in a north-northwesterly direction, and then west-northwestwards. Later it moved west-southwestwards and crossed Tamil Nadu and Puducherry coast close to Cuddalore between 0100 and 0200 UTC of 30th December, 2011 with a wind speed of 12-140 kmph.

The system was initially monitored by satellite. As the system came closer to coast it was monitored by DWR and coastal observations in addition to satellite observation. The crucial observations from ship and buoys also helped in estimation of location and intensity. The salient features of cyclone THANE are given below:

- The system intensified despite the relatively colder sea (SST 26-27^{0}C, low ocean thermal energy (<50 KJ/cm^2) over southwest Bay of Bengal near north Tamil Nadu coast.
- The continuous intensification could not be picked up by most of the NWP models which suggested slight weakening before landfall.
- The track was also rare, as there is no analogue in the month of December based on the recorded historical data of IMD during 1891-2010.

The statistics of the cyclonic disturbances formed during 2011 are given in Table 1.

Table 1: Cyclonic disturbances formed over north Indian Ocean and adjoining land areas during 2011

1.	Depression over the Bay of Bengal 02-03 February 2011
2.	Depression over the Arabian Sea (11-12 June 2011)
3.	Deep depression over the Bay of Bengal (16-23 June, 2011)
4.	Land depression over Jharkhand (22-23 July 2011)
5.	Depression over Bay of Bengal (22-23 Sept 2011)
6.	Deep depression over the Bay of Bengal (19-20 October, 2011)
7.	Cyclonic storm **‘KEILA’** over the Arabian Sea (29 October- 04 November, 2011)
8.	Deep Depression over the Arabian sea (06- 10 November 2011)
9.	Deep depression over the Arabian Sea (26 November to 1st December, 2011)
10	Very Severe Cyclonic Storm **‘THANE’** over the Bay of Bengal 25-31 December 2011

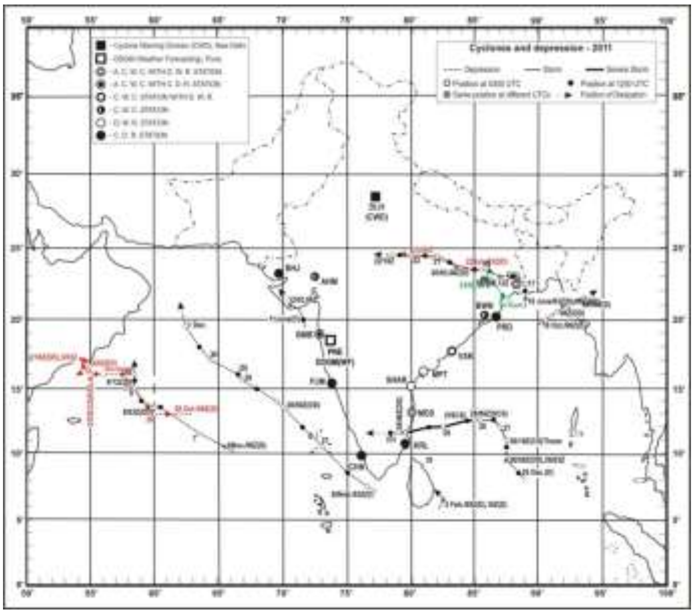


Fig. 1

(B) Description of cyclonic storms during 2011

2.1 Cyclonic storm ‘KEILA’ over the Arabian Sea (29 October- 04 November, 2011)

2.1.1 Introduction:

A cyclonic storm ‘KEILA’ developed over the Arabian Sea. It moved initially west-northwestwards and then northwestwards and crossed Oman coast close to the north of Salalah. It then remerged into the Arabian Sea and dissipated gradually. It caused death of 14 people in Oman. It caused death of 14 people in Oman. The salient features of the system are given below. The system was mainly monitored by the satellite imageries and products. However, the crucial ship and buoy observation also helped in estimating the location and intensity of the system. When the system came close to the Oman coast, coastal observations were also useful.

2.1.2 Genesis:

In association with active ITCZ, convective cloud cluster developed over southeast and adjoining eastcentral Arabian Sea during last week of October 2011. It gradually concentrated into a low pressure area on 27th October, 2011. It became well marked, while moving west-northwestwards on 28th October and concentrated into a depression over westcentral and adjoining southwest Arabian Sea and lay centred at 0600 UTC of 29th October 2011 near lat. 13.0^{0}N and long. 62.0^{0}E with gradual increase in depth and organisation of convection. The intensity of the system was T1.5 as per Dvorak’s technique applied to Kalpana imageries. The associated broken intense to very intense convection lay over the area between lat.

9.0^{0}N to 18.0^{0}N and long 56.0^{0}E to 72.0^{0}E. The lowest cloud top temperature (CTT) was -79^0 C. The sustained Maximum wind speed was 25 knots around the system centre with rough to very rough sea condition. The estimated central pressure was 1004 hPa.

The cyclogenesis on 29th occurred due to increase in relative vorticity and convection at lower levels and upper air divergence. It was also due to low to moderate vertical wind shear (5-10 knots) with decreasing tendency (5-10 knots in past 24 hours). The upper level divergence was provided by the anticyclonic circulation which lay to the northeast of the system centre with ridge running along 15^{0}N.

The best track parameters of the system are given in Table 2.1.1. The track of the system is shown in Fig.1. The typical satellite imageries showing the genesis and intensification/weakening of the system are shown in Fig. 2.1.1. The ECMWF analysis showing the lower level relative vorticity, lower level wind & upper level divergence and vertical wind shear are shown in Fig. 2.1.2. The genesis potential of the system could be picked up by the Genesis potential parameters of IMD.

2.1.3 Intensification and movement:

The favourable environmental condition prevailed over the Arabian Sea during 29-31 October 2011. However, the tropospheric ridge gradually moved northwards and ran along 18^{0}N on 1st November 2011. It resulted in west-northwestward movement of depression. The depression gradually intensified into a deep depression and lay centred at 0300 UTC of 1st November, 2011 over westcentral Arabian Sea near Lat. 16.0^{0}N and long. 56.0^{0}E, about 230 km east-southeast of Salalah (Oman).

As per Dvorak's technique, the intensity of the system was T2.0. The lowest CTT was -84^{0}C indicating increase in depth of convection. The maximum sustained wind speed was 30 knots and ECP was 1000 hPa.

The sea surface temperature over the central Arabian Sea and Gulf of Aden was about 28-29^{0}C as reported by the ships and buoys and the satellite estimation. However, the Ocean thermal energy was less (<40 KJ/cm^2) over Gulf of Aden and adjoining Arabian Sea. Considering all these the intensification of the system was slow. Further, the MJO was not favourable for intensification of the system as it lay in phase 8. Considering all these, the deep depression continued to move west-northwestwards, intensified into a cyclonic storm 'KEILA' and lay centred at 0300 UTC of 2nd November 2011 over westcentral Arabian Sea near lat 16.0^{0}N and long. 55.0^{0}E, about 150 km southeast of Salalah (Oman). The maximum sustained surface wind speed was 35 knots with ECP of 998 hPa. The intensity according to Dvorak's technique was T2.5. The lowest CTT was -85^{0}C.

As the cyclonic storm 'Keila' lay over colder sea surface and close to the land surface, it did not intensify further. Also there was cold air entrainment to the region. As a result, the cyclonic storm continued to move west-northwestwards and crossed Oman coast close to the north of Salalah between 1600-1700 UTC and lay centre at

1800 UTC of 2nd November 2011 over coastal Oman close to Salalah as a deep depression. Around the time of landfall, Salalah reported maximum wind of 23 knots at 1500 UTC and 6 knots at 1800 UTC of 2nd November 2011. It indicates that the system weakened just after the landfall.

On 3rd November the system lay to the north of the upper tropospheric ridge and in the periphery of the anticyclonic circulation to the east. As a result, the system re-emerged into the Arabian Sea on 3rd November. The anticyclonic circulation over Oman-Yemen area emerged into the Arabian Sea on 3rd November evening also. As a result, the system lay close to the anticyclonic circulation and meander over the region. At last the system moved eastwards and then southwards over the west central Arabian Sea and weakened gradually. It weakened into a low pressure area on 4th November 2011over westcentral Arabian Sea off Oman coast.

Crucial observation with respect to location and intensity are given in Table 2.1.2.

Table 2.1.1:Best track positions for cyclonic storm 'KEILA' (29 Oct-04Nov 2011)

Date	Time (UTC)	Centre lat.^{0}N/long^{0}E	C.I. No.	Estimated centre pressure (hPa)	Estimated maximum sustained surface wind (kts)	Estimated pressure drop at the centre (hPa)	Grade
29-10-2011	0600	13.0/62.0	1.5	1004	25	3.0	D
	1200	13.0/61.0	1.5	1004	25	3	D
	1800	13.0/61.0	1.5	1004	25	3	D
	0000	13.0/60.5	1.5	1004	25	3	D
30-10-2011	0300	13.0/60.0	1.5	1004	25	3	D
	0600	13.0/60.0	1.5	1002	25	3	D
	1200	13.5/59.5	1.5	1002	25	3	D
	1800	14.0/59.0	1.5	1002	25	3	D
31-10-2011	0000	14.5/59.0	1.5	1002	25	3	D
	0300	15.0/58.5	1.5	1000	25	3	D
	0600	16.0/57.0	1.5	1000	25	3	D
	1200	16.0/57.5	1.5	1000	25	3	D
	1800	16.0/57.0	1.5	1000	25	3	D
01-11-2011	0000	16.0/56.5	1.5	1000	25	3	D
	0300	16.0/56.0	2.0	1000	30	4	DD
	0600	16.0/56.0	2.0	1000	30	4	DD

	1200	16.0/55.5	2.0	1000	30	4	DD
	1800	16.0/55.5	2.0	1000	30	5	DD
02-11-2011	0000	16.0/55.3	2.0	1000	30	5	DD
	0300	16.0/55.0	2.5	998	35	7	CS
	0600	16.0/54.5	2.5	996	35	7	CS
	0900	16.0/54.5	2.5	996	35	7	CS
	1200	16.5/54.5	2.5	996	35	7	CS
	1500	16.8/54.3	2.5	996	35	6	CS
	The cyclonic storm 'KEILA' crossed Oman coast close to the north of Salalah (near lat.17.1^{0}N and long. 54.3^{0}E) between 1600-1700 UTC						
	1800	17.1/54.2	2.0	1000	30	5	DD
03-11-2011	0000	17.1/54.2	2.0	1000	30	5	DD
	0300	17.1/54.2	2.0	1000	30	4	DD
	0600	17.1/54.2	2.0	1000	30	4	DD
	1200	17.0/54.5	2.0	1000	30	4	DD
	1800	17.0/54.8	2.0	1001	30	4	DD
04-11-2011	0000	17.0/55.0	2.0	1001	30	4	DD
	0300	16.5/55.0	1.5	1002	25	3	D
	0600	The system weakened into a low pressure area over westcentral Arabian Sea off Oman coast.					

2.1.4 Realised Weather:

Heavy to very heavy rainfall occurred over coastal Oman.

2.1.5 Damage:

It caused death of 14 people and 200 people were injured in Oman.

Table 2.1.2 Crucial observation with respect to location and intensity of cyclonic storm 'KEILA;

Date/Time (UTC)	Station (Index/ Lat & Long.)	MSLP (hPa)	Wind (Direction/ speed)	Pressure fall (hPa)
30-10-2011/0300	Thumrait (41314)	--	--	-5.1
30-10-2011/1200	Salalah (41316)	1003.8	340/16	-2.8
	Yaaloni (41295)	1004.5	040/22	--
	Masirah (41288)	1007.1	090/18	--
	Buoy (16.3^{0}N/56.2^{0}E)	1003.2	--	-1.7
31-10-2011/0300	Al-ghaidah (41398)	1005.2	270/13	-1.8

	Salalah (41316)	1006.7	040/13	-1.7
	Buoy (16.3^{0}N/56.0^{0}E)	1003.6	--	--
	Ship (14.3^{0}N/59.4^{0}E)	1000.9	210/08	--
31-10-2011/1200	Salalah (41316)	1003.0	--	-0.9
	Ship(13.7^{0}N/55.4^{0}E)	1003.0	--	--
	Ship (14.5^{0}N/56.9^{0}E)	1002.5	310/12	--
01-11-2011/1200	Salalah (41316)	1004.0	--	-1.7
01-11-2011/1200	Salalah (41316)	1001.2	--	-1.8
02-11-2011/0300	Salalah (41316)	1004.0	--	--
	Buoy (16.3^{0}N/55.1^{0}E)	999.2	--	-1.1
02-11-2011/0600	Salalah (41316)	1005.9	350/13	--
	Buoy (16.5^{0}N/55.0^{0}E)	998.3		-1.0
02-11-2011/1200	Salalah (41316)	1000.5	320/16	-0.7
	Ship (15.6^{0}N/54.5^{0}E)	1003.5	--	-4.0
02-11-2011/1500	Salalah (41316)	1001.5	320/23	--
	Ship (16.5^{0}N/54.9^{0}E)	1002.5	--	--
02-11-2011/1800	Salalah (41316)	1003.4	330/16	-1.0
	Ship (16.2^{0}N/55.3^{0}E)	1009.1	190/23	+4.3
03-11-2011/0000	Salalah (41316)	1002.2	310/17	-1.2
03-11-2011/0300	Salalah (41316)	--	330/21	--
03-11-2011/1200	Salalah (41316)	1003.6	340/24	--

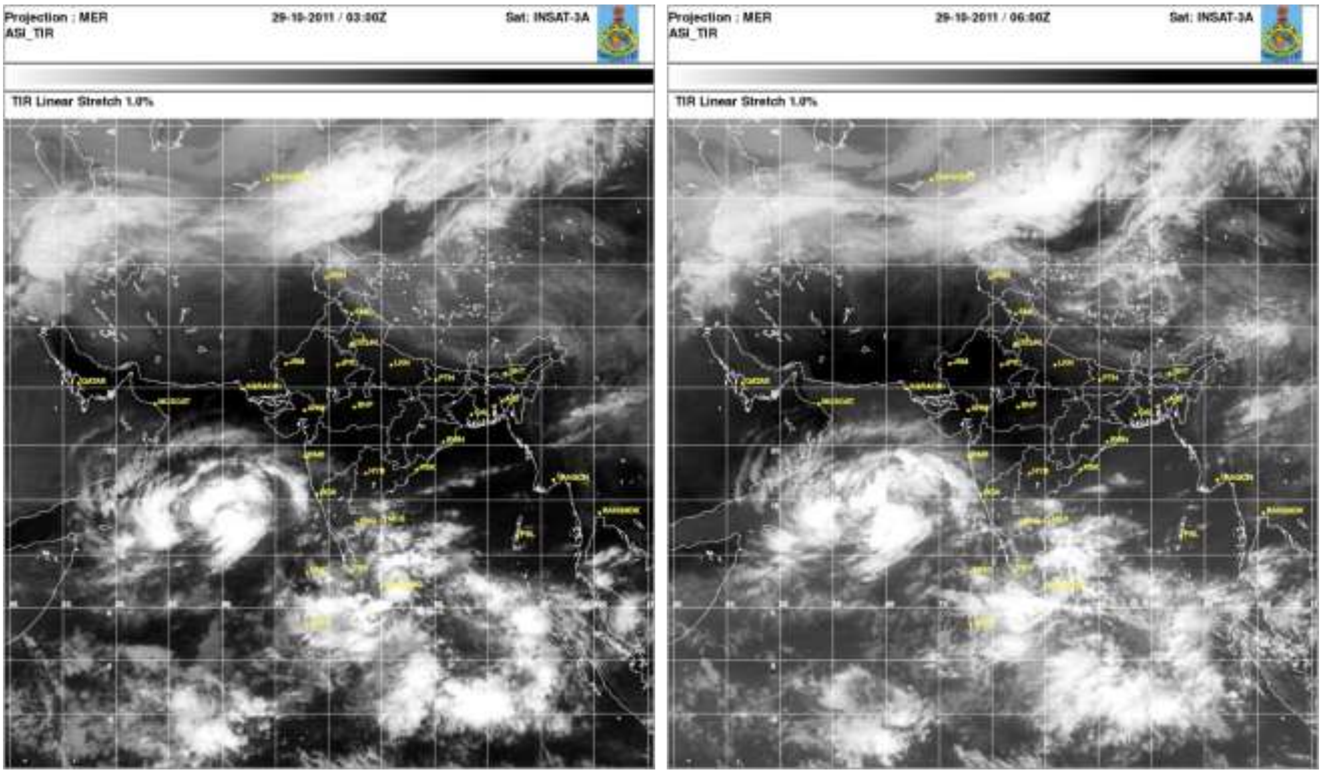


Fig. 2.1.1 The typical satellite imageries showing the genesis and intensification/weakening of the system.

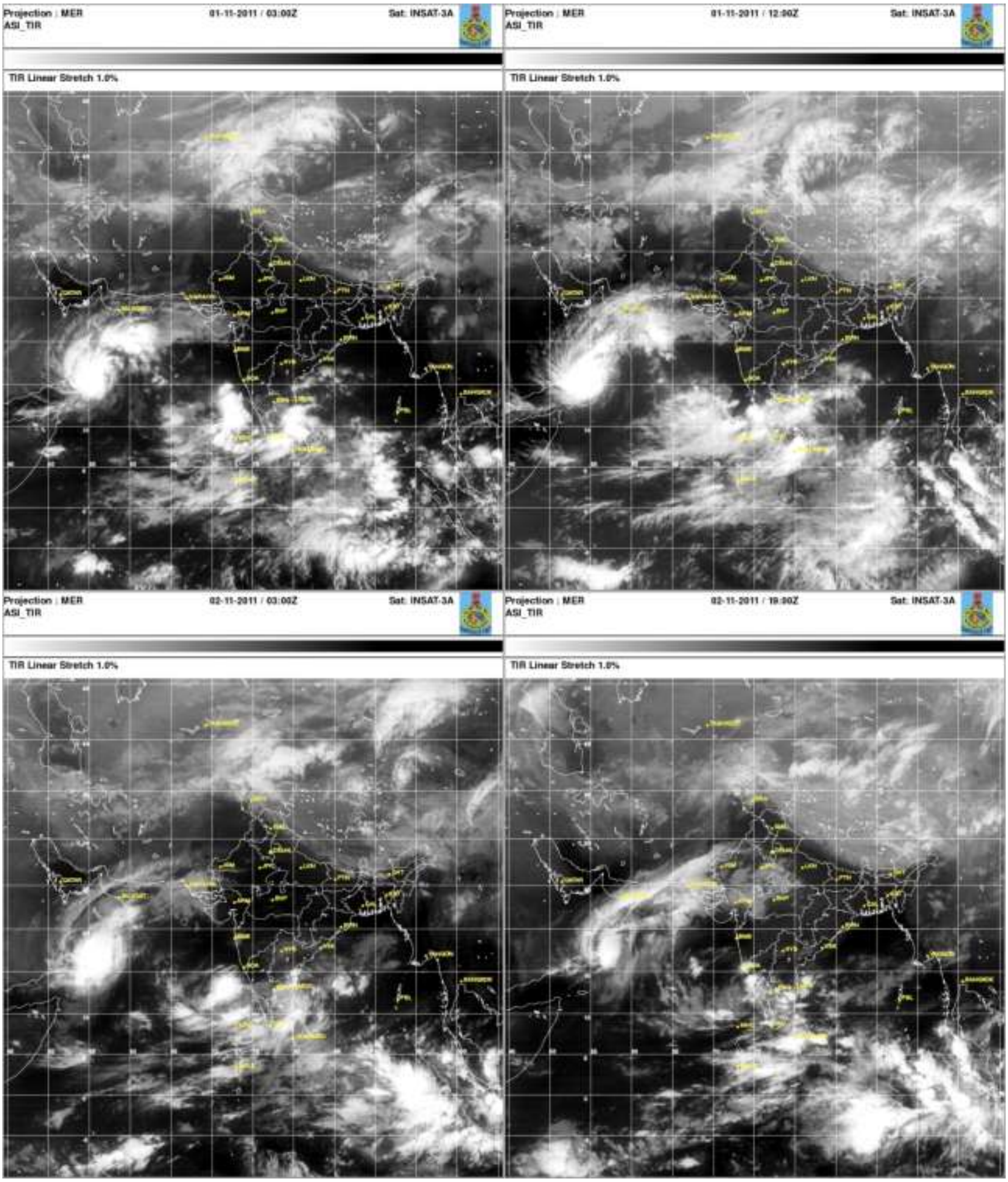


Fig.2.1.1 (contd) The typical satellite imageries showing the genesis and intensification/weakening of the system

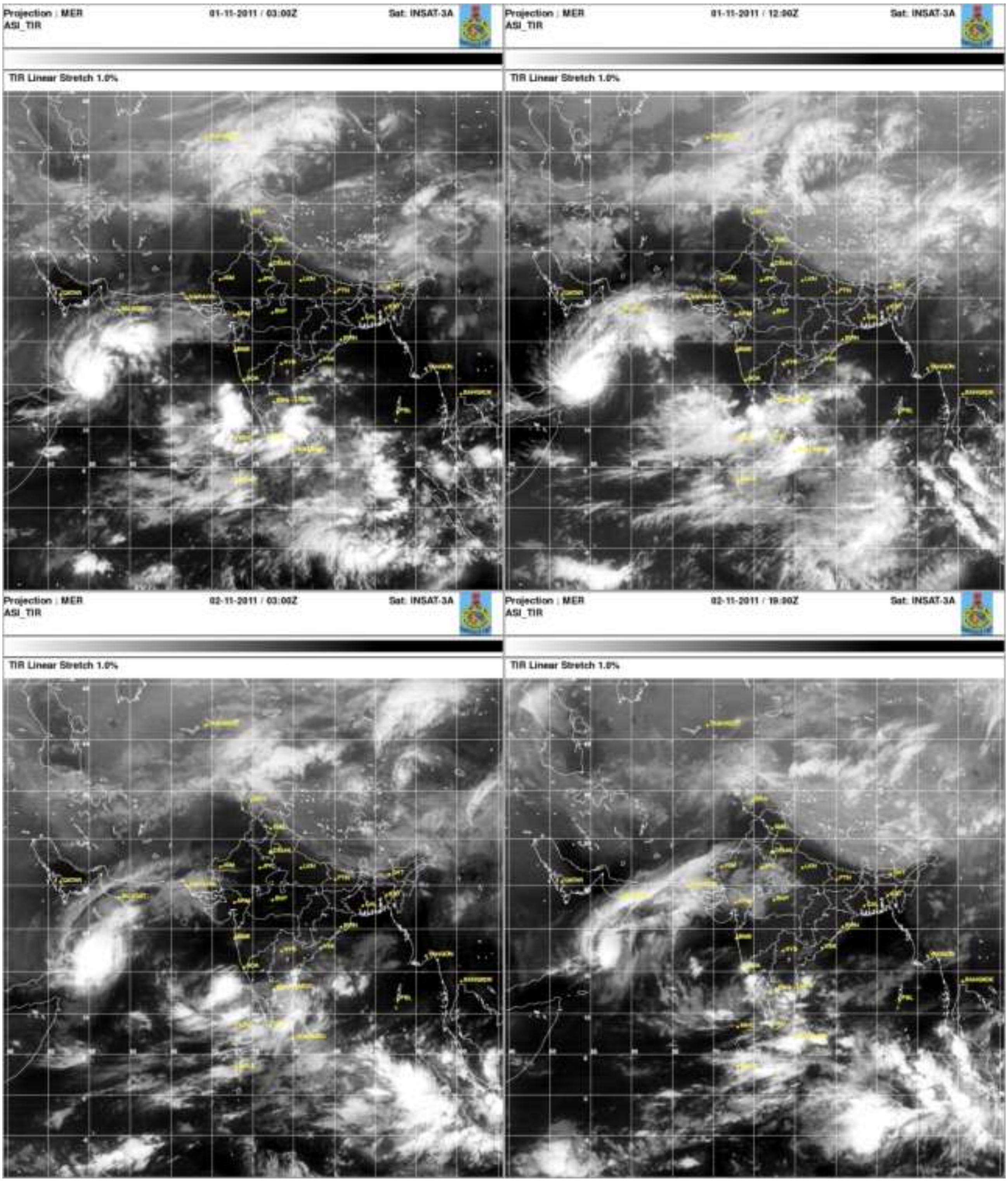


Fig. 2.1.1 (contd). The typical satellite imageries showing the genesis and intensification/weakening of the system

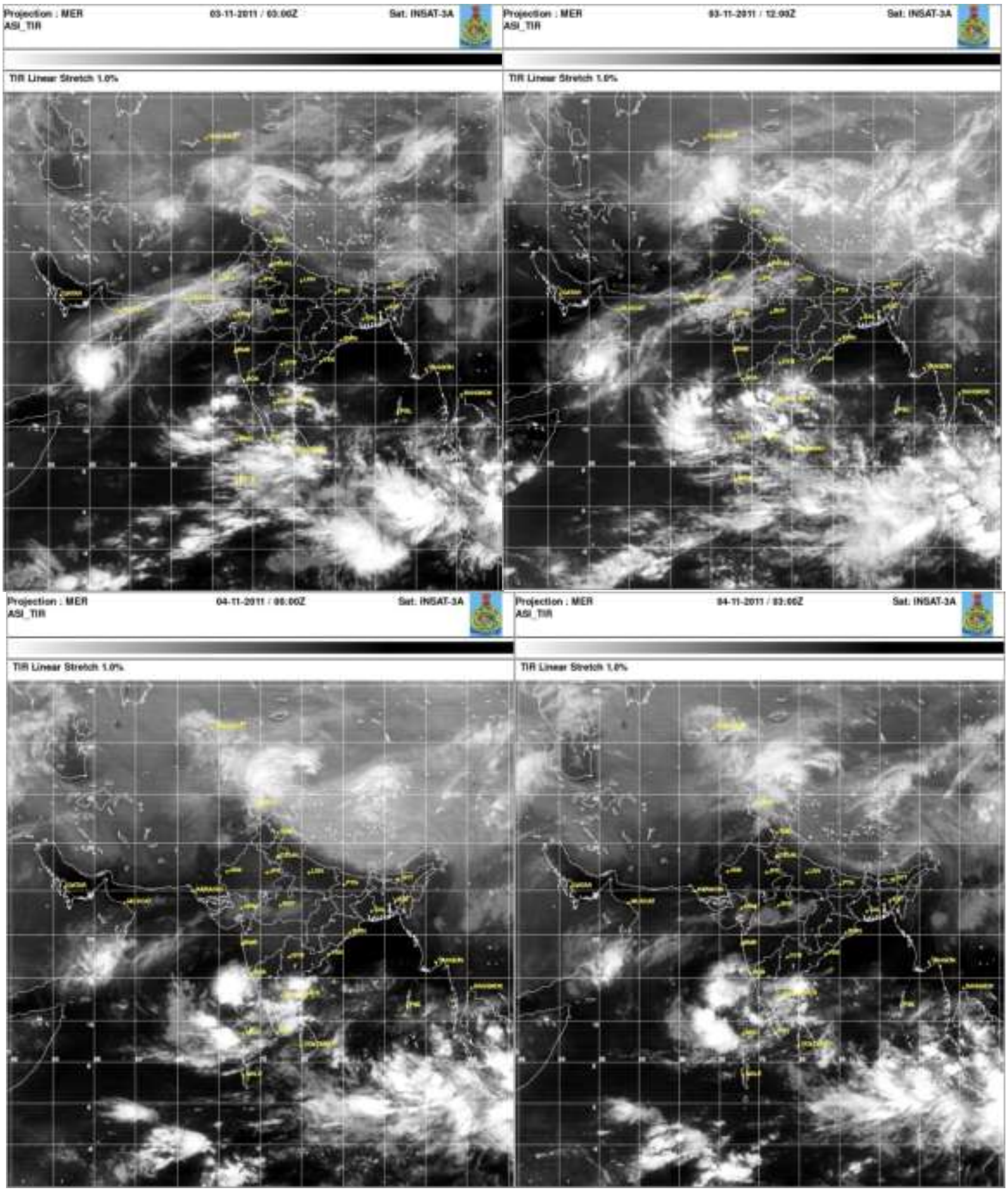


Fig.2.1.1 (contd) The typical satellite imageries showing the genesis and intensification/weakening of the system

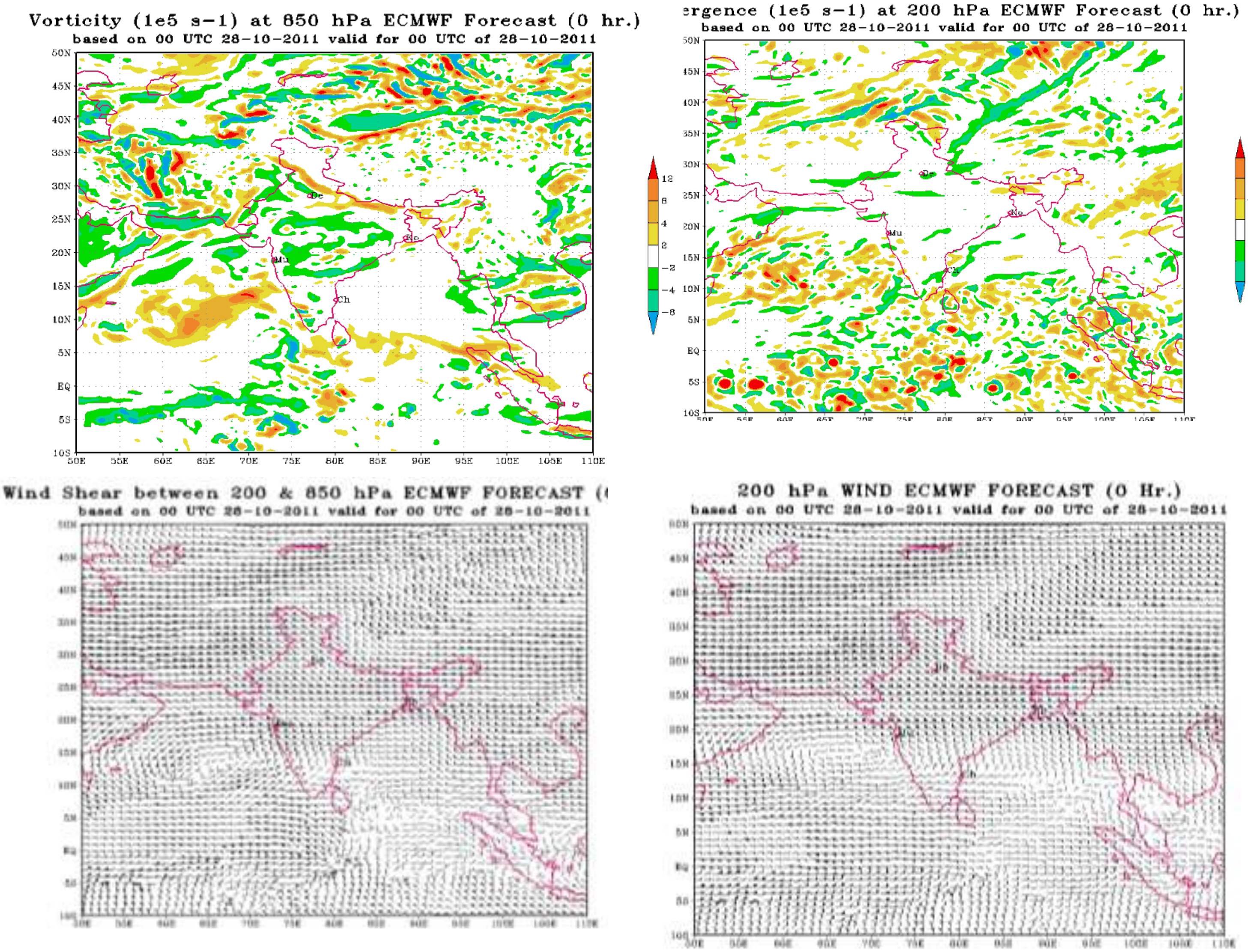


Fig.2.1.2 (a) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 28th October, 2011.

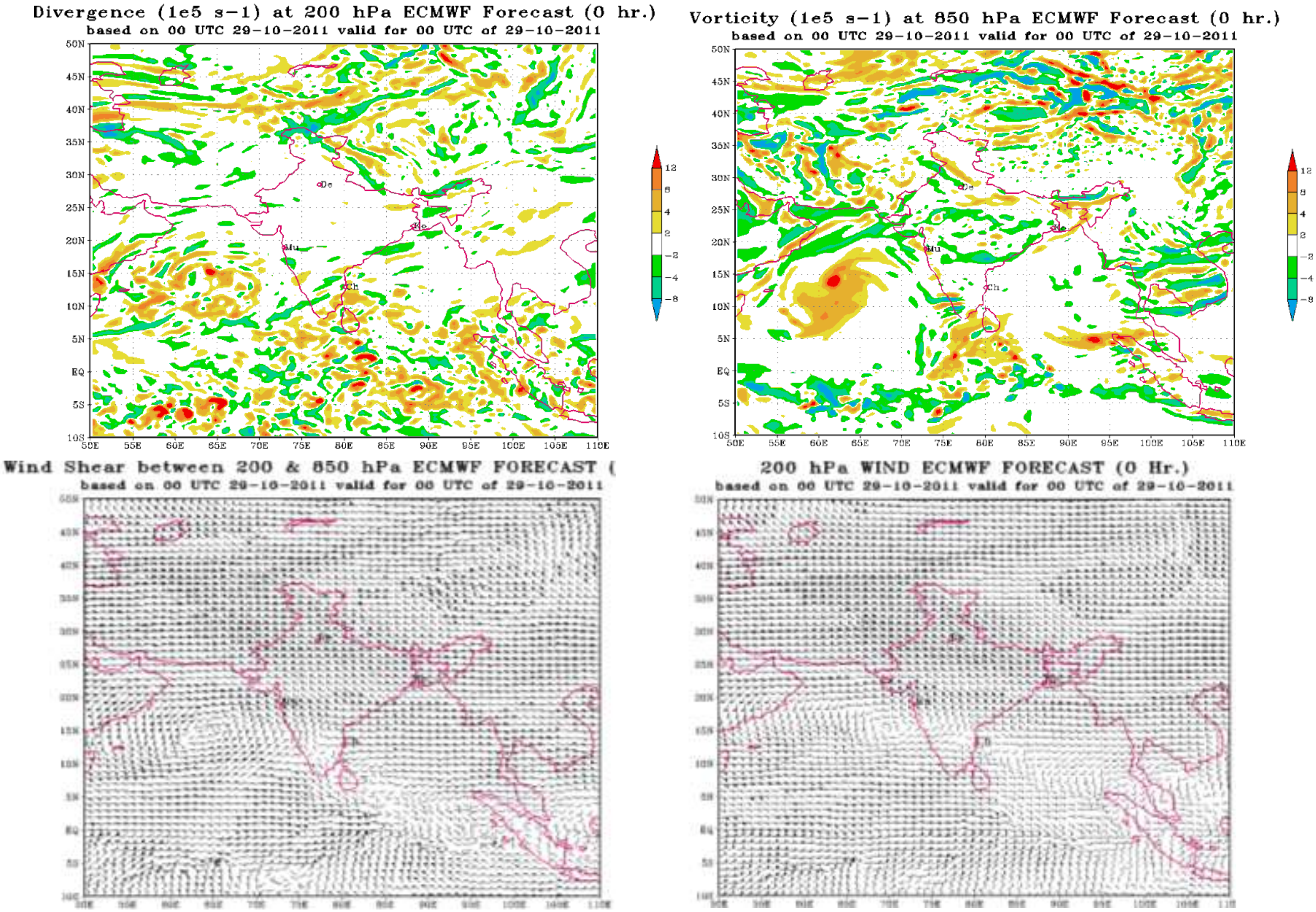


Fig. 2.1.2 (b) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 29th October, 2011.

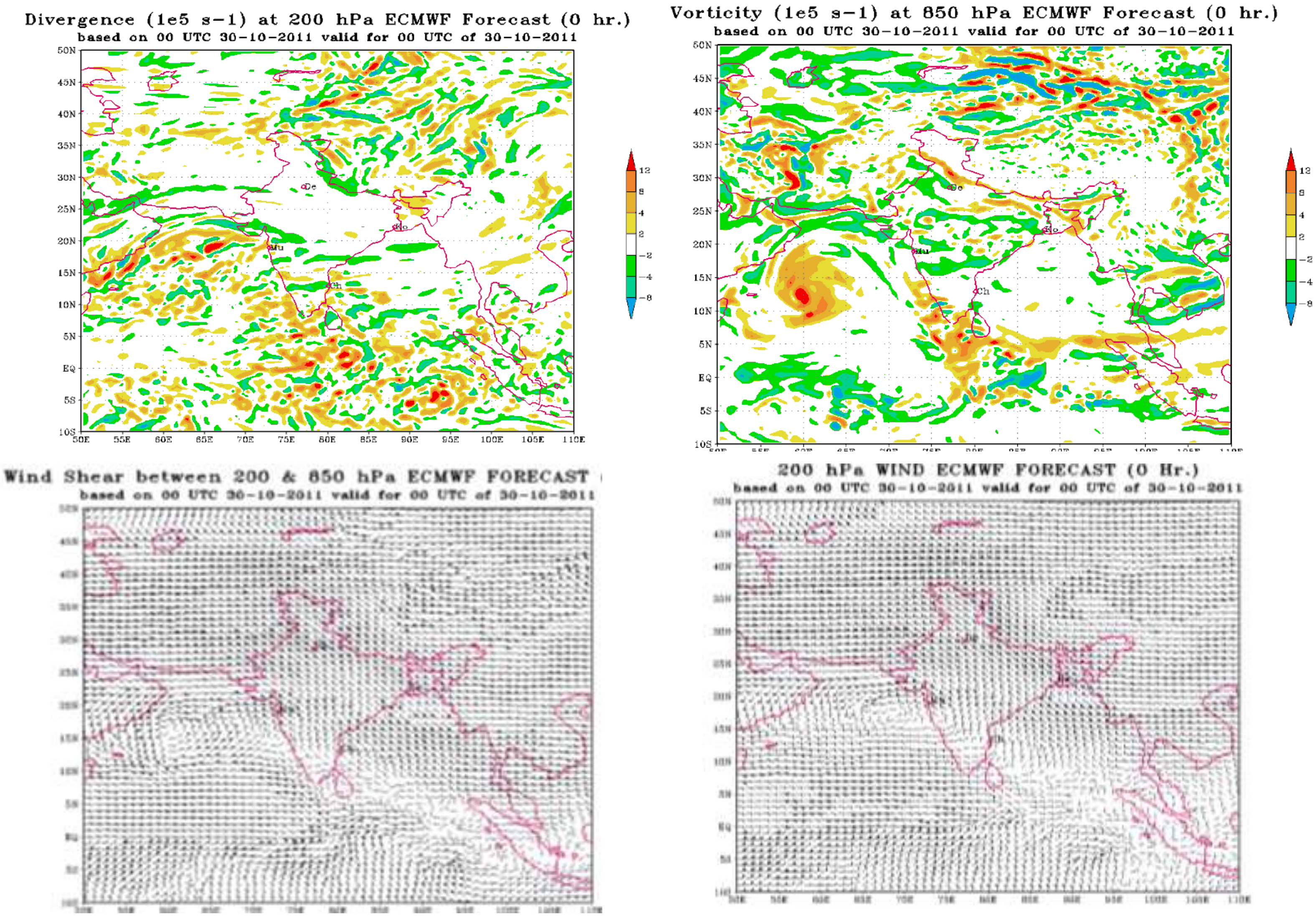


Fig.2.1.2 (c) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 30th October, 2011.

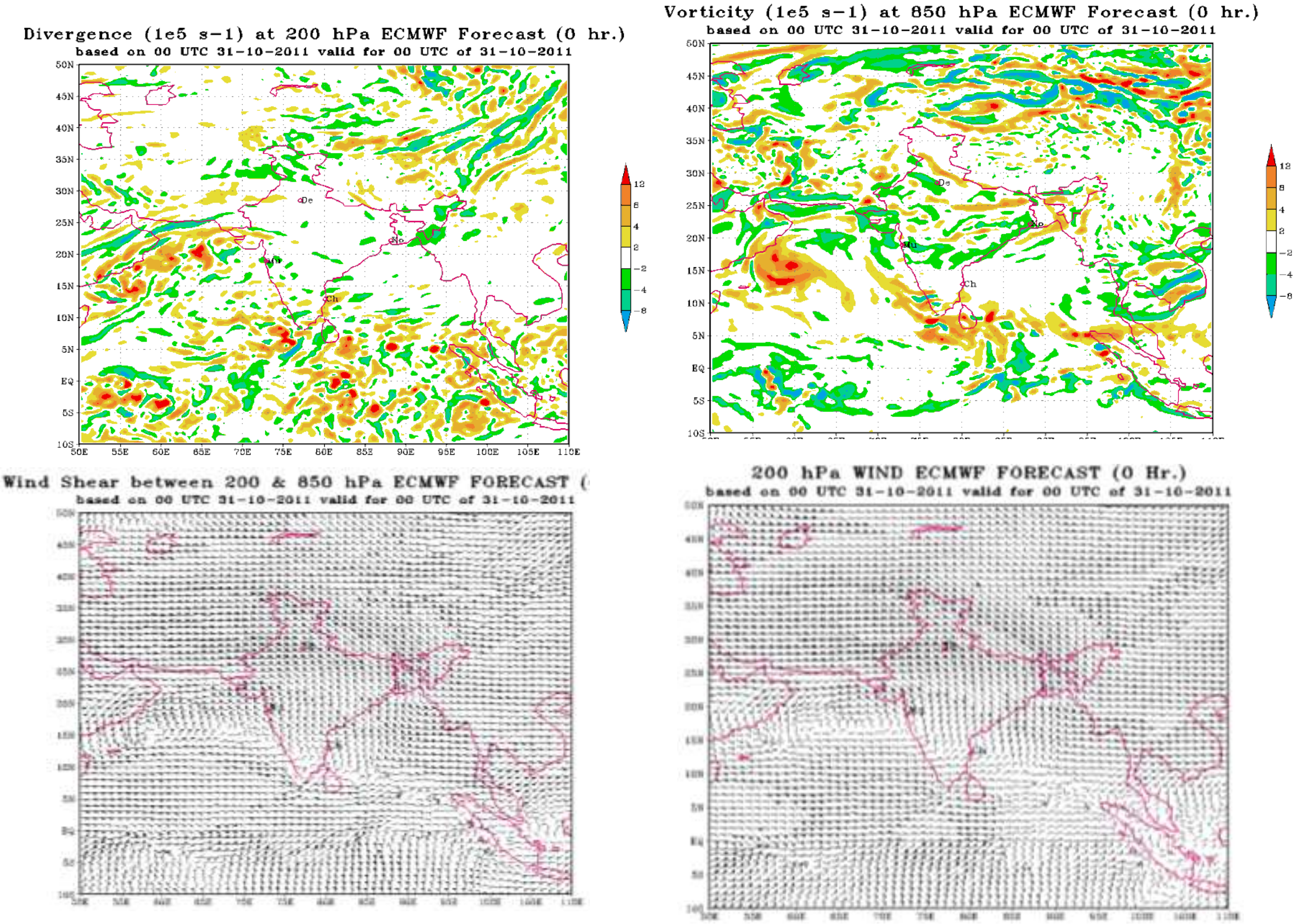


Fig. 2.1.2 (d) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 31st October, 2011.

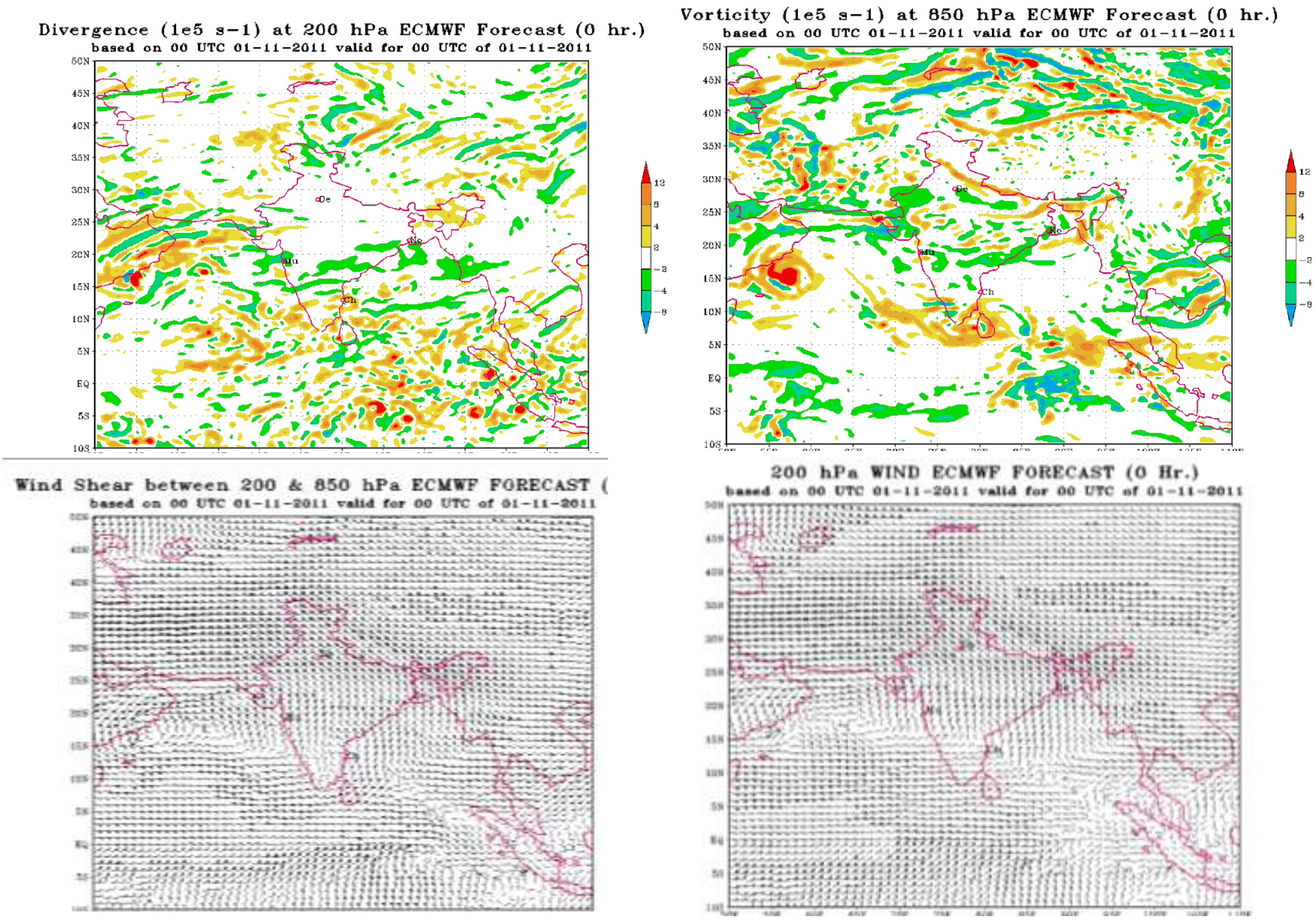


Fig. 2.1.2 (e) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 01st November, 2011.

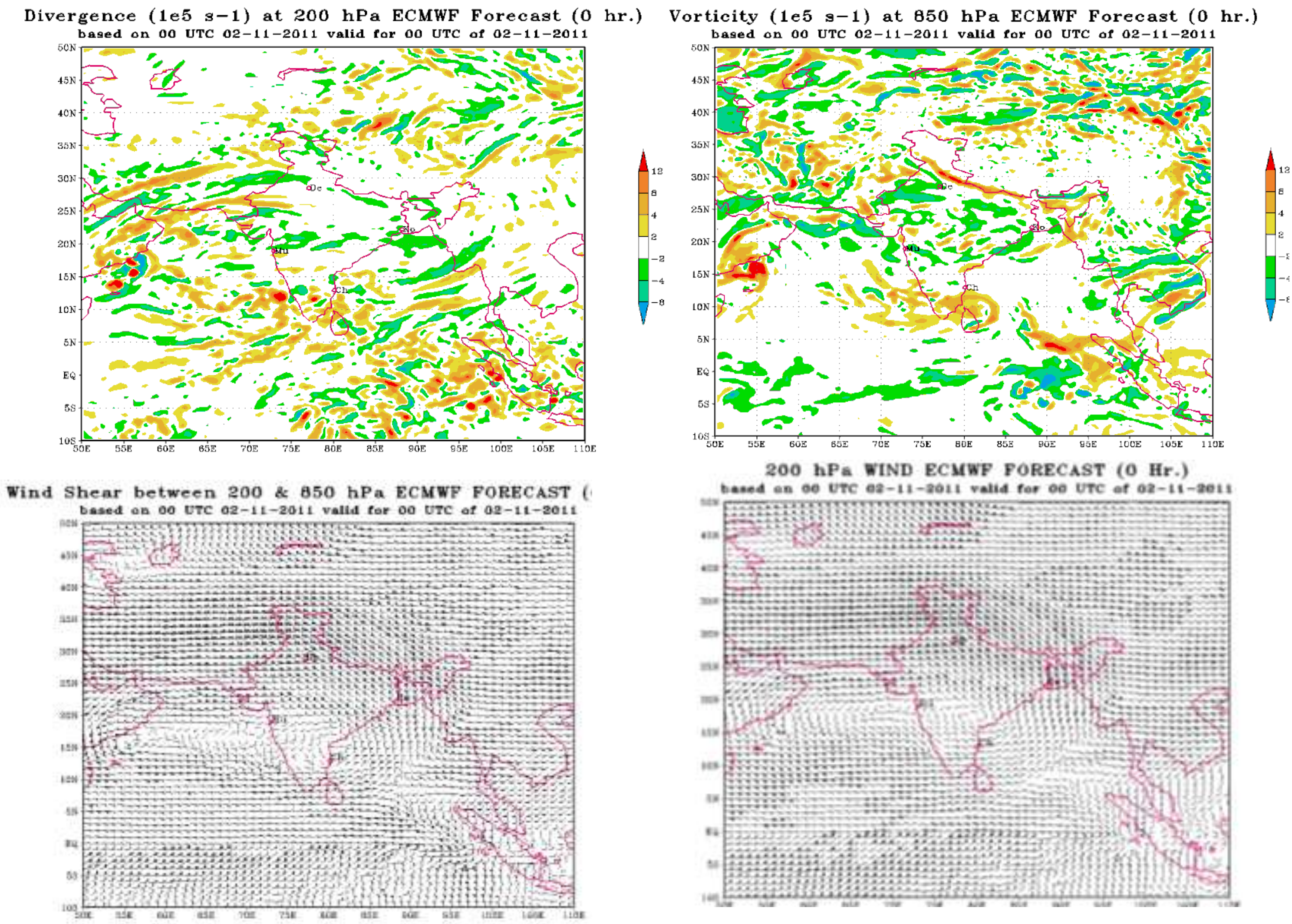


Fig. 2.1.2 (f) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 02nd November, 2011.

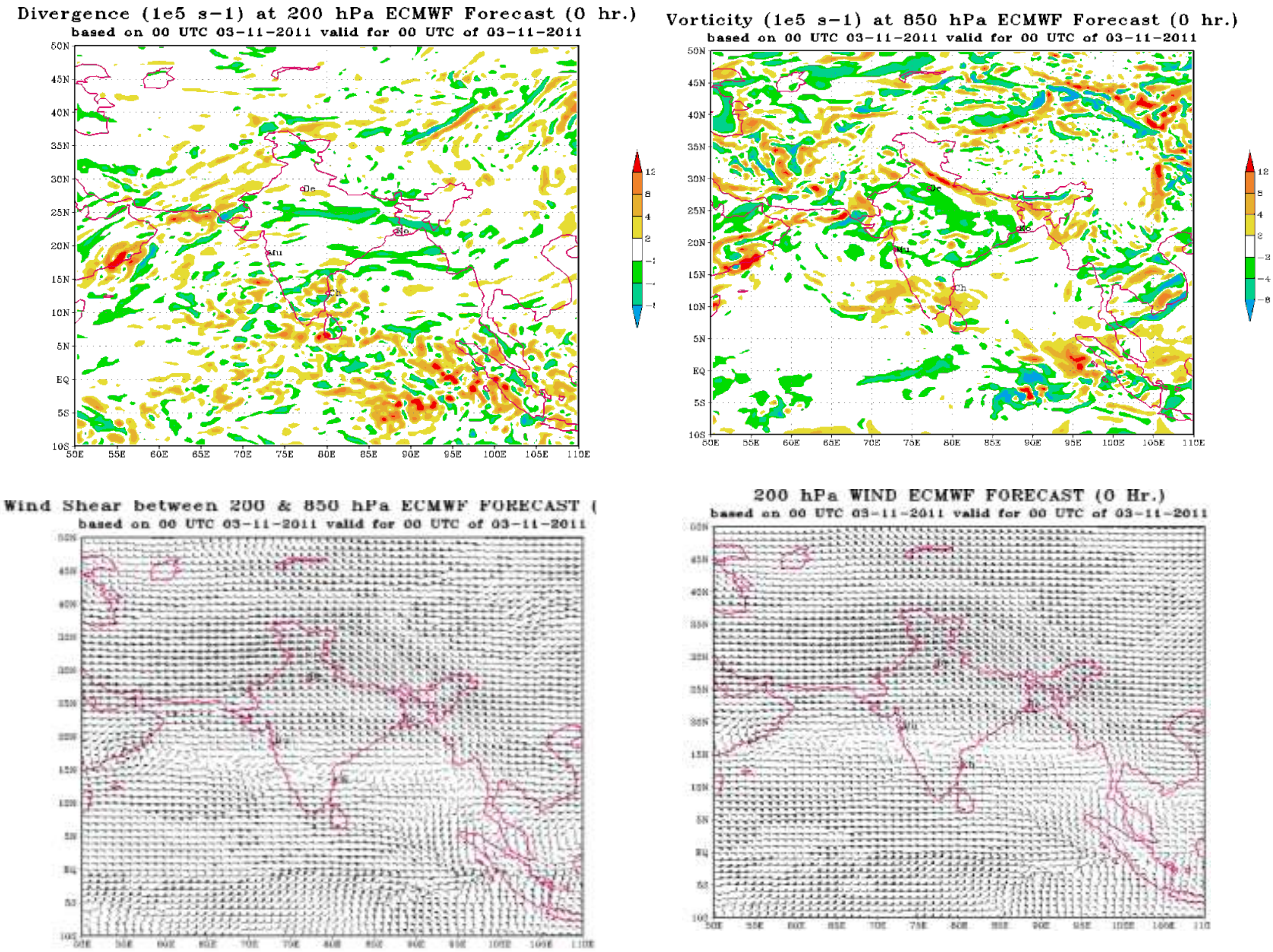


Fig. 2.1.2 (g) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 03rd November, 2011.

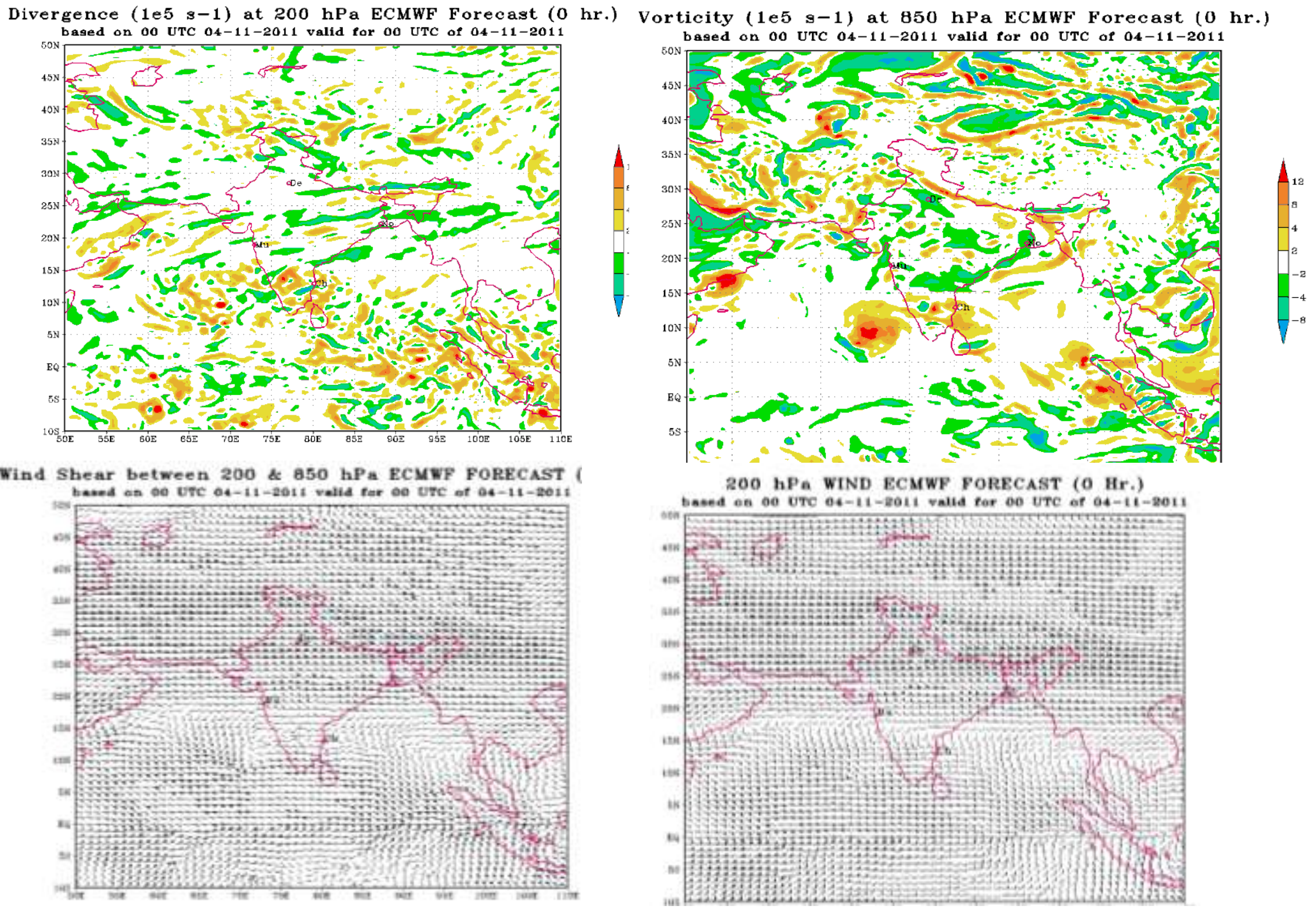


Fig. 2.1.2 (h) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) vertical wind shear of horizontal wind between 200 and 850 hPa level (iv) wind at 200 hPa level based on the ECMWF model analysis of 0000 UTC of 04th November, 2011.

2.2 Very Severe Cyclonic Storm "THANE" over Bay of Bengal (25-31 December, 2011)

2.2.1 Introduction:

A very severe cyclonic storm crossed Tamil Nadu coast on 30th December morning causing to life and property in north coastal areas of Tamil Nadu and Puducherry. About 48 people died due to this cyclone. The loss could be minimized due to accurate early warning and active disaster management by the Govt. of Tamil nadu and Puducherry. The very severe cyclonic storm 'THANE' was mainly monitored by Satellite during its genesis and early stage. When the system came within radar range, it was tracked by Doppler Weather Radar (DWR), Chennai (from 28th December evening till landfall). The system was also tracked by the available ships and buoy observations as well as hourly coastal observations from conventional synoptic network and AWS network. The characteristic features associated with the genesis, intensification, movement and landfall are described in the following sections.

2.2.2 Genesis:

In association with an active ITCZ, a cyclonic circulation formed over southeast Bay of Bengal on 23rd December 2011. It was associated with scattered convective cloud cluster over the region. Gradually the convective clusters deepened and came closer to each other and a low pressure area formed over the southeast Bay of Bengal on 24th morning with T1.0. It became well marked over the same region in the evening of 24th December 2011. Considering the environmental features, the sea surface temperature (SST) was about 27-28^0 C. over southeast Bay of Bengal, Andaman Sea and adjoining southeast and central Bay of Bengal. It was relatively less towards Tamil Nadu and Sri Lanka coast becoming 26-27^{0}C. The ocean thermal energy was about 50-80 KJ/cm^2 over southeast Bay of Bengal and neighbourhood. However, it was about 50 KJ/cm^2 near Tamil Nadu and north Sri Lanka coasts. The Madden Julian Oscillation (MJO) index lay over phase 5 witch is favourable for cyclogenesis over the Bay of Bengal. The upper tropospheric ridge at 200 hPa level ran along 10^{0}N and provided required poleward outflow for intensification of the system. As a result, the lower level convergence and upper level divergence were favourable for intensification. The vertical wind shear of horizontal wind was moderate (15-20 knots) around the low pressure area. It increased towards coast of Sri lanka and Tamil nadu becoming moderate to high (20-30 knots).

Due to all the above favourable features, the well marked low pressure area concentrated into a depression and lay centred at 1200 UTC of 25th Dec. 2011 near lat. 8.5^{0}N and long. 88.5^{0}E. The intensity of the system was T1.5 as per Dvorak's technique. The lowest cloud top temperature was -77^{0}C. Associated intense to very intense convection lay over the Bay of Bengal, south of lat.15.5^{0}N and east of long. 82.0^{0}E. The poleward outflow was distinctly visible in satellite imageries. The maximum sustained surface wind was about 25 knots and the estimated central pressure was about 1000 hPa.

Table 2.2.1 Best track positions and other parameters of very severe Cyclonic storm THANE over the Bay of Bengal during 25-31 December, 2011

Date	Time (UTC)	Centre lat.N/long. E	C.I NO.	Estimated Central Pressure (hPa)	Estimated max. sustained Surface wind(Kt)	Estimated Pressure drop at the Centre(hPa)	Grade
25.12.2011	1200	08.5/88.5	1.5	1000	25	3	D
	1800	09.0/88.0	1.5	1000	25	3	D
26.12.2011	0000	09.5/87.5	2.0	998	30	4	DD
	0300	09.5/87.5	2.0	998	30	4	DD
	0600	10.0/87.5	2.0	998	30	4	DD
	1200	10.5/87.5	2.0	998	30	5	DD
	1800	11.0/87.5	2.5	996	35	7	CS
	2100	11.0/87.5	2.5	996	35	7	CS
27.12.2011	0000	11.5/87.5	2.5	994	40	8	CS
	0300	12.0/87.0	2.5	994	40	8	CS
	0600	12.0/87.0	2.5	994	40	8	CS
	0900	12.2/86.7	2.5	992	40	10	CS
	1200	12.5/86.5	2.5	992	40	10	CS
	1500	12.5/86.5	3.0	992	45	10	CS
	1800	12.5/86.0	3.0	992	45	12	CS
	2100	12.5/86.0	3.0	992	45	12	CS
28.12.2011	0000	12.5/85.5	3.0	992	45	12	CS
	0300	12.5/85.5	3.0	987	45	14	CS
	0600	12.5/85.0	3.0	988	45	14	CS
	0900	12.5/85.0	3.5	986	55	16	SCS
	1200	12.5/84.5	4.0	982	65	20	VSCS
	1500	12.5/84.0	4.0	980	65	22	VSCS
	1800	12.5/84.0	4.0	978	65	24	VSCS
	2100	12.5/83.5	4.0	976	65	26	VSCS

29.12.2011	0000	12.3/83.0	4.0	974	70	28	VSCS
	0300	12.0/82.5	4.5	976	75	30	VSCS
	0600	12.0/82.0	4.5	972	75	30	VSCS
	0900	12.0/81.7	4.5	972	75	30	VSCS
	1200	12.0/81.3	4.5	972	75	30	VSCS
	1500	12.0/81.0	4.5	970	75	30	VSCS
	1800	11.8/80.6	4.5	970	75	30	VSCS
	2100	11.8/80.3	4.5	969	75	30	VSCS
30.12.2011	0000	11.6/79.9	4.5	969	75	30	VSCS
	The system crossed the Tamil Nadu coast close to south of Cuddalore between 0100 and 0200 UTC of 30th December, 2011.						
	0300	11.6/79.5	--	986	55	16	SCS
	0600	11.6/79.0	--	998	30	5	DD
	1200	11.6/78.2	--	1000	25	3	D
31.12.2011	0000	The system weakened into a well marked low pressure area over north Kerala and neighbourhood.					

2.2.3 Intensification and movement:

In association with the favourable conditions as discussed in the previous section, the depression moved initially northwestwards and further intensified into a deep depression at 0000 UTC of 26th and lay centred near lat. 9.5^{0}N and long. 87.5^{0}E. The best track of the system is shown in Fig. 2.1. The best track parameters are shown in Table 2.2.1. Some Crucial observations reported by Puducherry and Cuddalore are shown in Table 2.2.2. The typical satellite imageries of the system are shown in fig. 2.2.1.The DWR Chennai imageries are shown in Fig. 2.2.2. The NWP model analysis of IMD-GFS model are shown in Fig. 2.2.3.

Continuing its north-northwestwards movement, the deep depression intensified into a cyclonic storm 'THANE' at 1800 UTC of 26th December 2011 near lat. 11.0^{0}N and long. 87.5^{0}E. It then moved west-northwestwards and intensified into a severe cyclonic storm over southwest and adjoining southeast Bay of Bengal at 0900 UTC of 28th Dec. near lat. 12.5^{0}N and long. 85.0^{0}E about 500 km east-southeast of Chennai. It further moved westwards, intensified into a very severe cyclonic storm at 1200 UTC of 28th December near lat. 12.5^{0}N and long. 84.5^{0}E, about 450 km east-southeast of Chennai.

The very severe cyclonic storm 'THANE' then moved west-southwestwards and lay centred at 0300 UTC of 29th December 2011 near lat. 12.0^{0}N and long. 82.5^{0}E, about 270 km east of Puducherry. It continued to move west-southwestwards and crossed north Tamil

Nadu & Puducherry coast, close to the south of Cuddalore (near lat. 11.6^0 N) between 0100 and 0200 UTC of 30th December, 2011. It crossed as a very severe cyclonic storm with an estimated wind speed of 120-140 kmph and estimated central pressure of 969 hPa. After the landfall, the system moved westwards and weakened into a severe cyclonic storm at 0300 UTC of 30th December 2011 over north coastal Tamil Nadu. It further weakened into a deep depression at 0600 UTC near lat. 11.6^{0}N and long. 79.0^{0}E and into a depression at 1200 UTC of 30th December near Salem(Tamil Nadu). The depression moved further westwards and weakened into a well marked low pressure area over north Kerala and neighbourhood at 0000 UTC of 31st December 2011. It then emerged into Arabian Sea and lay as a low pressure area over southeast Arabian Sea at 1200 UTC 31st December 2011. It became less marked on 1st January 2012.

2.2.4. Size of the system, diameter of eye and central pressure

Rainfall reports and survey reports indicate that the system would have been of the size of 300 to 400 km length wise and 100-150 km breadth wise during landfall. During the survey around Marakkanam, Puducherry, Cuddalore, Parengipettai, Chidambaram, Kurinjipadi, Neyveli, Pantrui, Arasur, and Villupuram area it was understood that the lull period was experienced by the people from nine km south of Cuddalore to eight km north of Parengipettai in western sector up to Neyveli. The lull period lasted for a period of half an hour to one hour, suggesting that the eye diameter would be of the order of 20 to 25 kms range at the time of land fall. The DWR Chennai radar pictures show that the system had circular-open eye. The exact valve of the central pressure is not available. However the lowest pressure 969.4 hPa was recorded at MO Cuddalore at 0050 UTC of 30 December 2011 with a pressure fall of 35.6 hPa. Thereafter the pressure increased sharply and rapidly. The pressure gradient force was more on the northern side [20 hPa / 20 km] with more prominent closed isobars in the northern western sector of the system. i.e. north & northwest of Cuddalore and up to Puducherry. Less densely packed isobars from Cuddalore to Parengipettai was seen in the southern direction of the

system. At Cuddalore the fall of pressure during 2200 UTC of 29th to 0030 UTC of 30th December [991.3-971.5 hPa] was 19.8 hPa/3hour i.e the surface pressure decreased by 6.6 hPa per hour towards south during this period. The barograph of Cuddalore is shown in Fig.2.2.4.

2.2.5. Landfall point and time

The extensive survey of the cyclone affected areas and with available information gathered from various cross section of the people, their weather experience on 29/30 Dec 2011 and the direction of fallen trees in those areas indicated that the probable location of land fall is at Thiyagavalli [Lat: 11^o.37$'$ N / Log: 79^o.44$'$E], about fourteen km south of Cuddalore (Fig.2.2.5).

Table 2.2.2 Crucial observations reported by Puducherry (PDC) and Cuddalore (CDL) observatories of IMD

Date	Time	Station	Pressure (hPa)	Pressure fall in 24 hrs (hPa)	Surface wind Speed (knot)
29.12.11	0600	PDC (43331)	1004.3	- 2.8	NW/10 kt
29.12.11	1200	PDC(43331)	1003.7	- 4.0	NNW/10kt
29.12.11	1500	PDC (43331)	1003.7	- 4.0	NNW/10kt
29.12.11	1800	PDC (43331)	1005.5	- 7.6	N/25kt
29.12.11	2100	PDC (43331) CDL (43329)	0997.8 0996.6	- 9.4 - 10.8	NNW/35kt NNW/23kt
30.12.11	0000	PDC (43331) CDL (43329)	0991.7 0997.6	- 15.2 - 32.9	ENE/68kt NNW/62kt

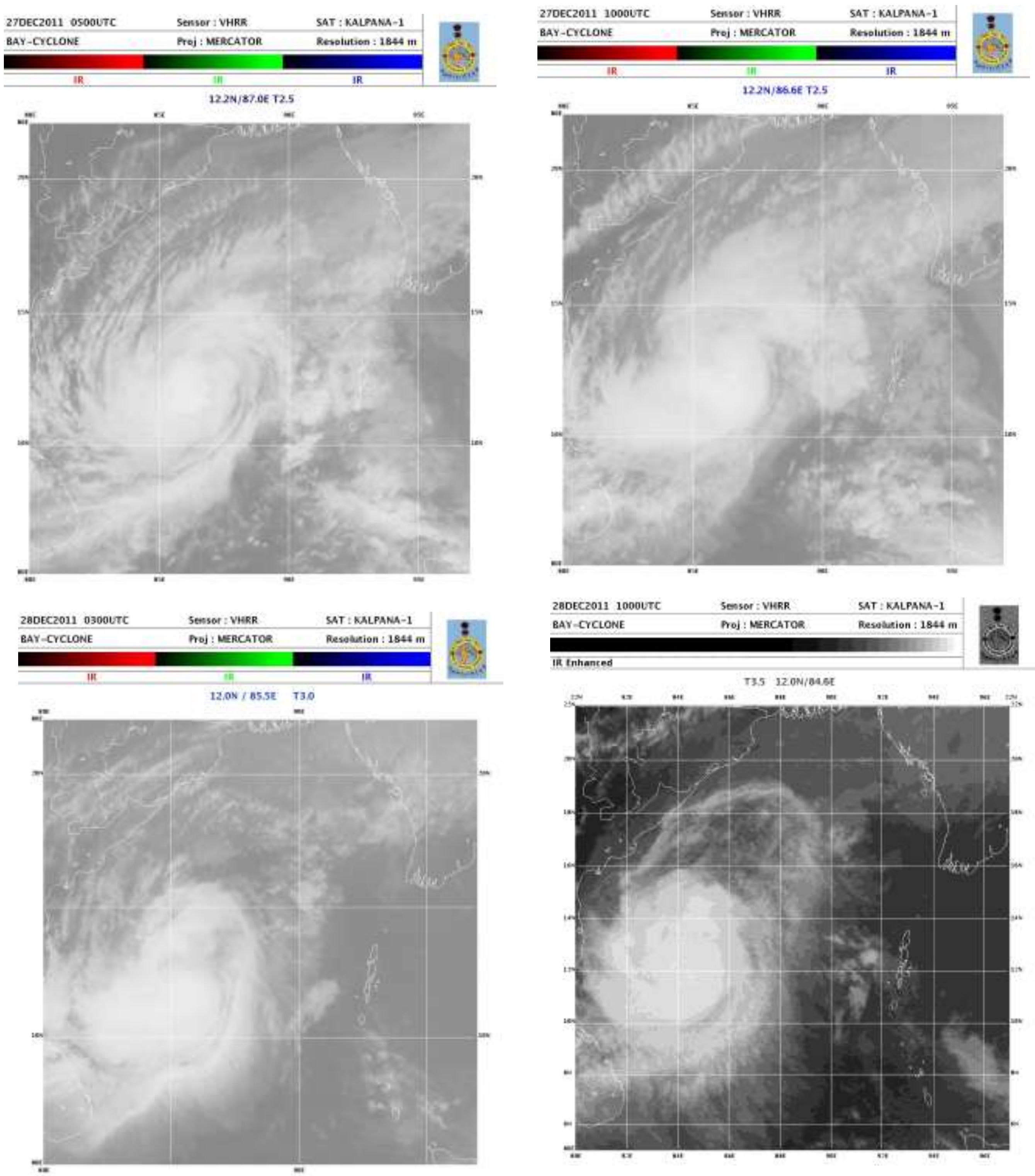


Fig.2.2.1. The typical satellite imagery showing intensification and movement of the system

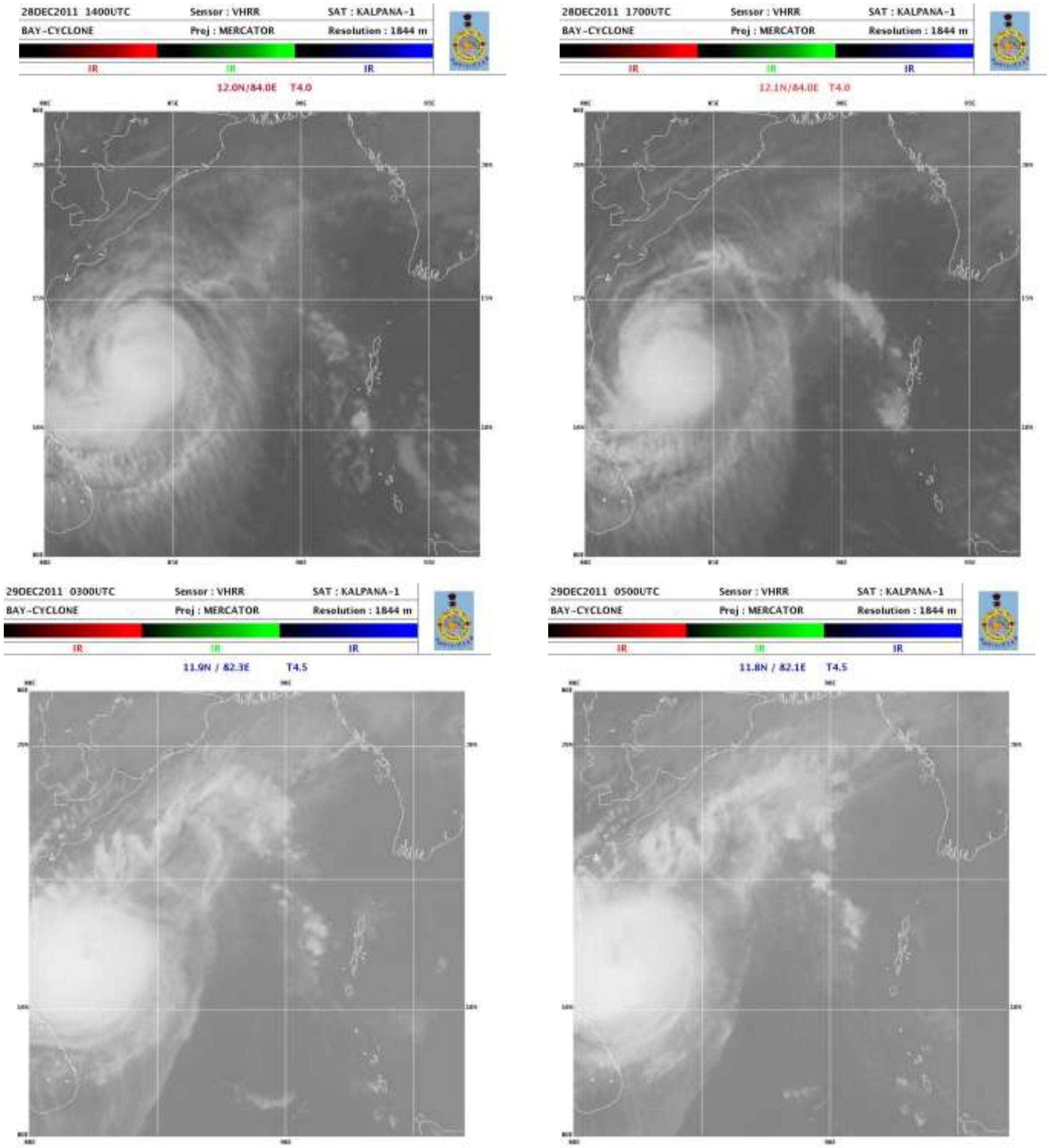


Fig.2.2.1(contd). The typical satellite imagery showing intensification and movement of the system

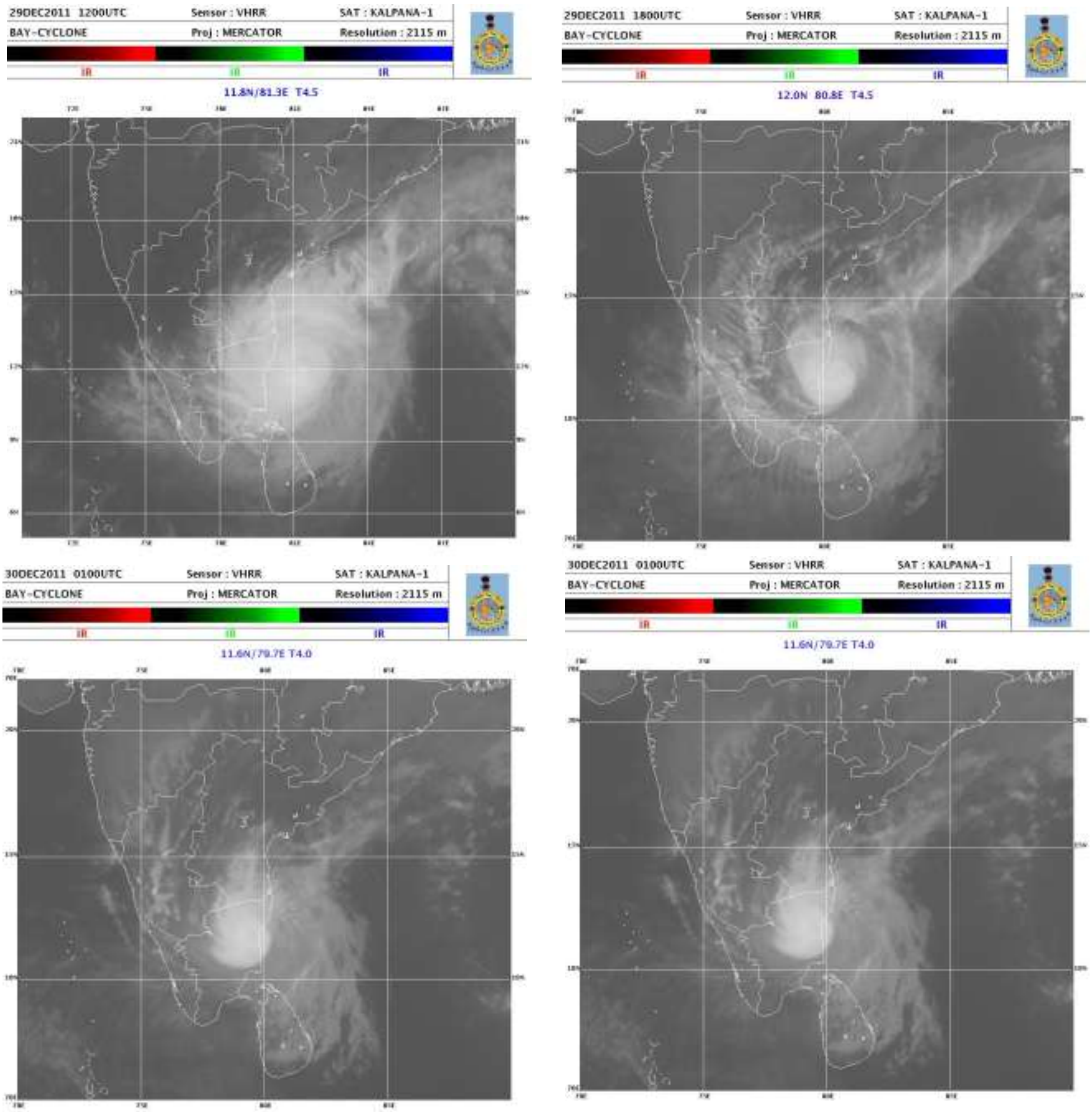


Fig.2.2.1(contd). The typical satellite imagery showing intensification and movement of the system

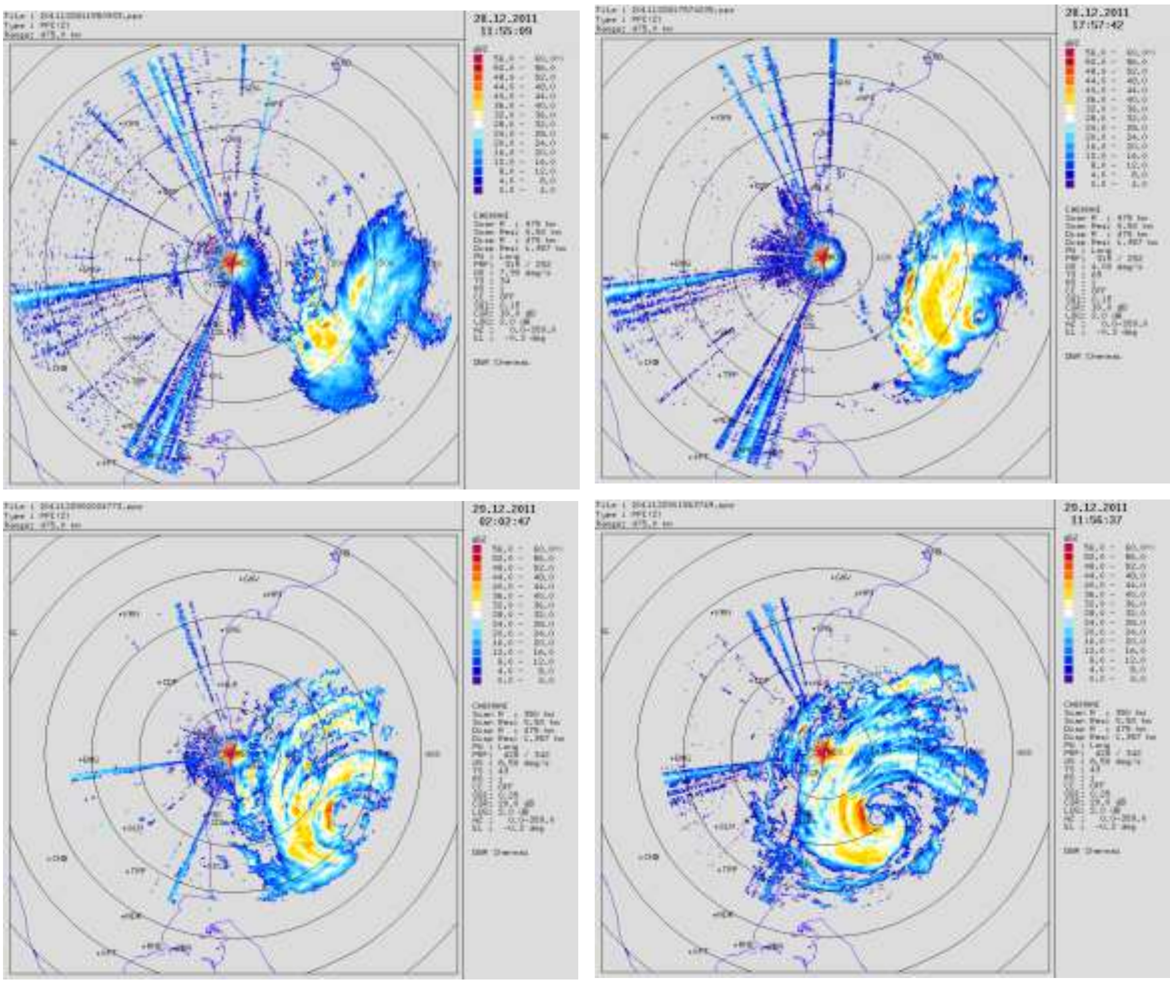


Fig.2.2.2. Doppler Weather Radar (DWR), Chennai imagery of very severe cyclonic storm, THANE showing the intensification of the system.

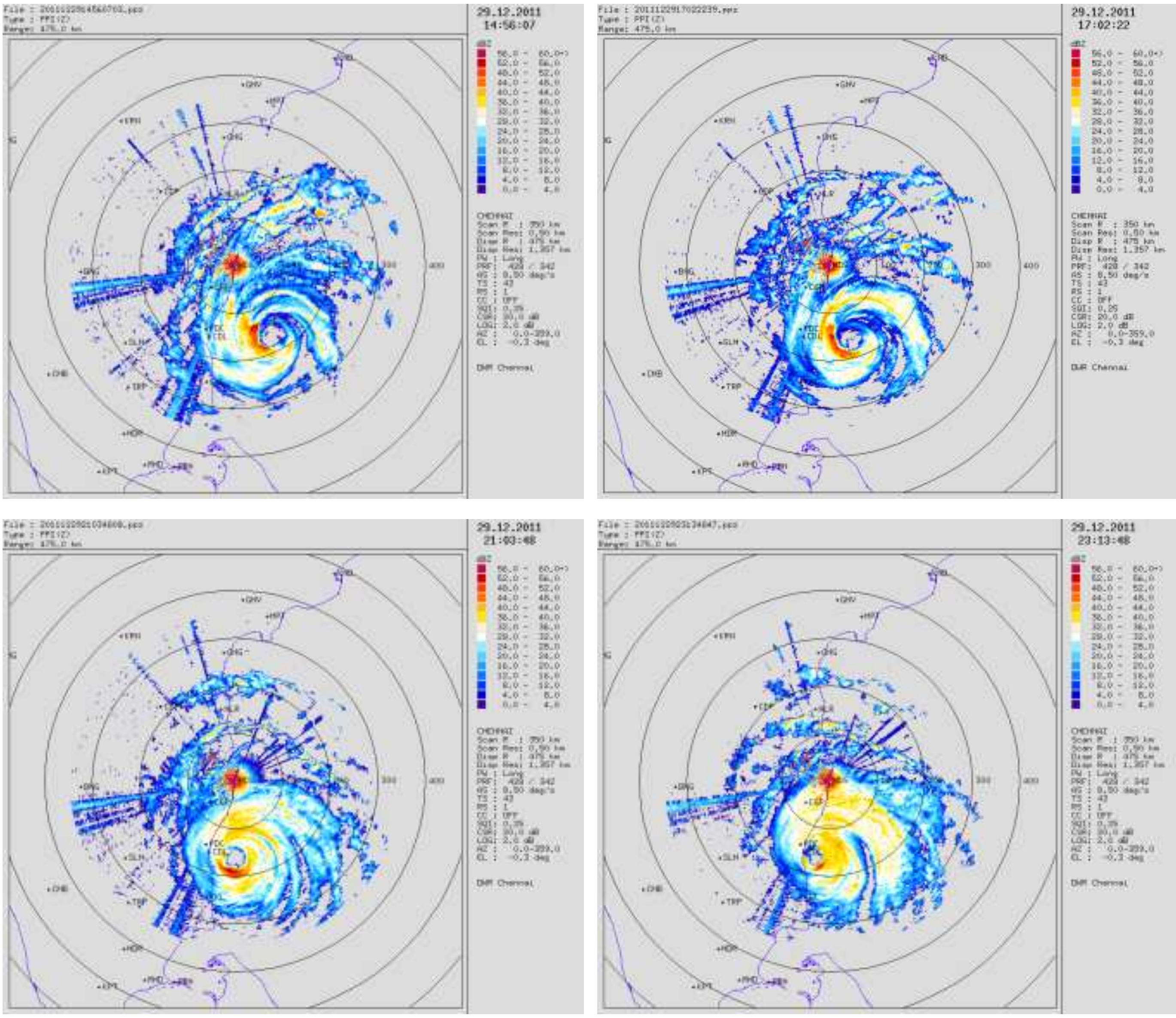


Fig.2.2.2(contd). Doppler Weather Radar (DWR), Chennai imagery of very severe cyclonic storm, THANE showing the intensification and movement of the system.

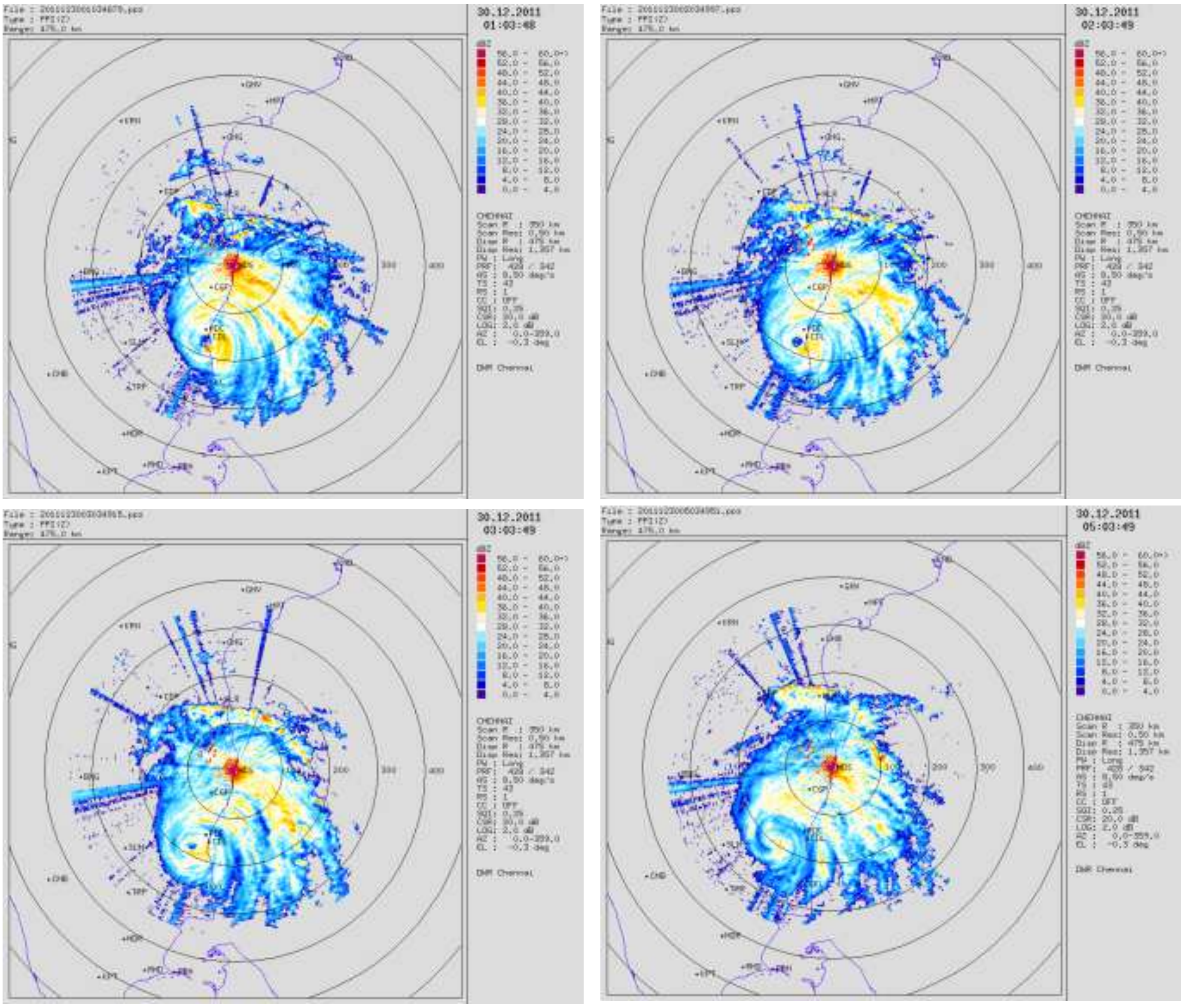


Fig.2.2.2(contd). Doppler Weather Radar (DWR), Chennai imagery of very severe cyclonic storm, THANE at the time of landfall.

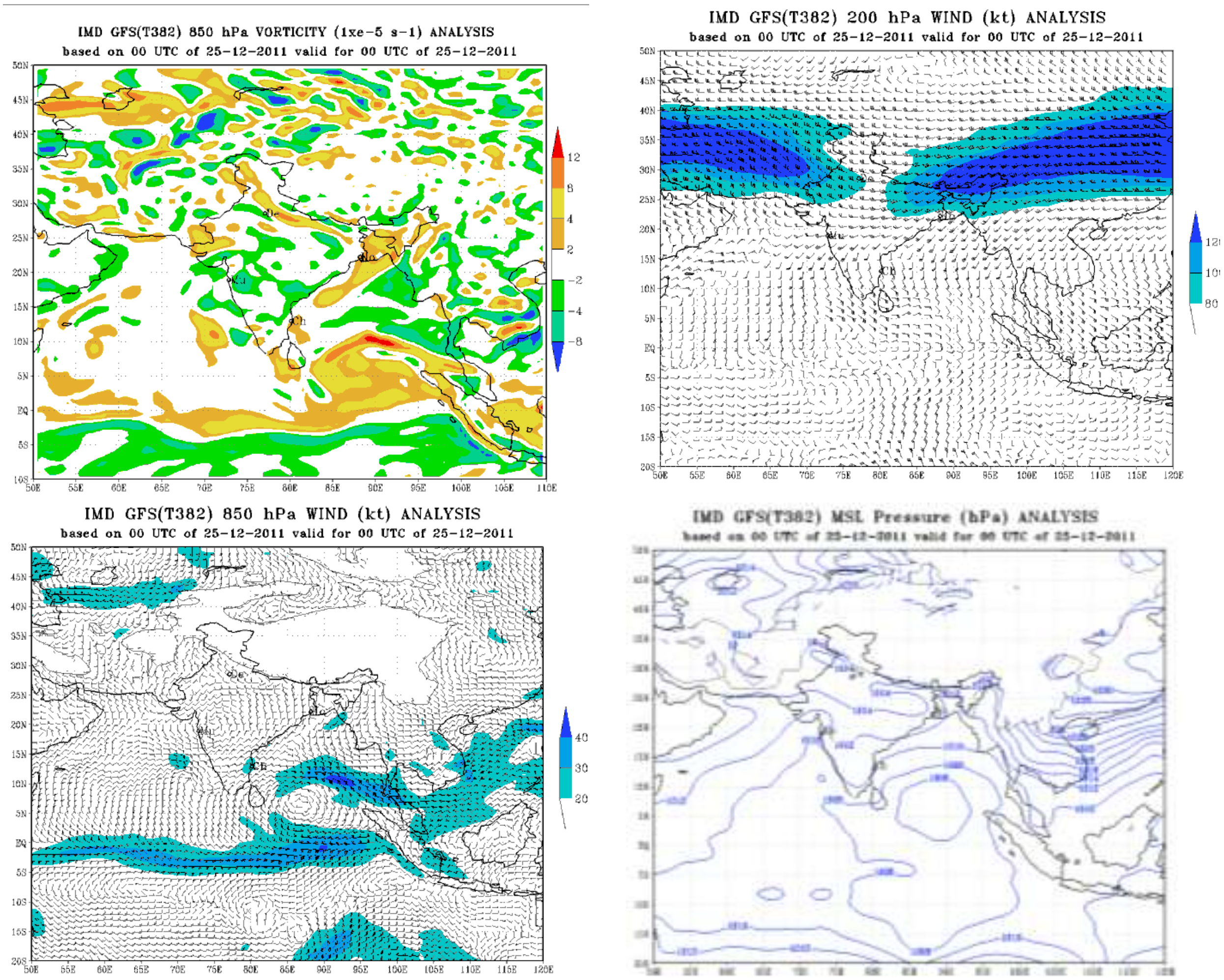


Fig. 2.2.3(a) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 25th December, 2011.

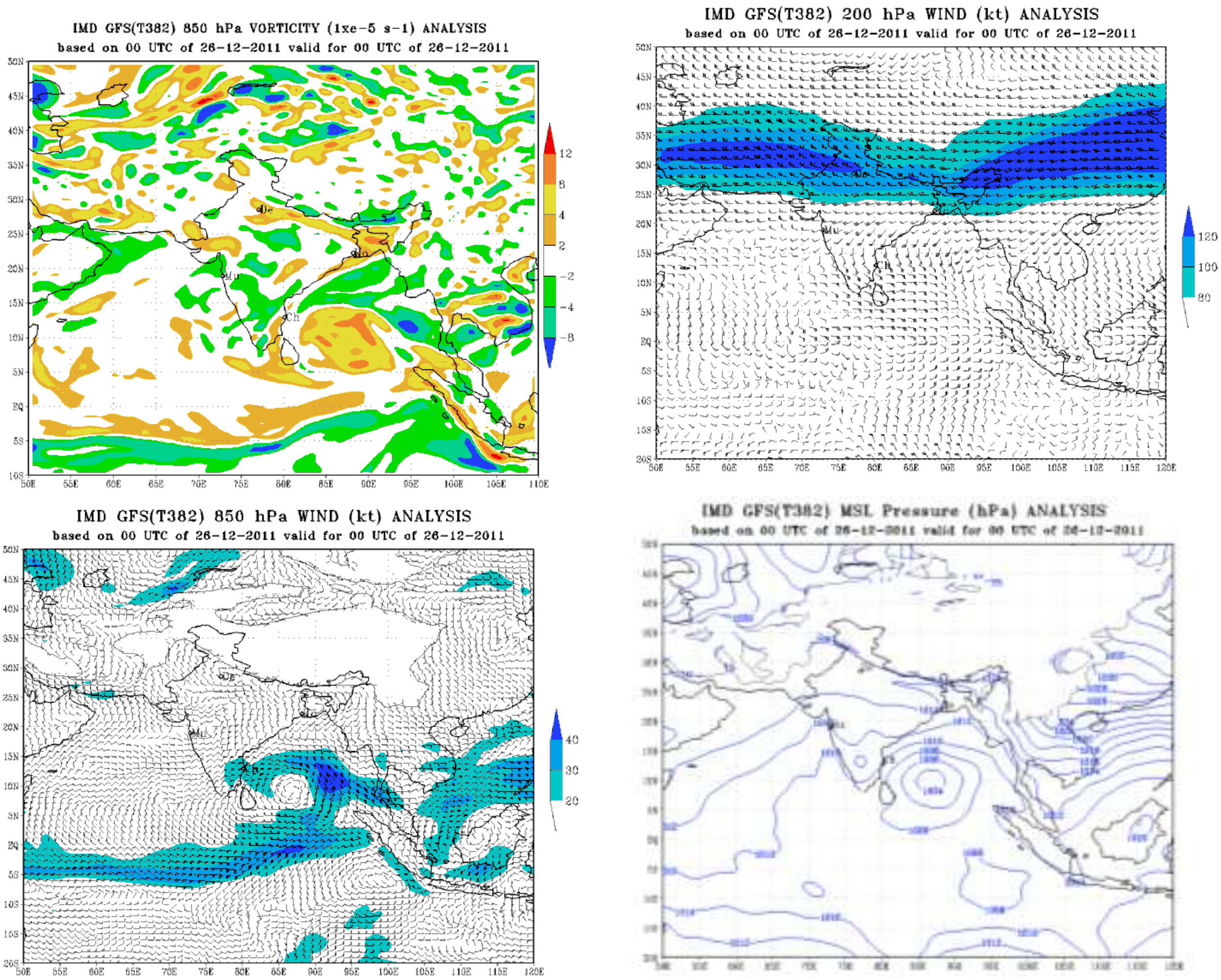


Fig. 2.2.3(b) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 26th December, 2011.

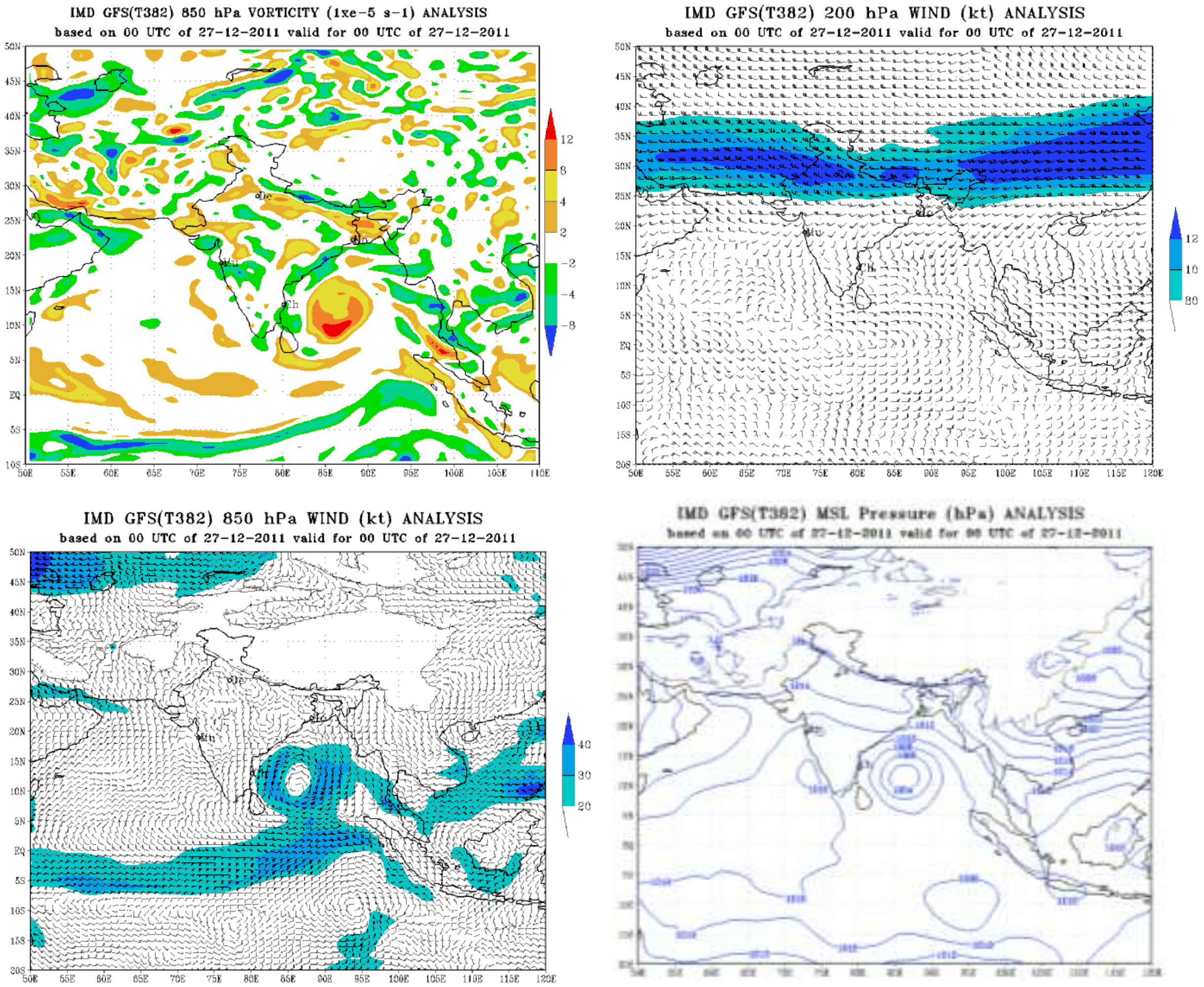


Fig. 2.2.3(c) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 27th December, 2011.

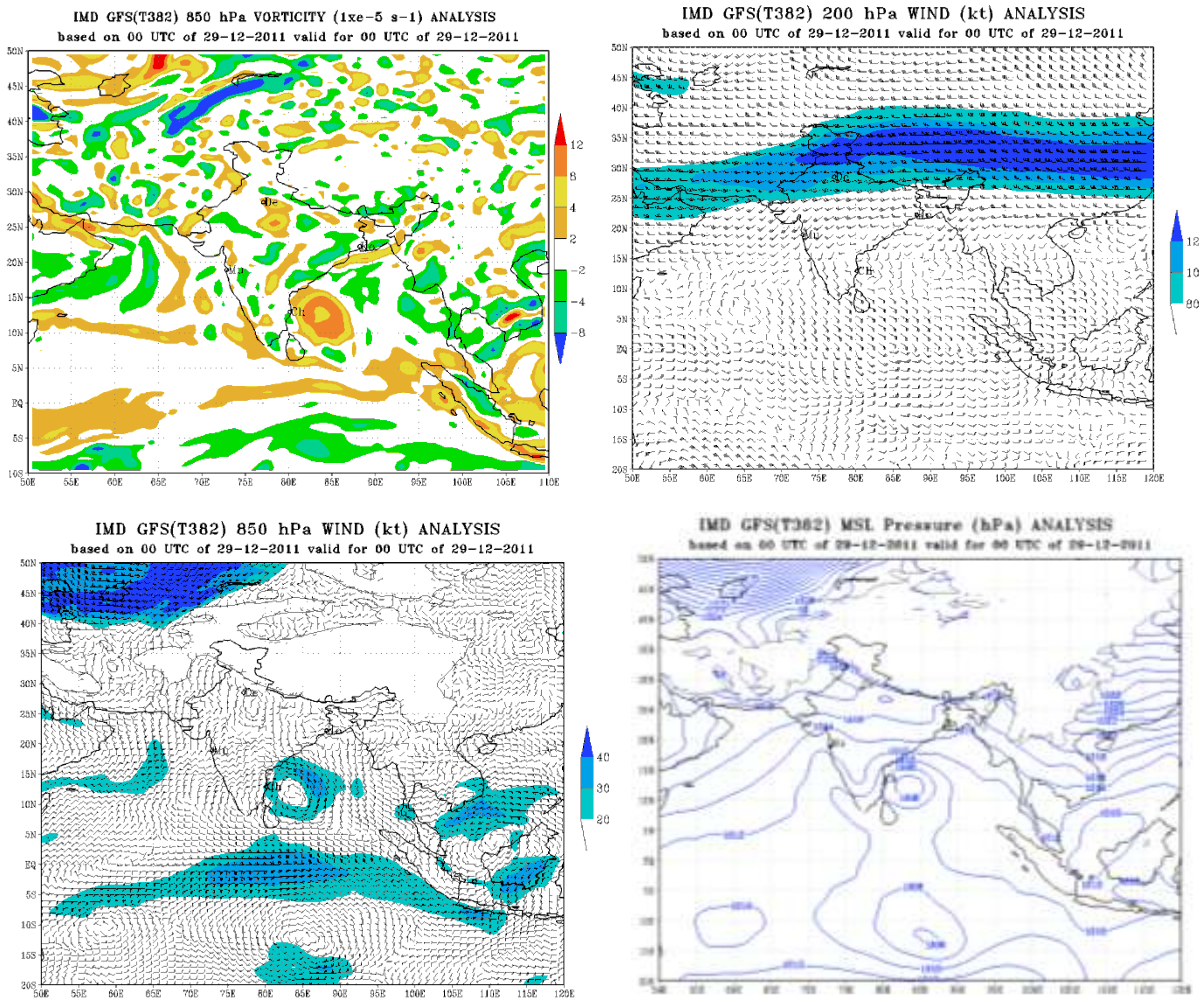


Fig. 2.2.3(e) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 29th December, 2011.

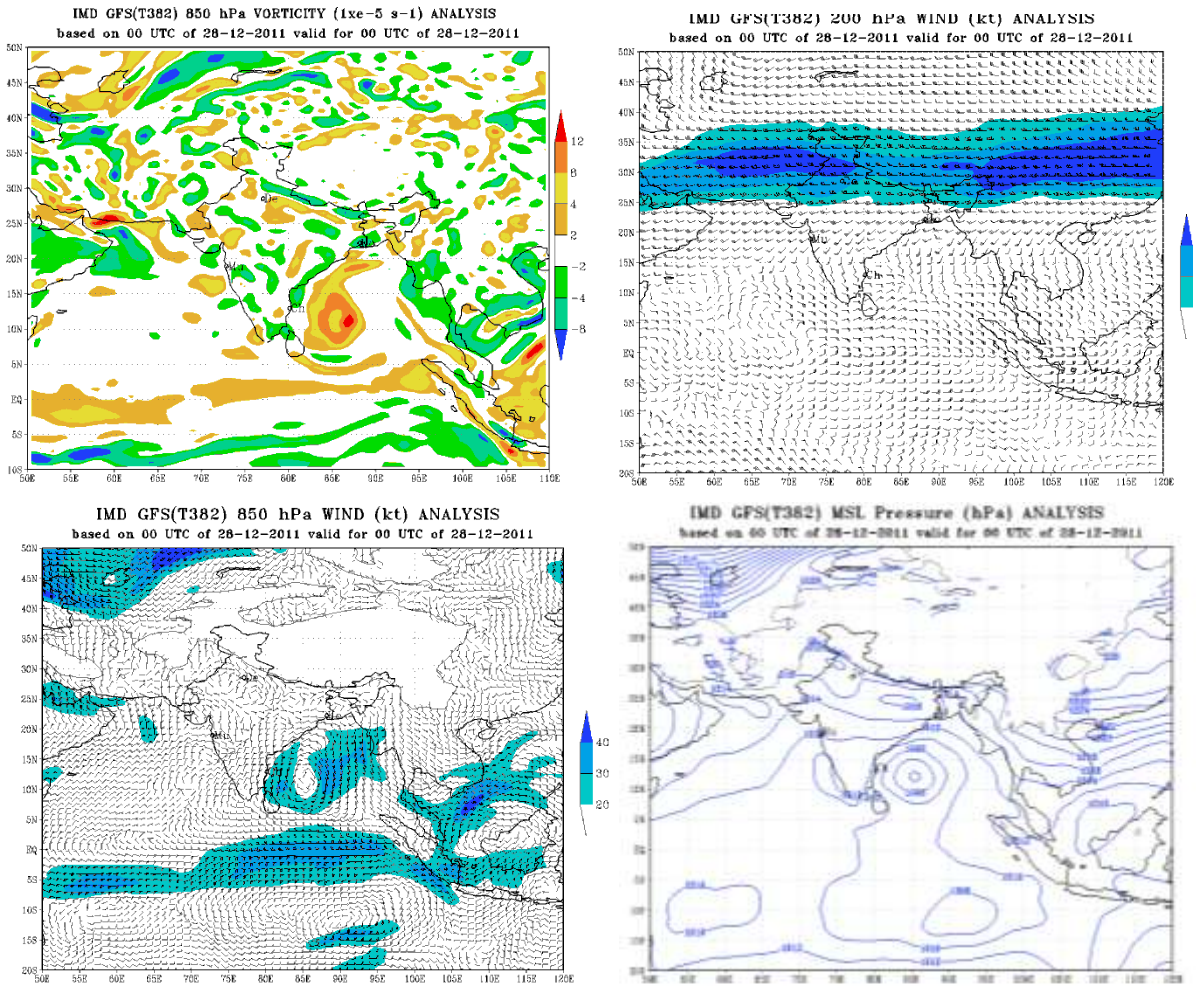


Fig. 2.2.3(d) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 28th December, 2011.

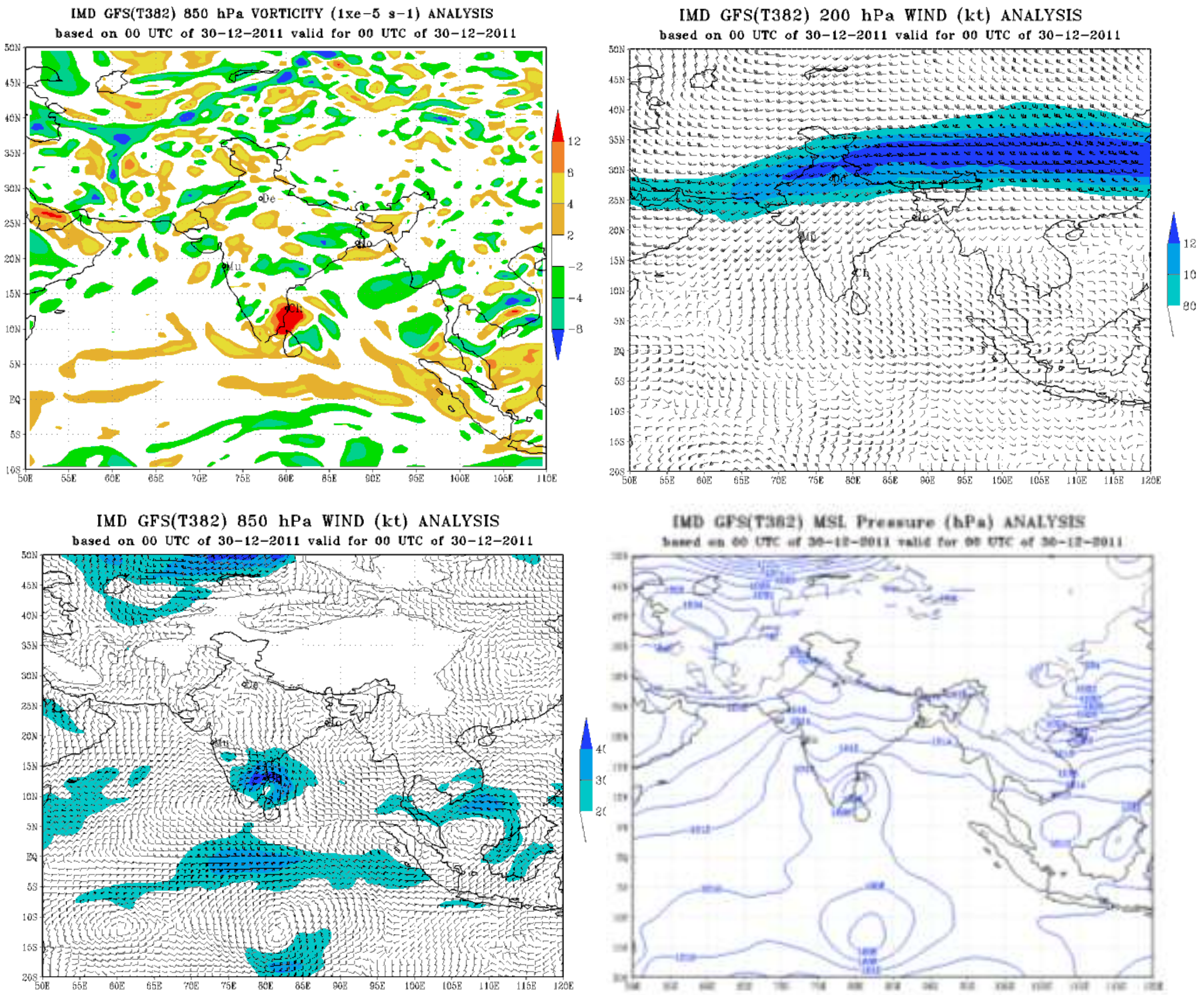


Fig. 2.2.3(f) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 30th December, 2011.

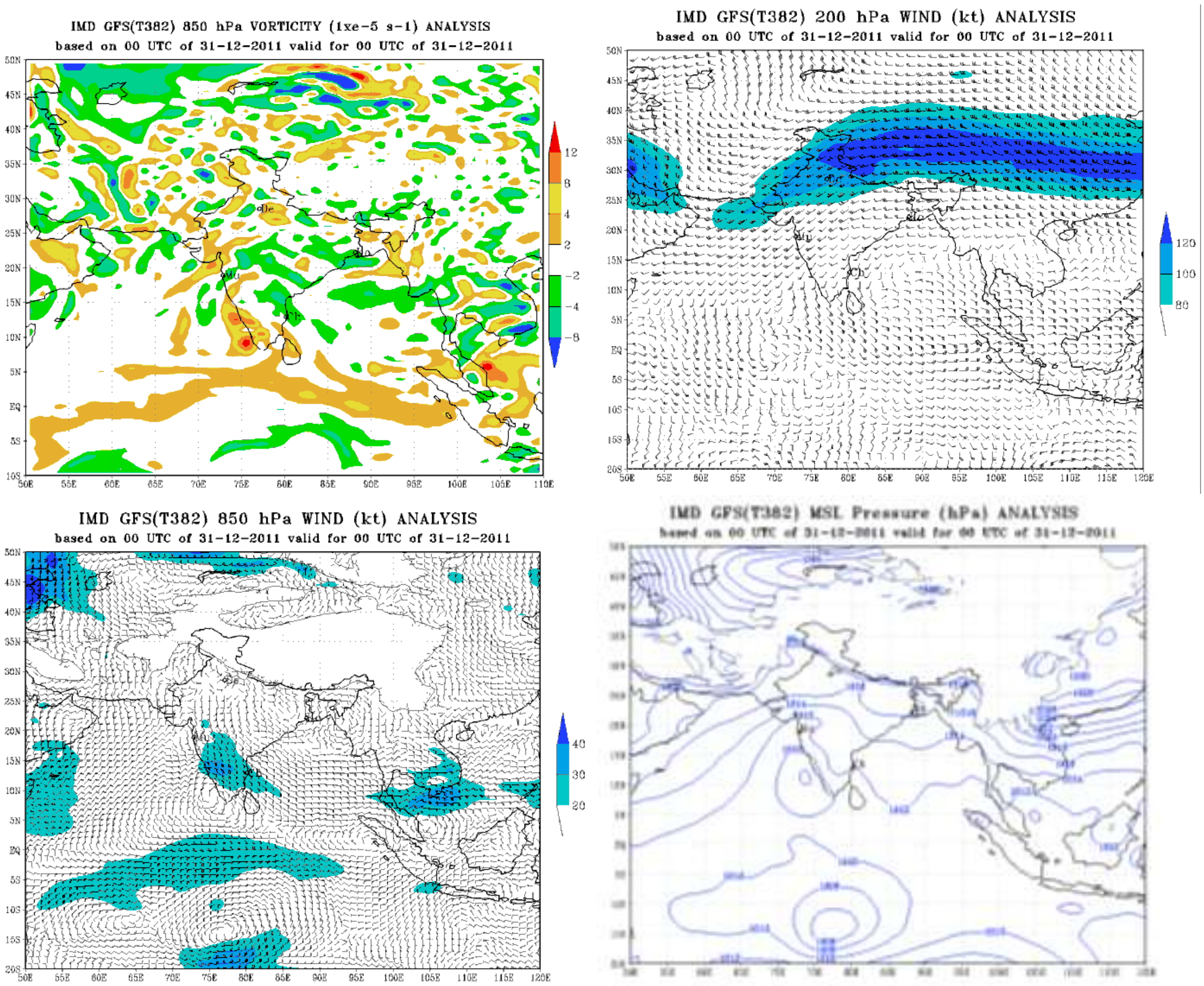


Fig. 2.2.3(g) (i) Upper level divergence at 200 hPa level (ii) low level relative vorticity at 850 hPa level (iii) wind at 200 hPa level (iv) MSLP based on the IMD GFS model analysis of 0000 UTC of 31st December. 2011.

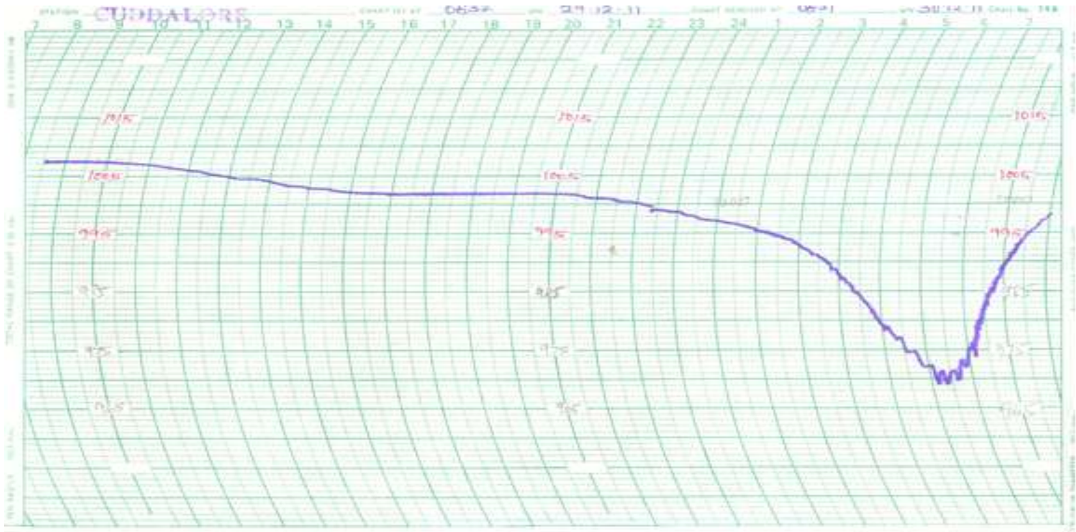


Fig.2.2.4(a) . Barograph of Cuddalore during 29-30th December 2011

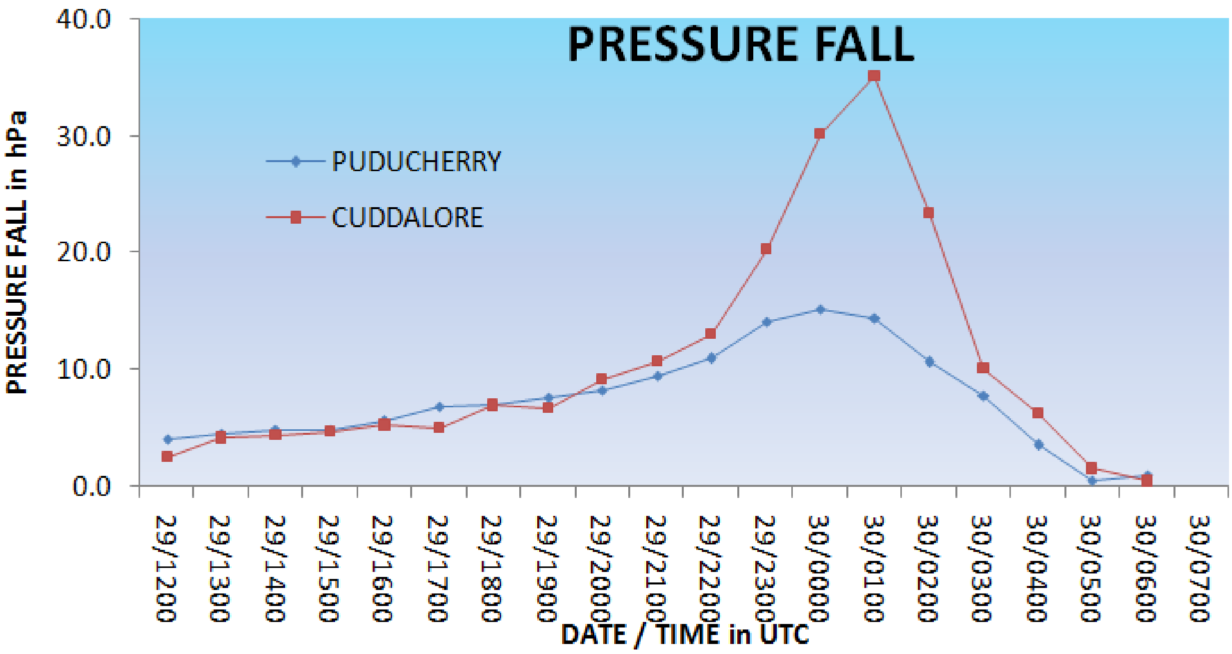


Fig.2.2.4(b) . 24 hr pressure fall of Puducherry and Cuddalore during 29-30th December 2011

2.2.5 Realised Weather

(a) Heavy Rainfall

Heavy to very heavy rainfall occurred at a few places over north Tamil Nadu and Puducherry on 30th and 31st December. Isolated heavy rainfall also occurred over south Tamil Nadu, south coastal Andhra Pradesh, Rayalaseema during this period and over Kerala on 31st December.The following stations recorded past 24 hrs heavy rainfall (7 centimeters or more) at 0830 hrs IST of 30th and 31st December 2011.

30 December 2011

Puducherry : Puducherry airport 15,

Tamil Nadu : Kalpakkam and Kelambakkam (both Kanchipuram dt) 10 each, Cuddalore, Maduranthagam and Uthiramerur (both Kanchipuram dt) 9 each, Chengalpattu and Mahabalipuram (both Kanchipuram dt) 8 each and Chennai airport, Tiruvallur and Chidambaram (Cuddalore dt) 7 each.

Andhra Pradesh : Rapur (Nellore dt), Puttur (Chittoor dt) 7 each,

31 December 2011

Kerala : Haripad (Alapuzha dt) 22, Tiruvananthapuram 18, Nedumangad (Tiruvanathapuram dt) 16, Kayamkulam (Alapuzha dt) 15, Thiruvalla (Pattanamthitta dt) 14, Chengannur (Alapuzha dt) 12, Neyyatinkara (Tiruvananthapuram dt) 11, Mavelikara (Alapuzha dt) 10, Konni (Pattanamthitta dt), Kanjirapally (Kottayam dt), Kottayam, Alapuzha 9 each, Varkala (Tiruvananthapuram dt), Kozha (Kottayam dt) 7 each,

Puducherry: Puducherry airport 10

Tamil Nadu : Kallakurichi (Villupuram dt) 18, Gingee (Villupuram dt) 16 each, Sankarapuram (Villupuram dt), Mylaudy and Nagerkoil (both Kanyakumari dt) 14 each, Uthiramerur (Kanchipuram dt) and Kuzhithurai (Kanyakumari dt) 13 each, Virudhachalam (Cuddalore dt), Cheyyar (Tiruvannamalai dt) 12 each, Mancompu (Alapuzha dt), Tozhudur (Cuddalore dt), Tirukoilur (Villupuram dt), Polur, Vanthavasi and Sathanur Dam (all Tiruvannamalai dt) 11 each, Kanchipuram, Maduranthagam (Kanchipuram dt), Arani (Tiruvannamalai dt) 10 each, Chengalpattu (Kanchipuram dt), Chembarambakkam (Tiruvallur dt), Ulundurpet (Villupuram dt) and Tiruvannamalai 9 each, Punalur, Tiruvallur, Boothapandy (Kanyakumari dt), Kanyakumari, Chengam (Tiruvannamalai dt) and Sholingur (Vellore dt) 8 each and Chennai airport, Cheyyur, Kelambakkam and Sriperumpudhur (all Kanchipuram dt), Poonamalli, Ramakrishnarajupet and Tiruvalangadu (all Tiruvallur dt), Tiruttani, Sethiyathope (Cuddalore dt) and Tindivanam (Villupuram dt), Kumbakonam (Thanjavur dt), Arakonam and Kaveripakkam (both Vellore dt), Vellore, Attur (Salem dt), Coonoor, Jayamkondam (Ariyalur dt) and Padallur (Perambalur dt) 7 each.

The daily cumulative rainfall on 30th and 31st December 2011 at recorded at 0300 UTC are shown in Fig.2.2.5. The SRRG chart of Meteorological Observatory, Puducherry is shown in Fig.2.2.6

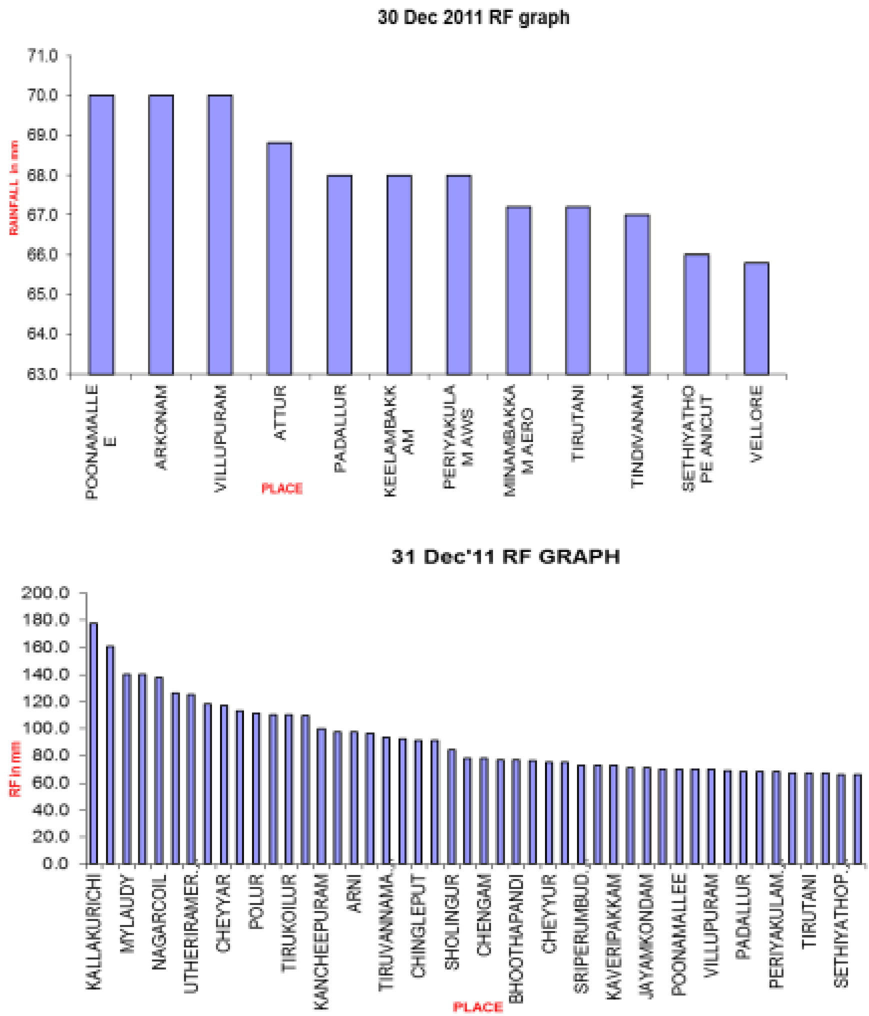


Fig.2.2.5. Daily cumulative rainfall on 30th and 31st December 2011 at recorded at 0300 UTC along the coast of Tamil Nadu and Puducherry

Fig.2.2.6. SRRG chart of Meteorological Observatory, Puducherry

(b) Gale wind

Gale wind speed reaching 120-140 kmph prevailed along and off north Tamil Nadu and Puducherry coast. Puducherry reported maximum wind of 68 knots (125 kmph) and Cuddalore reported maximum wind of 76 knots (140 kmph) at the time of landfall. The area affected by gale wind due to Thane is shown in Fig.2.2.7.

(c) Storm surge

As per post-cyclone survey conducted by IMD, the storm surge of about 1 metre height inundated the low lying coastal areas of Cuddalore, Puducherry and Villuparam districts at the time of landfall of the cyclone, THANE.

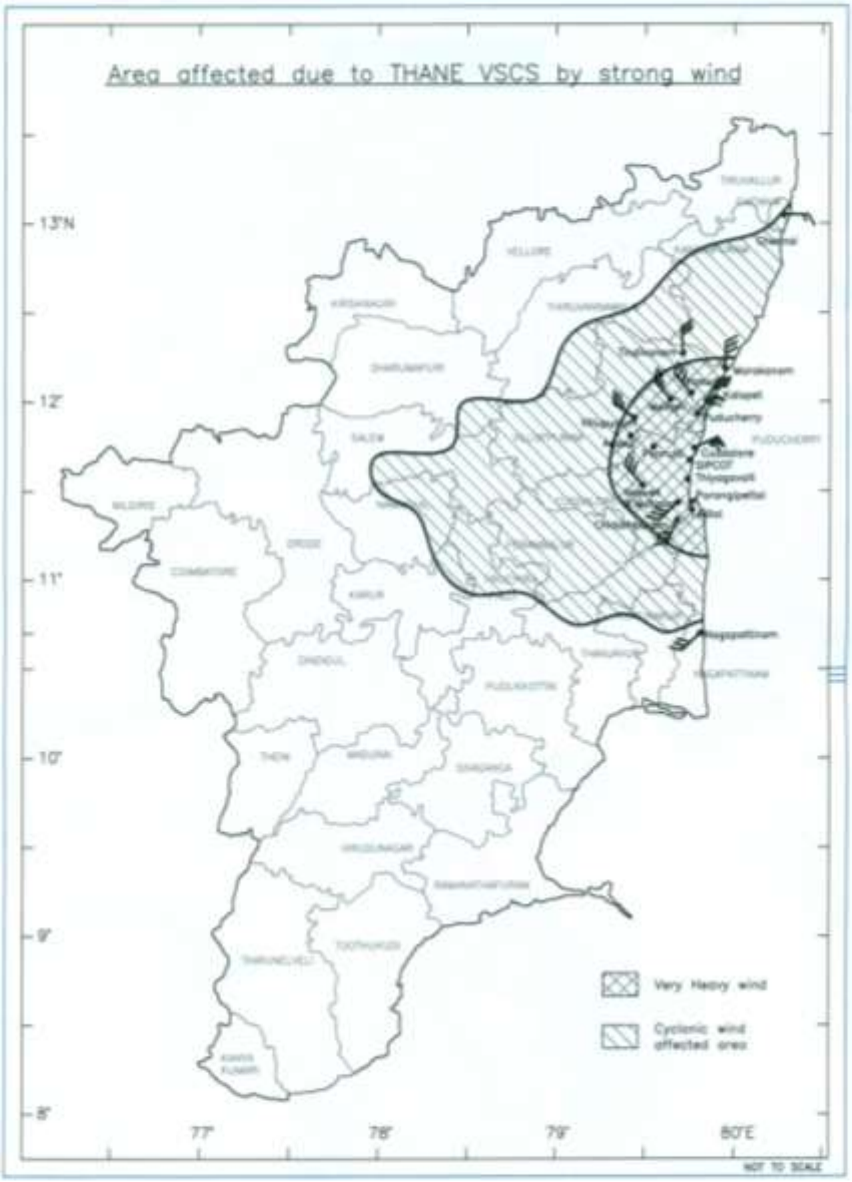


Fig.2.2.7. Area affected by gale wind due to Thane.

2.2.6. Damage:

As per media /Govt reports, 46 persons died due to the VSCS “Thane” in Tamil Nadu and Puducherry.

The samba crop grown in 1700 hectares in Thanjavur district; 2000 hectares in Tiruvarur district; Paddy crop in Cuddalore, Nagapattinam, Villupuram, Kanchipuram, parts of Thanjavur, Tiruvarur and Thiruvallur were affected besides sugarcane in 6000 hectares and coconut in about 500 hectares. In Salem district, many acres of tapioca, betel nuts, and banana crops were also affected

When the storm crossed the coast, heavy rains accompanied by squally winds speed reaching 140 Kmph uprooted trees, electric posts, disrupted power supply and transport services in Cuddalore district and Puducherry.

Due to wind and rain, 793 trees more than 35 years old in the roadside were uprooted In the cyclone affected coastal areas.

Around 6000 persons in Cuddalore, Villupuram, and Nagapattinam, Tiruvallur and Kancheepuram districts and low level areas were shifted to shelters. Besides, the supply of water, milk, diesel and kerosene has been affected and essential commodities go scarce in Cuddalore district and Puducherry. In Puducherry the storm has caused considerable loss to the Tourism Industry and the Silver beach in Cuddalore has been reduced to a strip as sea erosion caused the coast leaving little space for the sand.

About 73292 thatched houses were fully damaged and 94633 houses were partially damaged by wind and rain in the various affected districts of the state.

In agricultural sector, paddy crop in 58,200 hectares; sugarcane in 5,752; groundnut in 1,402; black gram in 945; coconut in 490 hectares were damaged in the entire cyclone affected areas. In horticultural sector, cashew in 23,500 hectares; banana plantation in 2,860; Jackfruit in 340; vegetables in 320; Mango trees in 317; Guava in 270; flowers in 250; betel nuts in 128; tuber in 73; amla in 12 hectares were damaged.

In Cuddalore district alone 4500 electric poles, 4500 transformer, 27 electric towers were damaged. Electric wire in 10,500 Km length was damaged. The damages are worked out to be 1300 to 1500 crores.

In fishing sector, in the coastal villages of Cuddalore and Puducherry, 240 country boats; 67 numbers motorized boats; 58 catamarans and four mechanized boats were fully damaged.

In the cyclone affected coastal areas, 1,430 catamarans; 106 motor boats; 101 mechanised boats and 16 country boats were partially damaged. Apart from this damage 1,94,000 fishing nets and 1262 engines were damaged. In animal husbandry sector, 47 Cows; 32 Calves; 9 Buffaloes; 5 Buffaloes calves and 4 Bullocks were dead. About 52,938 Chickens; 6200 Kadai; 1000 ducks and 246 goats also perished.

A few damage photographs are shown in Fig.2.2.8

a) Broken electrical post and submerged fishing boat at Cudallore


(b)Twisted cell phone tower at Cuddalore and blown up fishing boats at Cudallore


(c) Damages at Puducherry and fishing hamlet Puducherry coastal line.


(d) Up rooted trees Pondy Assembly campus and Damaged District Collectorate, Cudallore


Fig. 2.2.8 Some damage photograph due to the cyclone THANE in Cudallore district Puducherry.

CHAPTER-III

CONTRIBUTED PAPERS *ON* CYCLONES & DEPRESSION
Abstract of Papers Published in Quarterly Journal, *'MAUSAM'*

1. Simulation of monsoon depression over India using high resolution WRF Model – Sensitivity to convective parameterization schemes

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ABSTRACT.

The monsoon depression of September 2008, which crossed Orissa coast near Chandbali on 16th had contributed heavy rainfall over Orissa, Chhattisgarh and northern India along the track of the system. The sensitivity of three cumulus parameterization schemes *viz*., Kain-Fritch (KF) scheme, Grell-Devenyi (GD) scheme and Betts-Miller-Janjic (BMJ) Scheme are tested using high resolution advanced version (3.0) Weather Research Forecasting (WRF) model in forecasting the monsoon depression.

The results of the present study shows that the genesis of the system was almost well captured in the model as indicated in 48hr forecast with all three convective parameterization schemes. It is seen that the track of monsoon depression is quite sensitive to the cumulus parameterization schemes used in the model and is found that the track forecast using three different cumulus schemes are improved when the model was started from the initial condition of a depression stage compared to that when it started from the initial condition of low pressure area. It is also seen that when the system was over land all the schemes performed reasonably well with KF and GD schemes closely followed the observed track compared to that of BMJ track. The performance of KF and GD schemes are almost similar till 72 hrs with lowest landfall error in KF scheme compared to other two schemes, whereas the BMJ scheme gives lowest mean forecast error upto 48 hr and largest mean forecast error at 72 hr. The overall rainfall forecast associated with the monsoon depression is also well captured in WRF model with KF scheme compared to that of GD scheme and BMJ scheme with observed heavy rainfall over Orissa, Chhattisgarh and western Himalayas is well captured in the model with KF scheme compared to that with GD scheme and BMJ scheme.

Key words – Monsoon depression, WRF model, Track forecast, Heavy rainfall, Forecast error.

2. Modulation of cyclonic disturbances over the north Indian Ocean by Madden - Julian oscillation

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ABSTRACT.

The relationship of genesis and intensity of cyclonic disturbances (CDs) over the north Indian Ocean with the Madden – Julian Oscillation (MJO) has been examined using 33 years (1975 - 2007) data of MJO index and best track of (CDs) developed by India Meteorological Department (IMD). The MJO index based on outgoing long wave radiation (OLR) and zonal wind in upper (200 hPa) and lower (850 hPa) troposphere (Wheeler and Hendon, 2004) has been used for this purpose.

The MJO strongly modulates the genesis and intensity of CDs over the north Indian Ocean. However there are other factors contributing to cyclogenesis over the north Indian Ocean, as about 60% of cyclogenesis during monsoon and post-monsoon seasons are not significantly related with MJO. While the probability of cyclogenesis during monsoon season is higher with MJO in phase 4 and 5 (Maritime Continent), that during post-monsoon season is higher with MJO in phase 3 and 4 (east Indian Ocean and adjoining Maritime Continent). It indicates that while possibility of genesis during monsoon season is significantly suppressed with active MJO at phase 1, 7 and 8 (Africa, western Hemisphere and adjoining Pacific Ocean), there is no significant relationship between genesis and active MJO at phase 1, 7 and 8 during post-monsoon season. The anomalous cyclonic circulation at lower levels over central and north Bay of Bengal in association with MJO at phase 4 and 5 favours enhanced probability of cyclogenesis over the Bay of Bengal during monsoon season. The anomalous easterlies in association with MJO at phase 1 and development of anomalous ridge over south India in association with MJO at phase 7 and 8 which are weak monsoon features lead to suppressed cyclogenesis over north Indian Ocean during this season. The anomalous north-south trough in easterlies embedded with cyclonic circulation over the south west/west central Bay of Bengal in association with southerly surge over the region during active MJO in phase 3 and 4 most favourably influences the convection and enhances the probability of cyclogenesis over the north Indian Ocean during post-monsoon season.

The genesis of CDs is more sensitive to phase than the amplitude while the intensification of CDs is more dependent on the amplitude of MJO. Comparing monsoon and post-monsoon seasons, the modulation of genesis, intensification and duration of CDs by the MJO is more during the monsoon season than the post-monsoon season.

Key words – Cyclonic disturbances, North Indian Ocean, Madden-Julian Oscillation.

CHAPTER-IV

Activities of PTC Secretariat during the Intersessional Period 2010-11

- Summary of the PTC activities was submitted to the 67th Session of UNESCAP (19-25 May 2011, Bangkok, Thailand). The summary report was based on the draft report of 38th Session of PTC (New Delhi, 21-25 February, 2011)
- PTC Secretariat launched website of PTC (www.ptc-wmoescap.org). The PTC Members were encouraged to send their comments and suggestions for further improving the website.
- As decided by the PTC during its 38th Session (New Delhi, 21-25 February, 2011), the PTC Secretariat requested the Panel Member countries (through their respective PRs with WMO) for nomination of DDP experts/Focal Points for WG-DPP after coordinating with their respective National Disaster Management Offices responsible for disaster management / risk reduction / prevention / preparedness / mitigation in their countries. On receipt of the nominations from Members, PTC Secretariat prepared the list of DDP experts/ Focal Points for WG-DPP and also sent the same to NMHSs of all Member countries, the Chair and Vice Chair of WG-DPP, Focal Points for WG-DPP, UNESCAP and WMO. It was also uploaded on the PTC website at the following web link dedicated for the WG-DPP: 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.31 and 32) 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 following web link: www.ptc-wmoescap.org/newsletters
- Additionally, the PTC Newsletters have also been sent to P Rs of Saudi Arabia and Iran. PTC Secretariat in its formal letter has also renewed its earlier request to Saudi Arabia and Iran to consider joining PTC as members because both countries have shown their willingness to join PTC earlier and their representatives also attended the 36th Session of PTC (Muscat, Oman, 2-6 March 2009) as observers.
- About the intension of Bhutan to become a Member of PTC (as informed by the WMO), the PTC Secretariat extended the invitation to Bhutan (through PR of Bhutan with WMO) to join PTC and it was requested to complete formal procedure in this regard as soon as possible. Copies of the Coordinated Technical Plan 2009-2011 and PTC Flyer were also sent to P R of Bhutan with WMO.
- As decided by PTC at its 38th Session (New Delhi, India from 21 - 25 February, 2011), WMO made arrangements with the Indian Institute of Technology (IIT), New Delhi for the attachment of two storm surge experts - one each from

Myanmar and Thailand. PTC Secretariat extended invitation for this training to both countries through their P Rs with WMO. The training for Storm Surge Experts was hosted by IIT, New Delhi during the period from 12th – 23rd December, 2011. Financial support in lieu of travel and per diem was provided to the participants from the PTC Trust Fund through WMO.

- As requested by PTC at its 38th Session (New Delhi, India from 21 - 25 February, 2011), WMO made arrangements with the RSMC, New Delhi for the attachment of three Tropical Cyclone Forecasters - one each from Sri Lanka, Maldives and Thailand. PTC Secretariat extended invitation for this training to these countries through their P Rs with WMO. The training for the Tropical Cyclone Forecasters has been hosted by RSMC, New Delhi, India during the period from 20 February – 2 March, 2012. Financial support in lieu of travel and per diem was provided to the participants from the PTC Trust Fund through WMO.
- PTC at its 38th Session (New Delhi, 21-25 February, 2011) (as per Para 5.0.3 of the Final Report of PTC-38) urged for the organization of an Ad-hoc Group (under the Chairmanship of Dr. Chaudhy, Secretary of PTC) to collect the available knowledge and research papers on the impact of climate change on tropical cyclone activities in the Panel region from the Members during the next inter-sessional period. Subsequently, PTC Secretariat requested the PTC Members (through their P Rs with WMO) for sending the available information on the issue. Information from four out of eight Members was received to PTC Secretariat and a preliminary report on the issue was prepared for the PTC. However, owing to the importance of the issue, further information and research papers on the impact of climate change on tropical cyclone activities in the PTC region from Members need to be collected for some comprehensive analysis and assessment.
- Referring to WMO circular regarding holding of **Second International Conference on Indian Ocean Tropical Cyclones and Climate Change** (New Delhi, India from 14 to 17 February 2012), PTC Secretariat urged PTC Members for participation in the conference and invited research papers relevant to the thematic areas of the conference. The conference was organized by India Meteorological Department (IMD) and the WMO/WWRP Expert Team on Climate Change Impacts on Tropical Cyclones in collaboration with WMO's Tropical Cyclone Programme (TCP) and World Climate Research Programme (WCRP). The National Meteorological and Hydrological Services (NMHSs), scientists and representatives from countries located within the Indian Ocean cyclone basins were especially encouraged for participation and for sending their research contributions to the conference.

Information regarding financial support by WMO from the PTC Trust Fund and detailed breakup of expenses incurred by PTC Secretariat during the intersessional period (2011-2012) is given in **Appendix-II**

Appendix-I

Other Activities of WMO/ESCAP Panel member countries

(i) Annual Cyclone Forecasters Training Conducted by RSMC, New Delhi during 20 February to 02 March 2012

RSMC,New Delhi is conducting two weeks training for cyclone forecasters from WMO/ESCAP panel countries since 2005. Every year 2 to 3 cyclone forecasters from WMO/ESCAP panel countries participate in this programme. This year RSMC, New Delhi conducted annual cyclone forecasters training during 20th February to 2nd March 2012 for the cyclone forecasters, one each from Maldives, Sri Lanka and Thailand. The training is also attended by the forecasters from Area Cyclone Warning Centres (ACWCs) and Cyclone Warning Centres (CWCs) and National Weather Forecasting Centre (NWFC) of IMD. This training consists of both theoretical and practical aspects of cyclone monitoring, prediction and warning/advisory services over the North Indian Ocean. The important components of the trainings are mentioned below.

(i) Observational aspects (including surface, upper air, satellite and radar)

(ii) Monitoring aspects (Determination of location, intensity and structure

(iii) NWP modeling aspects

(iv) Forecasting aspects (forecast of track, intensity and quadrant wind upto 72 hrs)

(v) Warning aspects (prediction of heavy rainfall, gale wind and storm surge)

(vi) Warning products and bulletins (text and graphics) generation, presentation and dissemination

(vii) Check lists and road maps for monitoring and prediction and warning services

(viii) Forecast verification, documentation

(ix) Organisational aspects

(x) Feedback from the participants

(xi) Visit to different centres of IMD, NCMRWF and National Institute of Disaster Management (NIDM).

All the above aspects are taught with theoretical lectures and hands-on exercises. Out of about 70 hours of total training classes excluding lunch and tea break, 36 hours were dedicated to theoretical classes, 24 hours to practical/hands on exercises and 10 hours towards visit to different centres. The feedback was also collected from the participants for improving the training programme in future. The certificates were distributed to the participants on successful completion of the training. The brief inaugural and valedictory functions were also conducted in the beginning and ens of the training respectively.

(i) Brief report on the attachment of storm surge experts from DMH Myanmar and TMD Thailand to IIT Delhi during December 2011 within the framework and overall guidance and supervision of the Tropical Cyclone Programme (TCP) of the World Meteorological Organization (WMO)

The National Meteorological and National Hydrological Services of many countries have achieved some success in provision of storm surge warnings and for implementing improved models through co–operative and co–ordinated sharing of responsibilities within the framework and overall guidance and supervision of the Tropical Cyclone Programme (TCP) of the World Meteorological Organization (WMO). The TCP of WMO supports technology transfer from the Indian Institute of Technology-Delhi to run and make operational storm surge models for Bangladesh, Myanmar, Pakistan, Sri Lanka, and Oman. Every year since 2001, WMO has been sending two persons from North Indian Ocean countries to IIT Delhi for two weeks training and transfer of technology.

The TCP of WMO supported storm surge training and technology transfer to NMHS of Myanmar and Thailand from the Indian Institute of Technology-Delhi during **12-23 December 2011**.

Ms. Thet Htar Su Hlaing from DMH, Myanmar and Mr. Sorot Sawatdiraksa of TMD were attached to IIT Delhi for two weeks period in **December 2011** who were provided extensive hands on training in use location specific improved very high resolution storm surge model together with latest visualization softwares. During the period of their training Ms. Hlaing and Mr. Sawatdiraksa performed more than 30 numerical experiments using IIT model to understand the basic features of the storm surge phenomena through numerical simulations and to test the feasibility and sensitivity of IIT storm surge model in operational use. In particular numerical experiments were performed to test the effect of bathymetry (especially over continental shelf), the relationships between angle of cyclone landfall and the location (distance from landfall) and amplitude of surges, sensitivity of model to input parameters required for computing windstrss and impact of duration of cyclone. In order to validate the models, several simulation experiments were performed by using the data of severe cyclonic storms hitting the coasts of Myanmar/Thailand.

At the end of the training the latest version of the storm surge prediction model together with visualization software were transferred to the trainees for implementation in their respective weather services.

Appendix-II

Statement of PTC Secretariat Accounts (2011 - 2012)

Sr. No.	*Opening Balance and Receipts*	*Amount in Pak. Rs.*
1.	Balance after 38th Session of PTC	212,670/-
2.	Amount received during the inter-sessional period (US$ 4000/= equivalent to Pak Rs.354,400/-@US$ 1= 88.60)	354,400/-
	Total	**567,070/=**
	Expenditures	
1.	Printing of 31th and 32th Issues of the Panel News	90,000/-
2.	PTC Website Hosting Fee etc.	12,000/-
3.	Services for PTC website design and construction support.	10,000/-
4.	Services for compilation work of Panel News Issues	20,000/-
5.	Stationery, envelops, postages and other miscellaneous items etc.	9,000/-
6.	Honorarium to Meteorologist-PTC Secretariat @ US$100/= per month (equivalent to Pak Rupees)	106,320/-
7.	Purchase of Colour Toner for Colour Laser Jet printer	Nil
	Total	**247,320/=**
	Net Balance in hand	**319,750/=**