WMO

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AND

ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND THE PACIFIC

ESCAP

WMO/ESCAP PANEL ON TROPICAL CYCLONES

THIRTY-EIGHTH SESSION

New Delhi, India

(21 - 25 February 2011)

FINAL REPORT

GENERAL SUMMARY OF THE WORK OF THE SESSION

1. ORGANIZATION OF THE SESSION

The thirty-eighth session of the WMO/ESCAP Panel on Tropical Cyclones (PTC) hosted by India was held in New Delhi, India from 21 to 25 February 2011. The session was attended by xx participants from the eight Members of the Panel on Tropical Cyclones, namely, Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka and Thailand. It was also attended by observers from China, Indian Institute of Technology (IIT) Delhi and ICAO, ICHARM, RIMES and representatives from WMO, UNESCAP and PTC Secretariat. The list of the participants as well as the capacities in which they attended is given in **Appendix I**.

1.1 Opening of the session

1.1.1 An inaugural function of the session was held at 1100 hrs IST of 21 February 2011 at SCOPE Complex, Lodi Road, New Delhi.

1.1.2 Shri M. Sashidhar Reddy; Hon'ble Vice Chairman, National Disaster Management Authority (NDMA), Government of India, was the Chief Guest in the programme. Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Govt. of India presided over the meeting.

1.1.3 AVM (Dr) Ajit Tyagi, Director General of Meteorology, IMD and Permanent Representative of India with WMO welcomed the guests and delegates for the 38th Session of WMO/ESCAP Panel.

1.1.4 Distinguished delegates and invitees in the inaugural function included Dr Quamar-uz-Zaman Chaudhry, Secretary of PTC and Permanent Representative of Pakistan with WMO, Dr. T. Toya, Regional Director for Asia and Southwest Pacific, WMO; Mr. K. Kuroiwa, Chief, Tropical Cyclone Programme, WMO; Dr Yuichi Ono, Chief, Disaster Risk Reduction Section, ESCAP, delegates from the Panel Member countries including Bangladesh, Myanmar, Thailand, Sri Lanka, Maldives, Pakistan, Oman, delegates from China, ICAO, RIMES, Bangkok, delegates from India (IMD, Central water Commission, Govt of India and IIT, Delhi). The agenda of the inaugural programme is given in **Appendix II**.

1.1.5 The inaugural function began with the lighting of the ceremonial lamp by Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India and other distinguished delegates in the dais.

1.1.6 AVM (Dr) Ajit Tyagi delivered the welcome address and highlighted the objective and expected outcome of the 38th Session of WMO/ESCAP Panel on Tropical Cyclones.

1.1.7 Dr Quamar-uz-Zaman Chaudhry, Secretary of PTC, highlighted the Panel activities in his address. He appreciated the contribution of RSMC New Delhi and IIT Delhi for tropical cyclone monitoring, prediction, advisories and storm surge guidance. He suggested forming of a Working Group on Hydrology for addressing the hydrology related issues in the region.

1.1.8 Dr Yuichi Ono representing ESCAP also appreciated the services provided by RSMC New Delhi. He further proposed the strengthening of Working Group on Disaster Risk Reduction (WGDRR).

1.1.9 Speaking on behalf of Mr Michel Jarraud, Secretary-General of WMO, Dr Tokiyoshi Toya highlighted the achievements of Tropical Cyclone Programme of WMO and the future plans in his address in the meeting (summaries of the speeches of Dr Chaudhry, Dr Ono and Dr Toya are given in **Appendix III**).

1.1.10 The following two Meteorological Monographs published by Cyclone Warning Division of IMD were released by Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India and Dr T. Toya of WMO, respectively,

(i) A Report on the Super Cyclonic Storm "GONU" during 1-7 June, 2007
(ii) Characteristics of Best Track Parameters of Tropical Cyclones over the North Indian Ocean.

1.1.11 Dr Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India, in his address highlighted the need for the optimum observational network for monitoring and prediction of tropical cyclones over the north Indian Ocean. He discussed the scientific understanding of the core structure of the cyclone in this region and the need for aircraft probing of cyclone. Dr Nayak further stressed on the prediction of associated rainfall and coastal inundation due to the storm surge, need for improvement in NWP modeling in these aspects. He informed that though the cyclone warning services of RSMC, New Delhi has improved significantly in recent years with reduction in track and intensity forecast errors, warning services over the north Indian Ocean region needs further improvement.

1.1.12 Shri M. Sashidhar Reddy; Hon'ble Vice Chairman, National Disaster Management Authority, Government of India, delivered his speech as chief guest by video conferencing, as he could not be physically present in the inaugural function due to unavoidable circumstances. He congratulated Ministry of Earth Sciences and IMD for organizing the 38th Session of WMO/ESCAP Panel at New Delhi. He placed his concern for research issues, aircraft probing and nowcasting of severe weather events. He requested the delegates to develop the capability for translating forecast to actionable suggestions as required by disaster managers for successful management of risks due to cyclones.

1.1.13 Sri B.K. Bandyopadhyay, Director, Regional Specialized Meteorological Centre, New Delhi and DDGM (Services), India Meteorological Department extended vote of thanks to the Guests, delegates and all invitees attending the inaugural function. He conveyed his heartiest thanks to Mr M. Sashidhar Reddy, Hon'ble Vice Chairman, NDMA, Government of India, Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India and AVM (Dr.) Ajit Tyagi, Director General of Meteorology, IMD for sparing their time to grace the occasion. He also thanked all the distinguished delegates and invitees for attending the inaugural function. He thanked the local organizing committee for successfully organizing the programme.

1.2 Election of the Chairman and Vice-chairman

1. 2.1 Dr Ajit Tyagi, (India) and Dr Hrin Nei Thiam (Myanmar) were unanimously elected as Chairperson and Vice-chairperson of the Panel, respectively, to hold their posts until the next session.

1. 2.2 Mr S.H. Kariyawasam (Sri Lanka) was elected as Chairman of the drafting committee.

1.3 Adoption of the agenda

The Panel adopted the agenda as given in **Appendix IV.**

1.4 Working arrangements

The Panel decided on its working hours and the arrangements for the session.

2. FOLLOW-UP ACTION ON PTC-37

2.1 A detailed review of the follow-up actions taken to the recommendations of the thirty-seventh session was carried out based on the action sheet shown in **Appendix V**. The progress on the activities is incorporated into the relevant paragraphs below.

2.2 The representative of WMO informed the Panel that the update of the Global Guide to Tropical Cyclone Forecasting will be completed by the middle of 2011 after regional reviews by RSMCs/TCWCs as well as volunteers during March through May. The Typhoon Landfall Forecast Demonstration Project and the NW Pacific Tropical Cyclones Ensemble Forecast Project are successfully implemented in the Typhoon Committee regions under the initiative of CMA and JMA, respectively.

2.3 PTC Secretariat informed the Panel that only a few proposals were given from the Members in response to the request for Annual Operating Plan (AOP) for the meteorological component. The Secretariat suggested that a further discussion is necessary to formulate the AOP for the meteorological component.

2.4 As regards application of ensemble techniques into the track forecasting, RSMC New Delhi informed the Panel that the multi-model ensemble forecasts which are derived from the High Resolution Ensemble Forecast System (HREF) are available at the RSMC's website. Currently, a further improvement has been made to the website. Meantime, the Panel was informed by Pakistan that Pakistan Meteorological Department (PMD) started to provide probabilistic forecast of tropical cyclones for the purpose of disaster management.

2.5 Representative of the India Institute of Technology (IIT) Delhi reported on the experiments with river-ocean coupled models, IIT-D model has been modified to take into account one–dimensional river which allows penetration of storm surge inland. Preliminary results show that inland extent of penetration is over-estimated. Reason of over-estimate is that overland flooding as well as interaction with seaward river discharge is not included in model. IIT proposes to continue to improve model with more realistic models and river interaction.

2.6 Concerning the establishment of a linkage between the PTC-WGDPP and the Disaster Risk Reduction (DRR) Programme of WMO as well as RA-II Working Group on DRR, the session was informed that the first Meeting of RA II Working Group on Disaster Risk Reduction and Service Delivery (Daegu, 1-3 December 2010) developed the draft implementation plan, which includes the development of the regional guidance on methodology of DRR of responding to climate change and on how to strengthen links between National Meteorological Services and National Disaster Management Offices.

2.7 The Panel was informed by the Chair of WGDPP that the second meeting of the Working Group was successfully held in Bangkok, Thailand from 18 to 20 in August 2010 with the support of ESCAP.

3. REVIEW OF THE 2010 CYCLONE SEASON (Agenda item 6)

3.1 Report of RSMC – Tropical Cyclones New Delhi

3.1.1 The RSMC New Delhi presented a detailed review of the 2010 cyclone season on the basis of the comprehensive report entitled "Report on Cyclonic Disturbances over North Indian Ocean during 2010" which was distributed in CD-ROM to the Members during the session.

3.1.2 The RSMC New Delhi informed the Panel that the north Indian Ocean witnessed the formation of eight cyclonic disturbances during 2010. Out of eight disturbances six cyclonic disturbances formed over the Bay of Bengal and two over the Arabian Sea. Out of the six cyclonic disturbances over the Bay of Bengal, one intensified up to the stage of very severe cyclonic storm (GIRI), two up to the stage of severe cyclonic storm (LAILA & JAL), one up to the stage of deep depression and rest two up to the stage of depression. Out of two cyclonic disturbances formed over the Arabian Sea, one intensified up to the stage of very severe cyclonic storm (PHET) and the other up to the stage of cyclonic storm (BANDU).

3.1.3 The salient features of the cyclonic disturbances during 2010 were as follows:

- The number of total cyclonic disturbances (depression and above) during the year was far below normal, as only 8 cyclonic disturbances formed during 2010 against the normal of 13 cyclonic disturbances. However, five cyclones formed during the year which is the first such year after 1998 when six cyclones formed.
- Out of five cyclones, three cyclones made landfall with at least cyclonic storm intensity.
- There were no cyclonic disturbances formed over the north Indian Ocean during monsoon season (June-Sep.). Comparing with past records (1891-2009), there was only one such year viz. 2002. On an average, 7 cyclonic disturbances formed over the north Indian Ocean during the monsoon season. While the year 2002 was an all India drought year, the year 2010 was a normal rainfall year. It was mainly because of the fact that the absence of cyclonic disturbances was compensated by the number of low pressure areas over the region. There were 13 low pressure areas during the season against the normal of 6. Considering low pressure systems including lows and cyclonic disturbances (depression and above), about 13.5 such systems develop normally during monsoon season.
- The cyclone „Phet" over the Arabian Sea had the rarest of the rare track with two landfall points over Oman and Pakistan and longest track in recent years.

3.1.4 The review of individual storms in the 2010 cyclone season provided by the RSMC is given in **Appendix VI**.

3.1.5 The Panel expressed its appreciation to the RSMC New Delhi for its continued valuable support to the Members. It also stressed the importance of further strengthening of the existing cooperation and collaboration between the national Early Warning Centres and RSMC New Delhi.

3.1.6 In relation to tropical cyclone forecasts, Bangladesh and other Members expressed a concern about the difference in the maximum wind speeds of tropical cyclones between the forecasts issued by the Panel Members and those by the Joint Typhoon Warning Center (JTWC) which is found occasionally significant. Such differences arise apparently from the difference in the wind averaging periods; Members adopt WMO standard 10-min averaged wind speeds while JTWC and USA 1-min average. Although JTWC is operated in the service of US military forces, its forecasts are virtually freely available to the public.and media through internet and thus often cause embarrassment to the Members.

3.1.7 In this connection, Dr. Chaudhry referred to the importance of the impact of winds associated with tropical cyclones and suggested that careful consideration should be given to the advisories to the public about the impact of the strong winds. He emphasized that, to minimize the wind damage from tropical cyclones, it is most important to give users accurate understanding of gustiness. Therefore, information on the gust needs to be included in the advisories in addition to the maximum sustained wind speeds because tropical cyclone is a high-impact weather system with very high gusty winds which are most responsible for the

wind damage. A simple conversion of the winds of different averaging periods would mislead the users. He proposed that this issue be discussed at the next International Workshop on Tropical Cyclones (IWTC) and urged the Panel Members to raise the issue also at the coming WMO Congress to be held in Geneva, Switzerland in May, 2011 through their respective PRs.

3.1.8 WMO Secretariat informed the Panel that the difference in wind-averaging period between the WMO Members has been recognized as a longstanding problem in the tropical cyclone communities. Tropical Cyclone Programme (TCP) took actions to address this issue, which includes publication of "Guidelines for Converting between Various Wind Averaging Periods in Tropical Cyclone Conditions" that was distributed to the WMO Members in October 2010. TCP will also organize the International Workshop on Satellite Analysis of Tropical Cyclones in Honolulu in April 2011 in conjunction with the second workshop of the International Best Tracks Archive for Data Stewardship (IBTrACS), with a view to developing standardized procedures for tropical cyclone analysis. Noting the great deal of relevance between these workshops and the issue of different wind-averaging periods, the Panel requested the WMO Secretariat to report to the Panel Members about the outcome of the workshops as soon as they become available.

3.2 Reports of Members on the impact of tropical cyclones

3.2.1 The representatives of the Panel Members reported the session on the impact of tropical cyclones during the 2010 cyclone season of their respective countries. Most of the Members were significantly affected by the cyclones during the 2010 season except for Bangladesh and Sri Lanka which did not experience a direct effect of cyclones. Summaries of the Members' reports are given in **Appendix VII**.

4. COORDINATION WITH OTHER ACTIVITIES OF THE WMO TROPICAL CYCLONE PROGRAMME

4.1 The Panel was informed by the WMO Secretariat of the basic principles of the Tropical Cyclone Programme (TCP) in implementation of the Programme's activities as follows:

- To enhance support measures for TC forecasters; e.g. update of the "Global Guide to Tropical Cyclone Forecasting" and its linkage to the "Tropical Cyclone Forecaster's website".
- To transfer R&D results into operational forecasting through promoting the collaboration between operational forecasters and researchers.
- To establish Storm Surge Watch Schemes (SSWSs) and strengthen the storm-surge warning capabilities of National Meteorological and Hydrological Services (NMHSs).
- To continue to put high priority on capacity building.

4.2 The Panel was informed that the various international forums were organized by TCP in cooperation with the World Weather Watch Programme (WWRP) of WMO such as the Second International Workshop on Typhoon Landfall Processes (IWTCLP-II; Oct 2009, Shanghai, China), the Third International Conference on QPE/QPF & Hydrology (Oct 2010, Nanjing, China) and the Seventh International Workshop on Tropical Cyclones (IWTC-VII; Nov 2010, La Reunion). These forums promoted interaction between forecasters and researchers and thus contributed significantly to the application of research achievements to operational forecasting.

4.3 Typhoon Landfall Forecast Demonstration Project (TLFDP) and the NW Pacific Tropical Cyclones Ensemble Forecast Project (NW-P/TCEFP) are the tangible outcomes of IWTCLP-II, which were launched jointly by TCP and WWRP in 2009 targeting at the Members of the Typhoon Panel and have been implemented successfully. ITLFDP

developed the systems for real-time verification and monitoring/display of forecast products and will open a project website for the Committee Members. NW-P/TCEFP has recently improved its project website which was established at JMA/MRI in the middle of 2010. A survey will be conduct for the Committee Members for further improvement of the website and examination of the utility of the ensemble forecast products envisaging the operationalization of the TCEFP in the future.

4.4 The Panel was informed that update of the Global Guide to Tropical Cyclone Forecasting will be completed by the middle of 2011. It will provide comprehensive guidance on tropical cyclone forecasting from a multi-hazard point of view. Also, the new Guide will be web-based with a view to timely update and easier access. The WMO Tropical Cyclone Forecaster Website has been developed to provide a readily accessible source of forecast tools and analytical data necessary for operational forecasting. These two information sources will be linked with the TCP Website to serve as a comprehensive source of information/material/data that is expected to be of great value to operational forecasters.

4.5 The Panel noted with satisfaction that the study on suitable conversion factors between the wind speeds of different time ranges was completed and its outcome was distributed as a WMO Technical Document (WMO/TD-No.1555) to the WMO Members including those of the Panel in October 2010. Arrangements are being made with regional tropical cyclone bodies to include a summary of the study in the regional operational plans/manual as a guideline for the conversion of wind speeds.

4.6 The Panel was briefed about the joint JCOMM/CHy Coastal Inundation Forecast Demonstration Project (www.jcomm.info/CIFDP). The Project held its 2nd meeting in Geneva, September 20-22, 2010 at which time it reviewed progress since the kick-off meeting in June 2009, and proposed revisions to the overall Project Plan. The plan framework is generic to application any coastal inundation project; specific plans were developed for the first two proposed implementations, in Bangladesh and the Dominican Republic. The initial steps proposed for each implementation involved the organization of a combined stakeholder workshop and a technical workshop to define the national requirements for flooding warning systems and the appropriate forecast models, approaches and national mandates. As a precursor to project initiation however, WMO must obtain agreement from the responsible national agencies to support the project concept, and agree to work together to implement the joint storm surge and hydrological forecasting activities.

4.7 The focus of the CIFDP will be on the development of an integrated end-to-end forecasting and early-warning system for severe coastal events based on open-source components, and on encouraging communication platforms building between NMHSs, Disaster Management Agencies and met-ocean products end-user communities, through technology transfer activities based on open-source forecasting products, Integrated Flood Management capacity building and good practices sharing.

4.8 The components of CIFDP will be evaluated for a suitable packaging in view of the development of a demonstration version of a CIFDP/SSWS system to gain experience in the day-to-day operation of such a complex integrated system, with a focus on open-source forecasting products. The demonstration project will focus initially on the Bay of Bengal region (Bangladesh) in close coordination with the SWFDP, the TCP Regional Bodies, the UNESCO/IOC Northern Indian Ocean Project on Enhancing Regional Capabilities for Coastal Hazards Forecasting, the WMO/RIMES Program reducing impacts of coastal hazards in the region, the UNESCO/IOC Integrated Coastal Area Management (ICAM) and related activities under Regional Tsunami Warning Systems.

4.9 The Panel noted with pleasure the development of CIFDP and welcomed the decision of the CIFDP First Meeting to select the Bay of Bengal as a priority region for the project. In this regard, the Panel stressed that tropical cyclones and associated storm surges and heavy rains are most responsible for the coastal inundation in the Panel region.

Therefore, it is of the view that a close linkage with the Panel on Tropical Cyclones, including the RSMC New Delih in particular, will be indispensable to successful implementation of the CIFDP in this region. The Panel also recommended that, for the Pilot Project in Bangladesh, the Bangladesh Meteorologial Department (BMD) should play the leading role as the national counterpart for the Pilot Project, as BMD is the government agency responsible for the monitoring and warning of coastal hazards such as tropical cyclones, heavy rains and storm surges. Further, the Panel emphasized that BMD has enhanced its capability of storm surge forecasting based on the IIT's high-resolution storm surge model through the recent achievement of the storm surge watch scheme in the Panel region.

4.10 The Panel took notice of the NW Pacific Tropical Cyclones Ensemble Forecast Project (NW-P/TCEFP) in view of the increasing role of ensemble forecasts in the operational tropical cyclone forecasting. In response to the inquiry regarding the availability of ensemble forecast products to the Panel Members, the WMO Secretariat showed that it plans to extend the TCEFP to other regions including the Panel on Tropical Cyclones. Arrangement will be made in due course with RSMC New Delhi to examine the feasibility of conducting the project in the Panel region.

5. REVIEW OF THE COORDINATED TECHNICAL PLAN AND CONSIDERATION OF THE WORK PROGRAMME FOR THE NEXT THREE YEARS (Agenda item 8)

Consideration of AOP

5.0.1 The Panel reviewed the progress of its activities at both national and regional levels in five components - meteorology, hydrology, DPP, research and education - based on the reports presented by the Members. The Panel also held an extensive discussion about the way to develop the Annual Operating Plan (AOP) for 2011 for the five components to achieve the goals and objectives of the Coordinated Technical Plan (CTP).

5.0.2 Dr. Chaudhry shed light on the Expected Results and Strategic Goals of various components of PTC Coordinated Technical Plan (CTP) 2009-2011 so that Members may give their input effectively during the formulation of PTC Annual Operating Plan (AOP) for 2011. He also stressed the importance of the feedback from Members about their activities relevant to each of the Expected Results of CTP during annual sessions as most of the Members have already been performing various activities which could contribute to the achievement of the strategic goals of CTP.

5.0.3 In regard to the meteorological component, a proposal was made to carry out an assessment of the impact of climate change on tropical cyclone activities in the Panel region. The Panel supported the proposal in consideration of the increasing concern about this issue in the Member countries in recent years. It should be regarded as a cross-cutting activity with the research component. For implementation of the activity, the Panel decided to organize an Ad-hoc Group and invited Dr Chaudhry to serve as Chair of the Group. It was also agreed, as a first step, to collect available knowledge and research papers on this issue from the Members during the next inter-sessional period. In this respect, the Panel requested the PTC Secretariat to facilitate the establishment of the Ad-hoc Group and collection of the information with support of the WMO Secretariat.

5.0.4 For finalization of the 2011 AOP for each of the components, the Panel requested the Members to propose and send workable activities to the PTC Secretariat by the end of March 2011.

5.0.5 Concerning the AOP of the hydrological component, The Panel asked the delegates of India to consider taking a lead on the hydrological component. The delegates agreed to consider the request and respond to the PTC Secretariat. Mr. Osti Rabindra from the ICHARM advised the Panel i) to be cautious that extreme rainfall associated with climate

change is not the only factor to increasing floods in intensity and frequency; ii) to foster trust building in data sharing and data investment; iii) to acknowledge the importance of application of space based technology; and iv) to localize the existing standard hazard/vulnerability/risk model at the regional and country levels.

5.0.6 With regard to the DPP component, the Panel organized a brief parallel meeting of the Working Group on DPP during the plenary session to review progress and challenges in this component and discuss a realistic action plan for the year of 2011. The Meeting was attended by the delegates from three Members (Oman, Thailand and India), the ESCAP representative and the PTC Secretariat.

5.0.7 Based on the discussion at the Meeting, Mr Adthaporn Singhawishai of Thailand, Chair of the WG-DPP, reported to the Panel on the activities of the WG-DPP and stressed that activities on a national level should be reported based on AOP. He also emphasized the needs of conducting WG-DPP activities on a regional level according to the AOP.

5.0.8 The Panel recognized the need to establish a complete list of the WG-DPP focal points. In this regard, the PTC Secretariat will send a letter to the Members requesting the nomination of their focal points. It was also agreed that Oman, Thailand and India will identify at least one item for AOP, respectively, and implement it within the regional scope during 2011. The three countries will coordinate and inform the PTC Secretariat of their decisions.

5.0.9 Dr Yuichi Ono of ESCAP mentioned that he would explore potential sources of funding to support the WG-DPP activities and that it could be joint activities with the Typhoon Committee.

5.0.10 The Panel Secretariat agreed to develop the work space for the WG-DPP in the Panel website to share information effectively. The PTC Secretariat will inform the progress to the Chair of the WG-DPP.

5.0.11 Mr. Rabindra Osti of ICHARM informed the Panel that ICHARM would explore opportunities for PTC Member countries to benefit from ICHARM's regular capacity building programmes including application of Integrated Flood Analysis System (IFAS) in Member countries. In this respect ICHARM will coordinate with UNESCAP and WMO.

5.1 Meteorological component (agenda item 8.1)

Activities of the Members

5.1.1 The representative of Bangladesh informed the Panel that Meteorological Data from RTH New Delhi and 10 synoptic observatories of Bangladesh Meteorological Department (BMD) are exchanged on routine basis through WMO GTS. All the 35 observatories of BMD have been connected with NMCC Dhaka either by 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 VSAT link. NMCC uses MSS software obtained from WMO/UNDP Regional Computer Network programme for reception and transmission of all meteorological data. BMD has been using JMA Global Spectral Model (GSM) for Numerical Weather Prediction since October 2010. The resolution of GSM for the surface is 0.25°x0.25° and for upper air is 0.5°x0.5°. The model output are updated every day accordingly at BMD website www.bmd.gov.bd

5.1.2 India Meteorological Department is in the process of strengthening of its surface observational network in a phased manner. Under the IMD Modernization Programme Phase-I, 550 AWSs including 127 Agro-AWSs with additional sensors will be installed. So far

382 AWS station have been installed & commissioned by the end of 2010. To improve monitoring of district-wise rainfall a network of 1350 Automatic Rain Gauge (ARG) stations is being established. The ARG stations are also being installed on priority in flood prone river basins. Upper air observations are taken at 39 Radiosonde/Radiowind stations twice a day on operational basis. There are 62 Pilot Balloon observatories spread all over the country conducting upper air wind measurements 2 - 4 times a day. In the first phase of modernization, ten stations have been upgraded with new GPS based Upper air systems. After the introduction of new systems, data quality has improved substantially at these stations. At present 10 Nos of S-Band Radars are operational including 7 Doppler Weather Radar operational at Chennai, Kolkata, Machilipatnam, Visakhapatnam, Sriharikota (SHAR), Delhi (Palam) and Hyderabad. 3 conventional S-Band Radars are working at Kochi, Karaikal and Paradip. SHAR Sriharikota has indigenous DWR developed by Indian Space Research organisation (ISRO). At present IMD is receiving and processing meteorological data from two Indian satellites namely Kalpana1 and INSAT-3A. 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. Recently three-ground stations have been installed in New Delhi, Guwahati and Chennai for receiving real time MODIS and NOAA data. A polar orbiting satellite OCEANSAT–II has been launched by Indian Space Research Organisation (ISRO). IMD operationally runs Global Forecast System (GFS T382) for the forecast up to 7 days. Currently the meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is being operated daily twice, at 27 km and 9 km horizontal resolutions for the forecast up to 3 days. IMD has the plan to implement latest version of NCEP HWRF for the North Indian Ocean basin with the assimilation of local observations by the end of 2011. IMD maintains an 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. The AMSS at Regional Telecommunication Hub (RTH), New Delhi is upgraded with state- of art AMSS (Transmet) supplied by the M/s MFI, under the Modernization Project of IMD.

5.1.3 The representative of Maldives informed the Panel that radio-sonde observations at the Meteorological Office, Gan (WMO # 43599) that were discontinued in 2009 were resumed in 2010 when UK Met Office graciously donated consumables sufficient for 1 year. Like last several years, no upper-air observations were made at Male' (WMO # 43555) in 2010 as well. There is no upper air sounding equipment in Male'. The location of Maldives in the Indian Ocean happens to be a data sparse area, upper air observations from the south and central Maldives are very important to us as well as the entire meteorological community in the region. Hence, Maldives urge assistance from WMO/ ESCAP and Panel members to consider rebuilding of our upper air network. As regards surface observations, Maldives has 5 meteorological stations all are manned 24 hours, both synoptic and aviation reports are made on all five stations. Only one of them is categorized additionally as upper-air station. Total of 23 Automatic Weather Stations (AWS) has been installed up to 2010 and are in operation. 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. 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 during 2010 and IMD is taking measures to repair the system. The High Resolution Satellite Image Receiving System GEOSAT 500 made by Australians and the Doppler Weather Radar received as part of Multi-hazard Early Warning System are currently not functioning. Local technicians were unable to diagnose or rectify the problem or fault. MICAPS (meteorological data analyzing) System donated by China Meteorological Administration (CMA) is being used as an important tool in the Forecasting Office. 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.

5.1.4 In Myanmar, advancement of Southwest monsoon to the whole Myanmar areas was (5) days later and the withdrawal date was (15) days earlier than normal. Especially, during the month of May 2010, almost the whole country experienced the inconvenience hot weather caused by the increase of day temperature. Out of 75 reporting meteorological stations, 20 stations observed the highest maximum temperatures, which set new record compare to the previous 40 to 50 years data. In order to promote the tasks on daily weather issues, forecasts and early warnings of DMH, .the Government of Japan provided the valuable Meteorological Satellite Reception and data Processing System (MTSAT), worth of USD (175,000) to Myanmar through JICA. MTSAT system was installed successfully at Nay Pyi Taw in January 2011. Data received from MTSAT are also sent to weather forecasting sections of Yangon (Kaba Aye) and Yangon International Airport through Internet network. DMH's new website (http://www.moezala.gov.mm) is going to operational from 23 March 2011. It will link with the existing website (http://www.dmh.gov.mm), which was launched since 2005 WMO Day. The forecasting products like daily weather reports, weather analysis maps and warnings are created and timely up dated in DMH website.

5.1.5 Oman continues to run two upper air observation stations. The number of Synoptic Land Stations being inserted into the GTS still remained at 32 stations. However, Thirty Six Additional AWS stations were procured in 2010 and installation is expected to be completed in 2011. In addition, Five S-Band Dual Polarization Doppler Weather Radars was Tendered and Awarded to a German Firm Selex (Gematronix). The installation and commissioning of these Weather Radars will be completed in 2012. The Meteorology department continues to run a local regional model at 2 resolutions (7km and 28 km) twice a day. It also continues to run a local non hydrostatic model. A WAM based wave model was established with the kind cooperation of GKSS of Germany, which covers the Arabian Sea, gulf of Oman and Arabian gulf. In addition, a Tsunami Model for the Oman Sea and India Ocean is also run. Comit Model from IOC is used to develop some hypothetical experiments to simulate tsunami waves propagation and indentation. The Meteorology department is using a visual weather application for visualizing the meteorological data and GRIB format coded data. It is proved to be a useful tool for visualization, analyzing and forecasting the weather.

5.1.6 The representative of Pakistan informed the Panel that Pakistan Meteorological Department (PMD) has been using High resolution Regional Model (HRM) of DWD (the National Meteorological Service of Germany) as an operational model for numerical weather prediction since January, 2007. Initially the model was run with 28 Km resolution, however, from March 2008 on wards, the model was started to run with 22 Km resolution and the simulations are being performed twice a day by using GME data of 0000UTC and 1200UTC. Further, the model output (prognostic charts) are also uploaded at PMD's website www.pakmet.com.pk. In 2009, PMD procured additional servers/hardware with processing power of 1.7 T-FLOPS to upgrade its existing computer system and run the model with the resolution of 7 km. However, the upgradation of HRM at 7 km resolution was not successful for Pakistan due to complex topography. The HRM, a hydrostatic model is limited in representing the full spectra of waves (e.g., trapped lee waves), which are connected to steep slopes. Therefore, after up-gradation of hardware, the model with 11 km resolution has been operational since September 2010. Now PMD is planning to implement a non-hydrostatic model with higher resolution. In this regard, PMD is seeking support of DWD (Germany) and WMO for capacity building in NWP based on COSMO model (COnsortium for Small-scale MOdelling), a non-hydrostatic regional atmospheric model.

5.1.7 The representative of Sri Lanka informed the Panel that 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 and JMA with regard to potential tsunami situation. Data reception from 22 operational stations with the two stations

commenced in 2009 namely, Polonnaruwa and Anuradhapura (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. Radar wind observations in Colombo (43466) were carried out throughout except for a very few occasions. Sonde observations were done three times a week as the shortage of consumables. Out of three, two sonde observations were done using the old equipment and one were performed using the new GPS sounding. Pilot balloon observations were done at 0000, 0600 and 1200 GMT at Hambantota (497), Puttalam(424). The obscured surrounding of the ancient city Anuradhapura (421) was found to be not suitable for pilot observations hence; the pilot observations were not performed at the beginning of the year and shifted to Polonnaruwa, more towards the east with effect from May, with new annual transfers effective.

5.1.8 The reception of HRPT imageries are still not possible as the system is irreparable and funds are being sorted for a new one. Revived the FENYUNGCast system and operational. Storm surge model, as per WMO/ESCAP training received, is operational as a routine at the NMC. Digital Meteorological Data Dissemination system (DMDD) donated by the Government of India through India Meteorological Department was in operation. However, it became unserviceable towards the end of the year. Joint efforts with IMD are being made to correct. Ship observations are still not received at Colombo radio shore station. However, many are received through GTS. Reception of AIREPS at Airport Meteorological office is poor. 15 telemeter rain gauges were installed during the year at rain induced disaster prone areas to facilitate early warning about disasters and, along with this there are 19 locations with this facility. Completion of access road, site preparation and commencement of foundation work done for installation of Doppler radar at Gongala Peak. During the year 2010. Factory training for hardware and software has also been completed. With the improvement of security situation, Jaffna Meteorological office has been identified for reconstruction at a new location and a block of land has been acquired. 5rain gauge stations were reestablished in Jaffna district.

5.1.9 The Panel was informed by the representative of Thailand with pleasure that under the bilateral cooperation between Thailand and Myanmar after NARGIS a new radiosonde installation at Yangon would be completed by 2011. It was noted that the improvement in the upper air network in Thailand, three radiosondes which started the installations in the Northeast, the South (east coast) and the South (west coast) in 2011. Totally there are 5 radiosonde stations in Thai Meteorological Department. To strengthen severe weather observations and monitoring networks, and nowcasting of the country, three C-band Doppler Radars which started the installation in the Songkhla province, Surat Thani province (Samui) and Surin province in 2010. Totally there are 25 weather radars in the TMD's precipitation monitoring network. To enhance the capability in receiving meteorological information derived from the different platforms of meteorological satellites, such as MTSAT, FY-2, TIROS (NOAA-16, NOAA-18, NOAA-19), FY-1, FY-3, MODIS, METOP, the TMD’s implementation of the satellite signal receiving station, which began its installation in 2009, is now being in the last phase of the installation process, and it is expected to be successfully completed and will be in the operation in the early 2011. The IIT Storm Surge Model was adopted and applied using the 1 km. resolution bathymetry data interpolated from the GTOPO1. The maximum storm surge height map along the coastal areas of the Gulf of Thailand for each tropical storm category/ strength has been produced. To improve the receiving-disseminating of meteorological data on the network of the Global Telecommunication System (GTS) in order to fully support the information exchange in the form of the Table Driven Code Form (TDCF) as specified by the WMO, the TMD’s Meteorological Telecommunication Data Storing and Recording Project has been under implementation. Its installation was started in 2009, and is expected to complete by the end of 2011. The completion of this project will also lead to the increase in potential of TMD to be the RTH Bangkok WIS portal in the South East Asia region. To develop and enhance the telecommunication network for severe weather and weather-related disaster warning of the

country, and to develop the whole country observation data collecting system. To improve the aviation meteorological data reporting system, the improvement will disseminate the present meteorological data, forecast data, and the warning of severe weather data to pilots by using Short Wave Radio System. The project will take one year to complete, thus it will be in the TMD's operation by the end of 2011. To produce and display weather map of the Table Driven Code Form (TDCF) data, the Weather Chart Display System (WDS) has been developed. The WDS runs on the Messir Vision system to facilitate and assist forecasters to be able to visualize and analyze weather patterns produced by the system on an hourly basis.

Activities of WMO

5.1.10 The representative of WMO reported that the average availability of SYNOP reports ranged from 16% to 100% during 2010. The availability continued to be more than 70% for all countries, except for Myanmar and the Maldives, with the latter showing a significant decrease from 53% in the previous year to 16% in 2010. Overall, the total availability of reports also decreased slightly to 86% (in 2010) from 87% the previous year. The availability of expected TEMP reports on the MTN from a total of 53 upper-air stations (remained unchanged in 2009/2010) in the RBSN operated by Members of the WMO/ESCAP Panel on Tropical Cyclones according to the results of the IWM exercise carried out on a quarterly basis in 2009/2010 is also provided in the table below. The average availability of TEMP reports ranges from zero to 57%. The availability is less than 25% for the Maldives with Myanmar not reporting as in the previous year.

5.1.11 Overall, in spite of a decrease in the number of reports received from a majority of Panel Members in 2010 compared to the previous year, the average percentage of the total number of TEMP reports received increased slightly from 43% to 45% per cent during the same period. Deficiencies in surface and especially upper-air data coverage over certain areas in the region continued to be caused mainly due to financial difficulties encountered by countries concerned to rehabilitate and operate both observational and telecommunication equipment. Inadequate funds also resulted in the lack of trained staff, essential instruments and consumables.

5.1.12 As regards the relatively low availability of TEMP from India, the Panel was informed by the delegates of India that it is due mainly to the time-consuming process of procurement of the consumables as well as their qualities, the problem is being addressed by IMD. The Panel also raised the issue of non-reporting of TEMP from Sri Lanka, while upper-air observation is being performed normally three times a week at the station in Colombo. The Panel noted that the upper-air station of Sri Lanka should be duly registered at RBSN. It therefore requested the WMO Secretariat to take an action to facilitate the registration.

5.1.13 Noting the great significance of increasing the availability of upper-air data, the Panel also drew attention to the AMDAR Programme. As the Programme is conducted mainly on a regional basis, the Panel urged the Members to collaborate with the airlines for promoting the regional AMDAR programmes.

5.1.14 Following the 2010 extraordinary meeting of the Commission for Basic Systems (CBS) in Namibia, it is now clear that WIS has moved from its development stage and into implementation. Three candidate GISCs (Offenbach, Beijing and Tokyo) along with 15 DCPCs are now in preoperational mode. These and several other GISCs, including New Delhi, will be operational following endorsement from Congress XVI. The project to upgrade the Main Telecommunication Network (MTN) component of the GTS has now completed, and this improved MTN will form the core network of WIS connecting all GISCs. The Manual on WIS (WMO No. 1060) was prepared by CBS, along with the draft amendments to include WIS in the Technical Regulations (WMO No. 49) which will all be presented to Congress XVI for approval. These combined with a Guideline to WIS (WMO No. 1061) 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.

5.1.15 CBS Extraordinary 2010 also updated the Manual on GTS (WMO No. 386) and Manual on Codes (WMO No. 306) to allow the exchange of information in the form of Common Alerting Protocol (CAP) between WMO Members. This is in line with the decision of the WMO Council that recognized the benefits of using the Common Alerting Protocol (CAP, ITU Recommendation X.1303), which is a content standard designed for all-hazards and all-media public alerting, 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.

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

5.2 Hydrological Component

Activities of the Members

5.2.1 The Panel was informed by the representative of Bangladesh that 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 SWC, Dhaka and FFWC was established in 1998 through which FFWC receives meteorological and hydrological data (including rainfall and water discharge data of upstream) along with Radar and Satellite images. Through the completion of the establishment of Meteorological and Hydrological Doppler Radar in 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 staff for radar data calibration and its utilization.

5.2.2 The representative of India informed the Panel that the Central Water Commission (CWC) is the nodal agency for flood forecasting in the country. CWC maintains 878 stations for hydro-meteorological observations and issues flood forecasts for 175 stations in the country. Flood Meteorological Service of IMD provides quantitative precipitation forecast (QPF) to CWC through 10 Flood meteorological Offices FMOs) established in different parts of India for operation flood forecasting. 15372 QPFs were issued by FMO's during the Flood 2010, and supplied to Central Water Commission for flood forecasting purposes. During the year 2010, 7508 forecasts were issued. Out of this 6489 were stage forecast and 1019 inflow forecast to reservoirs. Out of the 7508 forecasts issued, 7369 were found to be within the permissible limits of accuracy. The percentage of accuracy is 98.15%. During the period from 15th May to 15th October 2010, seven stations namely Karimgunj on river Kushiyara in Karimgunj district of Assam, Basua on river Kosi in Supaul District of Bihar, Haridwar, Kannauj, Ankinghat, Kanpur on river Ganga in Dehradun District of Uttarakhand, Kannauj District, and Kanpur District respectively of Uttar Pradesh, Moradabad on river Ramganga in Moradabad District of Uttar Pradesh crossed the previously recorded highest flood level during 2010. The CWC has undertaken modernization of its flood forecasting and data collection network. So far, telemetry system has been installed at 221 stations and 2 Earth Receiving Stations have been set up at Jaipur and Burla. Under the modernized system, the data collection is being done with sensor-based equipments, transmission of data is done through satellite and VSAT systems, the flood forecasts are formulated using state-of-the-art mathematical model like MIKE-11 and the flood forecasts are disseminated expeditiously to the local administration reducing the human errors and time taken in earlier manual

processes. CWC has also planned to install telemetry stations at remaining 234 stations so that the entire network of 175 flood forecasting stations and their Base Stations including rainfall stations is covered. Ministry of Water Resources had conceived Hydrological Project with the assistance of World Bank. The objective of the project is to generate Reliable, Comprehensive, User friendly, quality data base of various hydrological components under Hydrological Information System. IMD is to look after all aspect of Hydrometeorology under the project and assist the 13 participating states to establish : Hydromet Network, Capacity building of state personals,.establish data centres in participating states and Validation of the hydro-meteorological data.

5.2.3 The representative of Maldives informed the Panel that Maldives Meteorological Service is the authoritative organization in the country for issuing advisories and warnings related to meteorological, hydrological, tectonic and oceanographic disasters. To accomplish these tasks, MMS has prepared the Standard Operating Procedures (SOP) to act upon any likely event of meteorological, hydrological, tectonic and oceanographic disasters. MMS acquired a High Resolution Satellite Image Receiving System, Doppler Weather Radar, number of Automatic Weather Stations, broadband and short-period seismometers within the framework of establishing a National Multi-Hazard Early Warning System. Our sea level network comprises of three tide gauges in Hanimaadhoo, Male' and Gan to monitor low frequency changes in sea level associated with global sea level rise or decadal climate variations like other gauges in GLOSS network. They have been upgraded with more sensors such as radar/ pressure/ float based water level sensors, and the reference level float switch sensors and with these improvements, it shall even detect any slight variations in sea level due to a tsunami wave. The National Multi-Hazard Early Warning Centre (NMHEWC) of MMS conducts awareness programs targeting at public and students in different atolls periodically. The National Multi-Hazard Early Warning 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 and Indian Tsunami Early Warning Centre through internet and GTS were also disseminated to public satisfactorily in time.

5.2.4 The representative of Myanmar informed the Panel that, on 1 August 2010, flood occurred at Myitnge in Dokhtawady river and it exceeded the danger level by ½ foot and stayed 3 days above danger level. The another flood at August was at Bago in Bago river and it exceeded the danger level by ½ foot and stayed 2 days above danger level. This flood caused the inundation about 2-6 feet at 9 wards at Bago and also flooded 2 feet depth on highway road between milepost No. 48/7 and 49/2 but there was no remarkable destruction. This flood was 7th highest flood at Bago by historical record (1965-2010). In October, the flood occurred at Kyauktaw of Kaledon and it exceeded about 1 foot above danger level and stayed about 1 day above danger level. This flood was also 6th highest flood at Kyauktaw by the historical record (1987-2010). This flood affected the 50 houses and 200 acres of paddy field by inundation. During October, another flood occurred at Myitnge in Dokhtawady river and this was second flood for Dokhtawady river for the year 2010. It exceeded 1½ feet above danger level and stayed 8 days above danger level. It inundated some roads, houses and agriculture crops from low land area. DMH has issued (4) flood warnings and (14) flood bulletins during 2010 flood season.

5.2.5 During the year 2010, there were less flooding by historical record. No flood occurred along Ayeyarwaddy, Chindwin, Sittoung, Thanlwin and Shwegyin rivers. Apart from river flood, inland flood and severe landslide occurred at Buthitaung Township of Rakhine State, due to the continuous heavy rain which amounted (35.53) inches within (6) days during the second dekad of June 2010. It caused (76) death toll and affected (29) Wards and villages in Buthitaung Township.The peculiar urban floods were also encountered in Central Myanmar during the first dekad of October, due to the locally heavy fall in the areas for (2) to (3) days, caused by the formation of depression in the North Bay. The rain enhanced overflowing of the small streams and inundated (2) to (5) feet in low land areas and streets of

Mandalay and villages and wards of nearby townships.At the year 2010, measurements of discharge, sediment discharge and bed profile were implemented at Sagaing and Pyay for Ayeyarwady river and Monywa for Chindwin River. During 2010, DMH has developed flood hazard analysis and flood simulation by using IFAS for upper parts of Chindwin river, Ayeyarwady river and Shwegyin river. Development of river catalogue for Chindwin river basin is now in processing. Moreover, DMH is also implementing the flood hazard map for Bago township at Bago river basin by technical assistance by ICHARM and financial support by JICA.

5.2.6 The representative of Oman informed the Panel that during the year 2010, a measurements of all hydrological parameters were measured through (4681 monitoring stations).Station includes (rain gauges, wadi gauges, flow peaks, aflaj, springs and water level) in addition to 32 dams distributed all over the Sultanate. There are 304 rain gauges, of which 219 Automatic and 85 of standard type. About 30 of these rainfall stations are fitted with telemetry using GSM modems. During the year 2010 the coastal area of the country was exposed with exceptional rainfall as a result of tropical cyclone Phet. The maximum annual accumulated rainfall was 603 mm in Quryat, while 472 mm were recorded in Al-Sharqyah region. Mhoot in AlWusta region recorded 68 mm. The other areas of the country recorded rainfall lesser the annual average. There are 137 wadi gauge stations to measure wadi flow and to compute flood volumes. In addition to 25 stations to measure the peak height of the wadi flow. The year 2010 is considered the largest year where high discharge rates were recorded since 1997. The total flood volumes during 2010 (712 Mm3) is about 3 times of the annual average. The highest recorded was (390 Mm3) in Muscat region. The Ministry of Regional Municipalities & Water resources operate a network of 2107 groundwater wells measured for water levels. 1700 of them are measured every month and the rest measured every three months. Analysis of data showed that as a result of increase in recharge there is a gradual increase in water levels in most areas of the Sultanate, particularly for the shallow alluvium aquifer which represents the main supplied source of irrigation water. There are 3 types of Dams in Oman. 61 surface retention dams, 32 recharge dams and 11 flood protections dams. On the 32 recharge dams stations for measuring flow and sedimentation. A total of 78.5 Mm3 was retained by recharge dams during 2010. In addition to this the Wadi Dayqah dam in Muscat region a total of 133 Mm3.

5.2.7 The representative of Pakistan informed the Panel that Pakistan suffered from history's worst extremely high floods during 2010-Monsoon season. Heavy rainfall spell during 28-30 July, 2010 in the north of Pakistan especially in Khyber Pukhtunkhwa (KPK) province and adjoining upper Punjab caused firstly severe flash flooding and then history's extreme high riverine flooding in Pakistan. The second wave of the flood in the Indus River and its tributaries was caused by the rainfall spell which occurred during 5-9 August 2010. PMD issued weather forecasts for these precipitation events a few days earlier. The second flood wave aggravated the already flooded fields of Punjab, KPK, Sindh and Balochistan provinces. This second flood wave practically merged with the first flood wave below Taunsa barrage (on the Indus River in Punjab) and created havoc in the surrounding areas and downstream Taunsa. and the phenomenon is referred to as the "2010 Super Flood." Several areas in all provinces were worst affected areas. The riverine floods were also predicted reasonably well by PMD's Flood Forecasting Division (FFD). In wake of 2010-floods, WMO established an ad hoc liaison office in PMD premises with Dr. Jaser Rabadi (WMO Representative for West Asia) to work as liaison officer to facilitate close collaboration with PMD and Islamabad-located organizations including UN Country Team in damages need assessment (DNA) and other processes from 14th October to 13th November, 2010. WMO also send a six-member fact-finding and needs-assessment Mission (headed by Dr. T. Toya, Director (Asia & southwest Pacific), WMO) to Pakistan with collaboration of UNESCAP from 4 to 8 November, 2010. In light of the recommendations of the WMO Expert Mission, it has been proposed to restore and strengthen the capacities of PMD with phased approach including: (i) short term needs (within a year), (ii) medium term needs (2-3 years) and (iii) long term needs (5-10 years). Some of the main items of the proposal include:

- Restoration of damaged meteorological and hydrological observational network; Establishment of around ten (10) localized Flash Flood Warning Systems for small rivers and streams (replica of Flash Flood Warning System for Nullah Lai basin (twin cities of Rawalpindi and Islamabad);
- Establishment of Regional Flood Forecasting Centers in KPK, Sindh and Balochistan provinces;
- Strengthening of Radar Network to give radar coverage to the whole country
- Improvement in hydrological/flood forecast model and NWP model;
- Capacity building/human resource development.

5.2.8 In Sri Lanka, The Department of Irrigation is the mandated agency for flood monitoring and issuing warning/ advisories in Sri Lanka. It maintains 33 river gauging stations to report hourly river water levels (manually) and 3 hourly rainfalls. In addition, 40 river gauges and 19 rain gauges have been installed at tributaries to record day time water levels which are read on contract basis. Special attention is paid to re-establish the river gauge stations and a few rainfall stations in the north and east and currently computer generated hydrology data are provided for the development projects in these areas as the data is missing. A World Bank funded project (DSWRPP component in HMIS) especially for the safety of dams is going on and it is expected to upgrade the existing hydro-met stations and establish new stations with automatic sensors and communication facility.

5.2.9 In Thailand, Office of Hydrology and Water Management, Royal Irrigation Department (RID) has responsibility of meteorological and hydrological data in the criteria of processing the data for studying or forecasting. There are 2,294 rain gauge stations and 522 stream flow gauge stations installed throughout Thailand. Flood management plans were set in terms of monitoring, prediction and warning by establishment of Water Watch and Monitoring System for Warning Center (WMSC) to monitor flood situations on a 24 hours basis. The state-of-art technologies were established, such as telemetry and flood forecasting systems. There has installed and operated about 208 telemetric stations in 13 of 25 main river basins have telemetry systems installed for water resources management and flood prevention and mitigation. RID collaborates with other national agencies (TMD, DWR, DDPM) to implement the plan for coping with local flood protection in economic zones where severe flood may occur through meetings and data sharing.

Activities of WMO

WMO Flood Forecasting Initiative (FFI)

5.2.10 WMO Flood Forecasting Initiative (FFI) progressed with regard to the specific activities that are outlined in the Strategy and Action Plan of the Initiative, especially with regard to establishing Flash Flood Guidance Systems. The Flash Flood Guidance System project is of high importance for the region. In RA-II it is presently fully operational in the Mekong River Basin.

5.2.11 A workshop on the Strategy and Action Plan (SAP) on FFI was held in December 2009 in Geneva. That workshop aimed at the documentation of priority activities on national level to implement that SAP. The RA-II WGH reviewed the outcomes of the workshop and identified the following areas to be highly relevant for the region:

- Wide promotion of the Activity Plan – together with the Strategy and Action Plan - to NMHSs;
- Facilitated national consultations to sensitize National Meteorological and Hydrological Services for an improved cooperation. WMO is seen as the lead agency to facilitate these consultation

- Integration of the Plan in the hydrological domain of WMO's Tropical Cyclone Programme such as in the Working Group on Hydrology of the Typhoon Committee;
- Prepare a training module for the use of the SAP and Activity Plan in NMHSs;
- Fostering twinning agreements between NMHSs with the objective of sharing know-how and technology in improved cooperation and the development and use of advanced forecasting products and their dissemination.

5.2.12 Activities under WMO-FFI to be implemented in 2011 and onwards include:

- Intercomparison of forecasting models currently in use in the various WMO Regions, to help the countries in identifying the most suitable models to serve their requirements;
- Development of a framework for the assessment of service delivery capabilities of hydrological services in flood forecasting.

5.2.13 In an 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.

5.2.14 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.

Regional activities

5.2.15 Thrust is to implement the RA-II (Asia) Strategic Plan for the Enhancement of National Meteorological and Hydrologic Services at the level of the services. Further, technical cooperation activities have been undertaken with a number of countries in the region, notably the support that WMO provides to the government of Pakistan after the disastrous floods in the monsoon season of 2010.

5.2.16 Progress has been made in the implementation of WHYCOS projects, and in particular the Mekong-HYCOS and the Hindu Kush Himalayan (HKH) HYCOS projects that are currently implemented. The objective of both HYCOS projects is the establishment of regional flood information systems.

5.2.17 The Coastal Inundation Forecasting Demonstration Project (CIFDP) is in full development with the objective to improve capacity for coastal flood forecasting and management (including deltas and estuaries. Major output of this project will be an end-to-end integrated software, coupling meteorological (tropical cyclone), hydrological (river) and ocean (storm surge) forecasting models to meet institutional end-users requirements.

5.2.18 The project aims to enhance NMHSs capabilities to produce and provide coastal inundation forecasting and warning services and to improving interactions between NMHSs, partners and end-users (Government, Disaster Management and Civil protection Agencies, Media, etc). Bangladesh has been chosen as the regional candidate to implement this demonstration project.

Theme areas of the RA-II WGH

5.2.19 With regard to achieve the objectives of the RA-II WGH, the following theme areas are currently under implementation and first draft reports for each of these areas are expected by end of April. The 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
- Water Resources Assessment, Availability and Use (Surface water and groundwater)
- Hydrological responses to climate variability and change and promotion of the use of climate information by water managers
- Regional exchange of hydrological data and information including WHYCOS and contributions of regional aspects of INFOHYDRO

Regional Cooperation

5.2.20 As a major step forward, the WGH during its session in November 2010 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

Recommendations

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

- Considers the establishment of Working Groups in analogy to the Typhoon Committee (TC) with active involvements of hydrologists and seeks to enhance collaboration with the TC;
- Establishes links with the RA-II WGH
- Develops a Requirements Document for hydrological services in support of PTC activities

5.3 Disaster Prevention and Preparedness (DPP) Component

Activities of the Members

5.3.1 The representative of Bangladesh informed the Panel that Bangladesh is vulnerable to recurring natural disasters including cyclone and the associated storm surge. These particular disasters are known to disrupt people's lives, livelihood, and devastate development momentum in some part of the country. Over the past few years, climate change has added significant perturbation in the hydrological cycle and increased the frequency and intensity of the hydro-meteorological disasters including cyclones. This reaches to the extent where the international community has placed Bangladesh as the worst victim of climate-induced disaster. In view of the cyclone season, the government intends to implement the provisions of the National Plan for Disaster Management, 2010 (Section 10:

Disaster Management Regulatory Framework, Section 11: Disaster Management Plans, and Standing Order Disaster, 2010) in the form of Response Plan for Cyclone Season. This response plan aims at eliminating or mitigating the cyclone risk by undertaking coordinated activities for the prevention of, preparation for, response to and recoveries from the impact of cyclone.

5.3.2 The representative of India informed the Panel that the complete Cyclone Warning Programme in the country is supervised by the Regional Specialised Meteorological Centre, New Delhi. It monitors the cyclonic disturbances in the Bay of Bengal and the 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. The cyclone warnings are issued to state government officials in four stages, Pre Cyclone Watch, Cyclone alert, Cyclone Warning and Post landfall outlook Disaster Management in India is a three tier system, at the National Level, State level and District Level. In the national level, National Disaster Management (NDM), the Ministry of Home Affairs (MHA) is the nodal agency at the National level for coordination of response and relief in the wake of natural disasters. It has constituted the National Disaster Response Force (NDRF), for the purpose of specialized response to a threatening disaster situation or disaster. We have National Disaster Management Authority (NDMA) as the apex body mandated to lay down the policies, plans and guidelines for Disaster Management to ensure timely and effective response to disasters. NDMA has formulated National Disaster Management Guidelines specific to each disaster. In its endeavor to spread awareness amongst the masses, NDMA has launched Public awareness campaigns through electronic and print media and included disaster management as a subject in the school curriculum. 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. The National Institute of Disaster Management (NIDM) undertakes quality research covering both natural and human induced disasters, with a multi-hazard approach. National Cyclone Risk Mitigation Project (NCRMP) is to be implemented in the cyclone affected coastal states and Union Territories (UTs) of the country, with financial assistance from the World Bank. The major components are Improvement of early warning dissemination system by strengthening the last mile connectivity, Cyclone risk mitigation Infrastructure (shelter, approach roads, bridges, culverts, coastal plantation), Capacity building and Implementation assistance.

5.3.3 The representative of Myanmar informed the Panel that the The main DPP measures of DMH are on two main components (1) Issuance of Early Warning from Multi-Hazards Early Warning Center - MEWC (2) Public Education and Awareness Program. DMH has closed collaboration with Relief and resettlement Department (RRD), the focal point of Disaster Management in Myanmar. DMH Staff always participate as trainers in Disaster Management trainings, conducted by RRD. Regarding public education, 6 articles on weather phenomena and behavior of storm were printed in State media, New light of Myanmar and the Mirror during 2010. Moreover, the functions and activities of Multi-hazard Early Warning Center also appeared in those newspapers as interview. DMH was actively participated in preparation of Myanmar action plan on disaster risk reduction (MAPDRR), and under this plan DMH has prepared (5) priority project proposals, which to be implemented with cooperation of other related agencies.

5.3.4 In Oman, National Committee of Civil Defense is the government unit responsible for disaster preparedness and response. It is chaired by H.E the Inspector General for Police and Customs (the equivalent of the minister of interior in most countries). It has 21 members from government agencies. The Committee is responsible for formulating national policies and strategies in regard to risk prevention and preparedness. The National Committee for Civil Defense (NCCD) keeps an excellent coordination and cooperation with the Meteorology department. During Phet, the national plan for disaster management was activated and the

main sectors were activated to run operations during Phet. There are royal directives to further improve the national plan for disaster management for such objectives as 1) Working towards establishing a fully equipped emergency management centre whose design needs to take into consideration all the physical and geographical features; 2) Building up-to-date databases for the civil establishments, roads, physical features and Geographical Information Systems (GIS); 3) Relocating the food reserve stores all over the Sultanate's Governorates and Regions in order to expedite the emergency-related administrative procedures and support provision and develop a national system to distribute relief supplies in the affected areas; 4) Activating the special plan developed by NCCD on how to deal with disasters related to hazardous materials; 5) Establishing quickly deployable hospitals which can be airborne; 6) Furnishing the emergency shelters with the necessary equipment and services, including the food supplies; and 7) Providing water reserves to the main hospitals for use in the event of desalination plants failure.

5.3.5 The representative of Pakistan informed the Panel that according to National Disaster Management Authority (NDMA) of Pakistan, the following were the losses and damages (as of 25 November 2010) caused by the 2010 super floods in Pakistan. Most of the deaths were caused by the severe flash flooding in the north of Pakistan especially in Khyber Pukhtunkhwa province. The weather and flood forecasts issued by PMD and flood warnings issued by the concerned department/organizations have helped the nation in minimizing the losses due the 2010 super floods in Pakistan. The Panel was informed that NDMA with assistance of JICA has prepared a National Disaster Management Plan for 2011-2021. 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 World Conference on Disaster Reduction (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 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 these 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). The Panel was also informed that PMD has been implementing a project "Pak-Seismograph Network" in collaboration with China Earthquake Network Centre (CENC) in order to further strengthen national seismic monitoring network in Pakistan.

5.3.6 In Sri Lanka, one Ministry was set up only for Disaster Management with effect from 30th April 2010. The Disaster Management Centre (DMC) which is the leading state agency for Disaster management has the responsibility of implementing and coordinating national and sub national level programms for reducing the risk of disasters with the participation of all relevant stake holders. Projects are being implemented for mitigation of floods, droughts and landslides etc by DMC. Hazard maps for various types of disasters, development of disaster preparedness plans, and response plans, community based disaster management projects, awareness programmes are conducted with coordination of the technical agencies. Emergency Operation Centre of DMC with coordination of Technical Agencies for warning and advisory preparation and other stake holders, forces, police, UNICEF, UNCHR, WFP,UNESCAP, UNOCHA and Red Cross etc. immediately responded to take early actions for warning dissemination, relief, search and rescue etc, at the time of disasters. DMC with SLMD conducted three tsunami drills to assess the performances and to find gaps of tsunami warning communication system and public preparation. The relief measures are taken predominantly by National Disaster Relief Services Centre (NDRSC) which was under the Ministry of Relief Services came under the purview of the Ministry of

Disaster Management it self for more efficient relief services (with effect from 30th April 2010). NDRSC has allocated over Rs 262million of which more than 86% was for flood relief (increased by about 20 % compared with previous years).

5.3.7 As one of the intermediary agencies in Thailand Disaster Management, Department of Disaster Prevention and Mitigation or DDPM is primary responsible for imposing and implementing program policy, formulating operational guidelines and establishing criteria on disaster management. In addition, DDPM still organizes and conducts training activities which are related to all disaster management by collaboration with local and international organizations. Recently, Disaster Management in Thailand has been focused on preparedness activities to reduce the vulnerability impacts and increase the resilience in disaster prone areas, as well as general public by using Community-Based Disaster Risk Management (CBDRM) approaches. As the center in disaster management of Thailand, DDPM in cooperation with all national involved agencies has initiated various successful projects, such as CBDRM, One Tambon (Sub-district) One Search and Rescue Team (OTOS), Mr. Disaster Warning, and Civil Defense Volunteers (CDVs). Through such programme, there are over 1 million villagers and local officers trained all over Thailand.

Future Activities

5.3.8 More activities are expected to come. This is due to the fact that the Work Program under the Asean Agreement on Disaster Management and Emergency Response (AADMER) has been launched and Thailand will need to implement many activities under the Work Programme such as disaster risk identification, monitoring and assessment, trainings, relief and recovery. Many of these new initiatives under ASEAN are cyclone-related.

5.3.9 New initiatives under TC such as TC Urban Flood Risk Management Project - As the chair of Working Group in Disaster Prevention and Preparedness, DDPM held the first kick-off meeting of the working group as requested by the committee at the 36th PTC Session (held in Muscat, Oman from 2-6 March, 2009). Department of Disaster Prevention and Mitigation (DDPM), Thailand hosted and organized the Workshop on Need Assessment of PTC WG-DPP in Implementation of Coordinated Technical Plan (CTP) in Bangkok, Thailand from 25-28 August, 2009, with the support toward the participants and experts from UN ESCAP and WMO. The result of the meeting is provided in the Summary Report of the WG-DPP Workshop. And in 2010, Thailand, in corporation with WMO/ESCAP, hosted Panel on Tropical Cyclones WG-DPP Meeting to finalize the Annual Operation Plan (AOP) on 18 August at United Nations Conference Center, Thailand. And also training on Preparation on Disaster Management Drills and Observance of DDPM National Crisis Management Drill 2010 (C-MEX 10) in Chantaburi Province on 19-20 August 2010.

5.4 Training component

Activities of the Members

5.4.1 The representative of Bangladesh informed the Panel that officials of BMD attended different trainings including the following:

- Mr. Md. Abdul Mannan, & Mr. Md. Nurul Karim, Meteorologist, participated in the "ICTP Targeted Training activity: statistical methods in seasonal prediction" at ICTP, Italy from 2 to 13 August 2010
- Mr. Md. Hafizur Rahman, Meteorologist, participated in the "seventh post graduate Course in Satellite Meteorology and Global Climate (SATMET-7)" at Ahmadabad, India from 1 August 2010 to 30 April 2011.
- Mr. Md. Shameem Hassan Bhuiyan, Meteorologist, participated in the "USDA Cochran fellowship program" in USA, from 25 October to 2 November 2010.
- Ms. Arjumand Habib, Director, participated in the "GEO-VII plenary meeting and 2010 GEO ministerial summit" at Beijing, China from 3 to 5 November 2010.

- Mr. Shamsuddin Ahmed, Assistant Director, participated in the "Challenge programme on climate, agriculture and development priorities and scenario development workshop" at New Delhi, India from 8 to 10 November 2010

5.4.2 The representative of India informed the Panel that the seminars/workshops was conducted for the cyclone forecasters in India during March and September 2010 as pre-cyclone exercise. One official each from Sri Lanka and Myanmar had received training on tropical cyclones monitoring and forecasting at RSMC, New Delhi during 1-12 February, 2010. Similar training in RSMC, New Delhi will be conducted during 28 February to 11 March 2011. The regular courses, Advanced Meteorological Training Course in General Meteorology with one foreign candidate from Maldives, Forecasters Training Course in General Meteorology and Intermediate Training Course in General Meteorology were conducted at Regional Meteorological Training Centre (RMTC), Pune. Series of trainings were conducted on newly installed Synergy forecasting system, PWS, climatology system and satellite based monitoring.

5.4.3 The representative of Myanmar informed the Panel that Meteorological course Grade III was conducted from 15 November 2010 to 31 January 2011 with 30 trainees, 15 from DMH and another 15 from Military. IFAS application training was conducted by the guidance of two Experts from ICHARM and 15 trainees from DMH had an opportunity to attend the course during the last week of June 2010. In order to improve the disaster risk reduction in Myanmar, JICA had been provided short-term experts dispatch program on the Improvement of Tropical Storm Forecasting and Warning to DMH. Mr. Kunio AKATSU, a well experienced expert of Japan has been dispatched to DMH from December 2009 to April 2010 for the first term, and technical transfer seminars have been conducted to improve the capacity of DMH weather forecasters. During 2010, 29 DMH staffs had having an opportunity to be trained (short term) at Japan, Thailand, Korea and Malaysia by the sponsorship of JICA, TICA, KOICA, KMA and MTCP. There are 5 DMH Staffs, who are pursuing M. Sc degree in Meteorology, Hydrology, Seismology and GIS & Remote sensing at Philippine, India, Japan and Thailand with the support of WMO, JICA and TICA.

5.4.4 The representative of Pakistan informed the Panel that 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 (BIP-MT) were conducted in 2008, 2009 and 2010 at PMD's Institute of Meteorology & Geophysics (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 for their participation in these courses. In 2010, such a course were conducted successfully at IMG, Karachi from 20th March to 23rd July. In this course, eleven (11) Met. Personnel from NMHSs of neighbouring countries, Bangladesh (2), Bhutan (3), Myanmar (1), Nepal (2), & Sri Lanka (3) participated. Under this project, the fourth (and final) such course has also been scheduled in 2011. For this course, around six participants from NMHSs of the neighbouring countries (Bangladesh, Bhutan, Myanmar, Nepal and Sri Lanka) are expected to attend. For the continuity of these training courses in the coming years, WMO is being requested for necessary support. 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, eight (08) officers have joined back to PMD (two of them joined in 2010) after seeking higher studies from United Kingdom, Canada, Norway, China and Thailand. Two (02) of these officers have done their PhD in Meteorology, while six (06) officers have completed their MS in Meteorology and Earth Sciences. During 2010, two (02) scientists have also completed their JICA sponsored postgraduate studies in seismology and tsunamis from Japan. Around eight (08) officers of PMD have also completed their MS (Meteorology) from Department of Meteorology, COMSATS Institute of Information Technology (CIIT), Islamabad during 2010-2011. PMD has also been providing teaching faculty support to CIIT. During 2010-2011, various regular and special courses on meteorology were also conducted at IMG, Karachi for Met. personnel

of PMD as well as for participants from other relevant organizations. In addition, during 2010-2011, PMD scientists also availed around 30 fellowships for attending short-term trainings/ training workshops abroad. These fellowships were offered mainly by WMO, China Earthquake Administration, UNESCAP, China Meteorological Administration, ICIMOD, JICA, and KOICA etc. During 2010-2011, various regular and special courses on meteorology were also conducted at IMG, Karachi for Met. personnel of PMD as well as for participants from other relevant organizations.

5.4.5 The representative of Sri Lanka informed the Panel that upon receipt of the offers from WMO, SLMD participated in the 4 training programmes and, SLMD conducted two roving seminars (funded by WMO) for farmers and the members of SLMD participated in training activities in various disciplines on their request.

5.4.6 The representative of Thailand informed the Panel that in 2010, TMD received WMO/ TCTF/ TCS support to attend a total of the nine overseas training courses and five local training courses.

Activities of WMO

5.4.7 The Panel reviewed the involvement of its Members in various education and training activities supported under WMO Voluntary Co-operation Programme (VCP), Regular Budget (RB), UNDP and TCDC arrangements.

5.4.8 The Panel noted the training events and workshops which were organized in 2010 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.

5.4.9 The Panel noted the forthcoming training events planned for 2011, and the Members were encouraged to make maximum benefit of the training seminars, workshops and courses to be organized or co-sponsored by WMO.

5.4.10 The Panel also expressed appreciation to its Members who offered their national training facilities to other Members under bilateral and cost-sharing arrangements. These national training institutions in the Region contribute significantly to the training of meteorological personnel and the cooperative efforts by the Panel Members have been found by the recipient countries to be very useful. The Panel strongly recommended that such endeavors should continue in the future and be strengthened.

5.4.11 The training activities offered by the Members are extremely valuable. Therefore the Panel Members were encouraged to advise WMO of their activities for reporting and planning purposes.

5.4.12 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.

5.5 Research component

Activities of the Members

5.5.1 The representative of Bangladesh informed the Panel that BMD provides information on significant weather and new developments related to meteorology through BMD newsletters. Research studies have been carried out on the following topics by the BMD scientists:

- Analysis of Extreme Rainfall events

- Analysis of Tropical Cyclone “AILA”.
- Analysis of Significant Nor‘wester events

5.5.2 The representative of India informed the Panel that Forecast Demonstration Project on landfalling tropical cyclones over the Bay of Bengal has been taken up. Its main objective is to minimize the error in prediction of tropical cyclone track and intensity forecasts, at least 48 hrs in advance. Like last year, the pre-pilot phase was conducted during 15 Oct - 30 Nov, 2010. Several national institutions participated for joint observational, communicational and NWP activities. There were one very severe cyclonic storm, GIRI, one severe cyclonic storm JAL and a deep depression over the Bay of Bengal during the FDP Campaign of 2010. There were 10 days of intense observation period conduced during this phase. Compared to 2008 & 2009, there were four additional observations viz. (i) on board observation from Sagarkanya cruise; (ii) Oceanset observation of surface wind; (iii) observations from five buoys; (iv) microwave imageries and products. Systematic verification of operational cyclone track and intensity forecasts issued by IMD has been introduced. A report on cyclone hazard prone districts of India has been prepared. A preliminary study has been completed to find out the potential predictors for seasonal prediction of cyclonic disturbances over the north Indian Ocean. Modulation of genesis and intensity of cyclonic disturbances over north Indian Ocean by Madden Julian Oscillation (MJO) has been analysed to expose possibility of extended range prediction of cyclonic disturbances over north Indian Ocean based on predicted MJO index. A project to make web enable version of IMD’s Storm Track Atlas (e-Atlas) has been taken up. Two Meteorological Monographs on following subjects have been published.

1) A report on Super Cyclonic Storm, GONU during 1-7 June, 2007
2) Characteristics of best track parameters of tropical cyclones over the north Indian Ocean.

5.5.3 The representative of Pakistan informed the Panel that PMD with financial support by the Ministry of Science and Technology has been carrying out wind potential survey of various areas of the country since 2001. In Phase-II of this project, PMD carried out wind survey of Northern areas of Pakistan for determining the assessment of wind power potential of these areas. For the purpose of this project, the Northern areas of Pakistan included districts of Swat, Dir, Chitral, Gilgit, Skardu, Haripur, Shangla, Buneer, Nowshara, Peshawar, Mohmad Agency, Khyber Agency and Azad Jammu and Kashmir (AJK). The results of this study would ultimately provide a platform for the establishment of Wind Mills / Farms for power generation. The project was initiated in 2005-2006 and was completed in 2010-2011. Wind data from 42 stations have been collected and analyzed. The reports of all 42 stations have been drafted on the basis of collected data. The comprehensive final draft report of this project is under preparation. The analysis of data suggests that Shaheed Gali (in AJK), Sost (in Gilgit-Baltistan region), Swat and Mardan in (Khyber Pakhtunkhwa province) have the potential for establishing small to medium scale wind power projects. In Phase-III of this project, similar study would be carried out for northern and western parts of Balochistan province. It is pertinent to mention that in Phase-I of the project, PMD had already completed the wind power potential of the coastal areas of Pakistan (Sindh-Makran coast).

5.5.4 On the basis of the wind data analysis, a wind corridor in Gharo has been identified in Sindh, which covers an area of about 9,700 Square Kilometers and it has the exploitable Electric Power Generation Potential of 11000 Mega Watt. A number of Research work / small projects related to forecasting techniques, climate change, climate modeling, downscaling for seasonal and monthly prediction, glaciology and glacial melting, were also carried out by the scientists of PMD and they presented their research work at various conferences/ symposia / workshops at national and international levels during 2010-2011. During 2010-2011, PMD published two issues (No. 12 & 13) of its research journal “Pakistan Journal of Meteorology” (PJM) which was started in 2004. These issues contain research papers contributed by the scientists of PMD and international scholars. In addition, 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 or proceedings of the international conferences/ seminars.

5.5.5 The representative of Sri Lanka informed the Panel that research studies have been carried out in the following topics by the members of the Department:

1. Analysis of extreme rainfall events
2. Analysis of rainfall change with the onset of SWM and NE monsoon
3. Impact of Indian ocean dipole to the weather in Sri Lanka
4. Checking the accuracy of the Astrological weather predictions
5. Studying the MJO effect
6. Studying for Seasonal Forecasting
a. Using the forecasts provided by the regional websites
b. Using the ITACS model
7. Developing a Visual Basic program and a Database for Training/Seminar participants information
8. Seasonal rainfall forecasting using CPT
9. Decreasing trend of tropical cyclones in Bay of Bengal and Arabian sea.

5.5.6 The representative of Myanmar informed the Panel that the research studies are being carried out in DMH with the following topics;

a) Dryness and wetness during 1970 to 2099
b) Drought Index for dry Zone of Myanmar in 21st Century
c) Storm track shift due to climate change over SE Asia
d) Climate change in Myanmar during 21st Century by ECHAM 5 Model with Global Warming Experiment
e) New definition of monsoon onset and withdrawal for Myanmar
f) Analyzed the Evapo transpiration in Dry zone

Activities of WMO

5.5.7 The Seventh International Workshop on Tropical Cyclones (IWTC-VII) was successfully held in La Réunion, France from 15 to 20 November 2010. Chaired by Chris Velden (USA) and Jeff Kepert (Australia), the quadrennial workshop brought together tropical cyclone researchers and operational experts (forecasters and warning specialists). Workshop participants reviewed and examined recent developments in the science of tropical cyclone forecasting and sorted out priorities for future research and operational activities with special regard to the varying needs of different regions. It was attended by 128 tropical cyclone experts from 38 WMO Members with the WMO/ESCAP Panel on Tropical Cyclones (PTC) being represented by 5 operational forecasters. The workshop proceeding is currently being finalized and will subsequently be distributed to participants and to PTC Members. Included in the proceedings are a number of very important and useful recommendations, formulated by the participants and addressed to the WMO Secretariat, to NMHSs and to the research community.

5.5.8 The Third International Conference on Quantitative Precipitation Estimation (QPE) and Quantitative Precipitation Forecasting (QPF) was successfully held in Nanjing, China from 18 to 22 October 2010. The five-day conference, attended by 107 experts covered a wide range of issues relation to QPF including new observational approaches and technique development for QPE, advances in data assimilation, modelling and verification for QPF, user needs and the challenges of operational QPF. One of the foci of the 2010 conference is on QPF for tropical cyclones and monsoons. The conference proceeding is currently being finalized and will be available for download at the WGTMR/WWRP webpage.

5.5.9 There are three organized projects on tropical cyclones which are currently underway namely:

a) NW Pacific Tropical Cyclone Ensemble Forecast Project for Typhoon Committee members (Lead: Japan Meteorological Agency);
b) Typhoon Landfall Forecast Demonstration Project (Lead: Eastern China Regional Meteorological Center/CMA);
c) Severe Weather Forecast Demonstration Project (SWFDP) for Southern Africa (2008-2011; Lead: RSMC Pretoria) and for the South Pacific Islands (2009-2011; Lead: RSMC Wellington)

5.5.10 The book "Global Perspectives on Tropical Cyclones: From Science to Mitigation", edited by Johnny C.L. Chan (HK, China) and Jeffrey D. Kepert (Australia) was published in April 2010. The book is a completely rewritten, updated and expanded new edition of "Global Perspectives on Tropical Cyclones" (published in 1995) which in turn was a revision of A "Global View of Tropical Cyclones" (published in 1988). It presents a comprehensive review of the state of the science and forecasting of tropical cyclones together with the application of this science to disaster mitigation.

5.5.11 WGTMR's Expert Team on Climate Change Impacts on Tropical Cyclones is organizing the Second International Conference on Indian Ocean Tropical Cyclones and Climate Change tentatively in New Delhi, India in September 2011. The broad thematic areas of the conference includes: current status of the operational tropical cyclone forecasting and warning system, progress on the understanding of tropical cyclone genesis, climate change and tropical cyclone activity, tropical cyclone risk and vulnerability assessment and tropical cyclone disaster preparedness, management and reduction.

5.6 Publications

5.6.1 Publications issued under the programmes of the Panel fall into two categories (a) Panel News, and (b) the Annual Review of the Tropical Cyclones affecting the Bay of Bengal and the Arabian Sea. Information on the current status of each is presented below:

Panel News

5.6.2 Two issues of Panel News (No.29 and 30) were published during 2010-2011 and were distributed among the PTC Members, WMO, ESCAP and other concerned thirty-eighth session of the PTC (New Delhi, India, 21-25 February, 2010). The publication of Panel News issue No. 31 has been scheduled in April 2010. The Panel therefore, requested the Members to kindly provide their contributions to PTC Secretariat through their Panel News Correspondents more actively to avoid any delay in the publication of the next issue. The Panel also requested the Members to please send updated information about their News Correspondents especially if there is any change. The Panel also requested the Members to consider provision of news material for Panel News in more pictorial format and having policy information and development activities in order to target the policy makers and planners more effectively and to make the Panel News more informative and attractive.

6. REVIEW OF THE TROPICAL CYCLONE OPERATIONAL PLAN

6.1 Mr. B. K. Bandayopadhyay, rapporteur of Tropical Cyclone Operational Plan (TCOP), presented a comprehensive review made to produce the 2010 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 2011. The 2010 Edition of TCOP is available on the WMO TCP website. For the early issuance of the 2011 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 2011.

6.2 A proposal was made by the WMO Secretariat to include in the Plan a summary of the study on suitable conversion factors between the wind speeds of different time ranges. The study was undertaken by the Systems Engineering Australia Pty Ltd (SEA) to arrive at suitable conversion factors between the WMO 10-minute standard average wind and 1-minute, 2-minute and 3-minute "sustained" winds. Arrangement has been made by WMO/TCP to include the summary in the regional tropical cyclone operational plans and manual. Noting the significance of setting guidelines for converting the maximum wind speeds of tropical cyclones, the Panel endorsed the proposal and decided to include the summary in the Chapter I as an appendix.

7. PTC Secretariat

7.1 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 Met.) PMD as the Meteorologist of PTC Secretariat.

7.2 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.

7.3 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 **Appendix VIII.**

7.4 Panel was informed that the launching of new website of PTC was under process. In this connection, necessary Registration Form along with prescribed fee and the proposed webpage design/format has been submitted by the PTC Secretariat to the service providers in Islamabad. The address of the website has been proposed to be: www.ptc.wmoescap.org. Some of its various webpages and links are under construction. For making the website more informative and useful, the PTC Members were requested to kindly send their views and comments to PTC Secretariat. The new email address of the PTC Secretariat has been proposed to be PTC.Sectt@ptc.wmoescap.org. In this regard, PTC Secretariat would formally inform the Members during coming weeks.

7.5 The PTC Secretariat provided the Panel with a detailed breakdown of its expenses incurred during the Intersessional period (see **Appendix IX**). Keeping in view some savings, PTC Secretariat requested the Panel for provision of US$ 4,000 for its expenses during the year 2011-2012.

8. SUPPORT FOR THE PANEL'S PROGRAMME

8.1 The Panel was informed of the technical cooperation activities of WMO and ESCAP in support of the programmes of the Panel carried out in 2010, including the WMO Voluntary Cooperation Programme (VCP), Trust Fund arrangements, Emergency Assistance Fund scheme and Technical Cooperation among Developing Countries (TCDC) activities, and expressed its appreciation to WMO, ESCAP and collaborating partners for providing assistance to Members of the Panel.

8.2 The Panel noted that, in 2010, Maldives and Myanmar made cash contributions to the Voluntary Cooperation Fund (VCP(F)). Two new VCP project requests were submitted by Pakistan for the restoration of Automatic Weather Stations (AWSs) and meteorological

observing stations damaged by the severe floods in July-August 2010. A VCP project for Maldives for the provision of upper-air consumables at Gan station was supported by UK and completed in April 2010. China offered to provide support for upgrading FengYunCast receiving systems to CMACast for Myanmar and Sri Lanka.

8.3 The Panel was informed of the progress of the Trust Fund project for Sri Lanka for the installation of an S-band Doppler radar system, including completion of access road, site preparation and commencement of foundation work at Gongala Peak site. 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 2011.

8.4 Within the framework of the TCDC, China organized the International Training Seminar on South-South Cooperation on Weather and Climate in November 2010 in Nanjing Regional Training Centre. Three members of the Panel participated in the Training Seminar. The 2010 China Study Tour was carried out in May 2010 in conjunction with the opening of the MeteoWorld Pavilion in Shanghai Expo 2010 and three members of the Panel participated in the Study Tour. It further noted that Pakistan's third training course was conducted from May to September 2010 for 10 meteorological officials from four countries (including Bangladesh and Sri Lanka). The fourth training course for 2011 was offered to Afghanistan, Bangladesh, Maldives, Nepal and Sri Lanka. India continued attachment training for tropical cyclone forecasters and storm surge forecasters and offered an INSAT Digital MDD to Myanmar in 2010. Thailand carried out on-the-job training and offered to provide an upper-air system and consumables to Myanmar. In expressing its appreciation to India, Pakistan and Thailand for their active contributions to the Panel's capacity development requirements through TCDC, the Panel encouraged other Members to exploit similar training opportunities for other Members, and agreed to continue sharing of information on training opportunities available for Panel Members.

8.5 The Panel also noted the recent and ongoing emergency assistance provided under the Emergency Assistance Fund scheme to WMO Members affected by natural disasters, including Bangladesh, Myanmar and Pakistan. Following Cyclone Sidr, three SSB transceivers and two sets of Automatic Weather Stations (AWSs) are being provided to Bangladesh with the support of France, UK, VCP(F) and the WMO Emergency Assistance Fund. Following Cyclone Nargis, 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 to Myanmar in 2008-2010, and more reliable Internet connectivity is to be provided with the Emergency Assistance Fund and the VCP(F). Affected Members who need emergency assistance were advised to utilize this scheme, and all Members were requested to consider providing support to affected NMHSs.

8.6 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 in November 2010 in collaboration with ESCAP and in coordination with UNESCO. The mission assessed the current capability of the Pakistan Meteorological Department (PMD) and assisted PMD in the development of a proposal for the enhancement of its meteorological and hydrological services to implement effective flood early warning systems. The findings and recommendations of the mission were reported to the Government authorities and to potential donor Members for consideration of assistance to restore essential hydrometeorological infrastructure (AWSs, conventional synoptic meteorological stations, etc.) in Pakistan.

8.7 The Panel was further informed that WMO is collaborating with the Regional Integrated Early Multi-Hazard Early Warning System for Africa and Asia (RIMES) for the development of, mobilizing resources for, and implementing joint projects for capacity building of NMHSs and other stakeholders. A similar Memorandum of Understanding (MoU)

to that with ADPC was concluded with RIMES on 3 November 2010 to replace the MoU with ADPC. A WMO-RIMES joint project proposal for "Reducing risks of tsunami, storm surge, large waves and other natural hazards in low elevation coastal zones" for Bangladesh, India, Maldives, Myanmar, Sri Lanka and Thailand was submitted to UNESCAP for funding under the ESCAP Tsunami Regional Trust Fund in August 2010, and the project has been approved in January 2011 for implementation.

8.8 In this connection, the Panel noted that the ESCAP Tsunami Regional Trust Fund, established in late 2005 with initial contribution of US$ 12.6 million for effective regional early warning systems for tsunamis, has officially expanded its scope in January 2011 to include other hazards and climate preparedness. The Panel Members were encouraged to utilize the above resource mechanisms to support the Panel's Programme.

8.9 In view of the close collaboration established between the WMO RA II Working Group on Hydrological Forecasts and Assessment and the Working Group on Hydrology of the Typhoon Committee, the Panel was encouraged to enhance cooperation with the WMO RA II Working Groups, among others, between Panel's WG on DPP and RA II WG on DRR and Service Delivery.

8.10 The Panel noted with appreciation that WMO and UNESCAP would continue to undertake activities in support of the Panel on Tropical Cyclones.

Panel on Tropical Cyclones Trust Fund (PTCTF)

8.11 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.

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

8.13 A detailed financial report on the Trust Fund as of 31 December 2010 was submitted by WMO to the Panel (see **Appendix X**).

8.14 The Panel endorsed the use of the Trust Fund for 2011 for the following specific purpose:

- Support for the attachment training at RSMC New Delhi for per diem of the participants (US$ 6,000)
- Support to PTC Secretariat for its operating expenses including those for printing Panel News and running PTC-website. (US$ 4,000)
- Support for participation of PTC in the 8th Session of ICG/IOTWS, Melbourne, Australia from 3-6 May, 2011 (US$3,000)

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.

9. SCIENTIFIC LECTURES

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

- Pakistan Super Floods 2010: Increasing Climate Change Indicators
  by Dr. Qamar-uz-Zaman Chaudhr (Pakistan)

- Characteristics of best tracks of cyclones over the North Indian Oceant
  by Dr. M Mohapatra (India)

- Enhancing Forecasting Capabilities for North Indian Ocean Storm Surges
  by Prof. S. K. Dube (IIT)

- Modelling of Coastal Inundation due to Storm Surges
  by Prof. A. D. Rao (IIT)

- Air Traffic Management applications of Tropical Cyclone Information
  by Mr. Christopher Keohan (ICAO)

- ICHARM Support to Asian Countries in Disaster Risk Management

  by Mr Osti Rabindra (ICHARM)

- Developing innovative strategies for flood-resilient cities
  by Dr Yuichi Ono (ESCAP)

- Recent Advances on China Operational Tropical Cyclone Forecasting and Warning Services
  by Dr Xu Yinglong (China)

- Meso-Scale simulation of tropical cyclones over the North Indian Seas
  by Dr Potty Jayaraman (RIMES)

9.2 The Panel expressed its deep appreciation to the above lecturers for their informative and excellent presentations. Summaries of the presentations are given in **Appendix XI**.

10. DATE AND PLACE OF THE THIRTY- NINTH SESSION

10.1 The dates and venue of the 39th session in 2012 would be determined based on the consultation between WMO, ESCAP, Chairman of the Panel and PTC Secretary.

11. ADOPTION OF THE REPORT

11.1 The report of the thirty-eighth session was adopted at 1230 hours on Friday, 25 February 2011.

12. CLOSURE OF THE SESSION

12.1 The Panel expressed its sincere appreciation to the Government of India, 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 Ajit Tyagi, Chairperson of the Panel, Dr Hrin Nei Thiam, Vice-chairperson of the Panel as well as Mr S.H. Kariyawasam, Chairman 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 Shri B. K. Bandyopadhyay of Inida Meteorological Department for their hard work in organizing the session, assistance provided to the participants and producing a session report.

12.2 The thirty-eighth session of the Panel was concluded at 1300 hours on Friday, 25 February 2011.

LIST OF APPENDICES

APPENDIX I

LIST OF PARTICIPANTS

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Inaugural Programme

21st February, 2011

Mirza Ghalib Hall, Scope Complex, Lodi Road, New Delhi

Ceremonial Lighting of the Lamp	*1100-1105 A.M.*
Welcome address by AVM Dr. Ajit Tyagi, DGM, IM D and PR of India	*1105-1115 A.M.*
Address by Secretary, PTC	*1115-1125 A.M.*
Address on behalf of ESCAP	*1125-1135 A.M.*
Address on behalf of Secretary General, WMO	*1135-1145 A.M.*
Release of Reports published by RSMC, New Delhi.	*1145-1150 A.M.*
Address by Secretary, MoES, Govt. of India	*1150-1200 A.M.*
Address by Chief Guest	*1200-1210 P.M.*
Vote of thanks by Mr. B.K. Bandyopadhyay	*1210-1215 P.M.*
High Tea	*1215 P.M.*

Summaries of the Speeches

Dr Qamar-Uz-Zaman Chaudhry

Dr. Qamar-uz-Zaman Chaudhry Secretary of PTC and Vice president of WMO/RA-II (Asia) welcomed the participants at the thirty-eighth Session of the PTC and extended his warmest greetings. He remarked that tropical cyclones and associated storm surges are one of the severe weather hazards in our part of the world, claiming precious lives and causing extensive damages to property and infra-structure, however, Member countries are fully aware of the challenges offered by the tropical cyclones and associated storm surges and through the forum of PTC, they have been putting maximum efforts for implementing the agreed programmes of action especially concerning tropical cyclones and associated storm surges. He particularly shed light on the capacity building of NMHSs of Member countries through PTC in specialized areas of tropical cyclones forecasting and storm surge modeling. In this regard, he commended Regional Specialized Meteorological Center (RSMC) and Indian Institute of Technology (IIT), New Delhi for their pivotal role in offering these trainings which are source of profound knowledge on the development, formation and forecasting of tropical cyclones and associated storm surges and which finally aim at safety and wellbeing of the people of this region. Further, in wake of the extreme hydrometeorological events and floods during 2010, he urged PTC Members for the establishment of PTC Working Groups concerning main components of PTC Coordinated Technical Plan especially Hydrology. He envisaged that through the establishment of Working Group on Hydrology, PTC Member countries can coordinate and contribute more effectively in Hydrological Component of Coordinated Technical Plan. He remarked that Working Group on Hydrology would also provide a platform for the hydrological experts of the PTC region to not only share their knowledge and experience in flood forecasts and best practices in flood management but also to suggest ways in adopting best water management practices aiming at improving water security and reducing hydrological disaster risk in the PTC region. He also offered his sincere thanks to the Government of India for hosting this 38th Session of PTC and wished all the distinguished guests a pleasant and comfortable stay in New Delhi.

Dr Yuichi Ono

Dr. Yuichi Ono, representing ESCAP delivered an opening remark. He thanked the Government of India for hosting the session. He mentioned that the Working Group on Disaster Risk Reduction chaired by Thailand made its first efforts last year, and he asked supports for the initiative in the early stage. He stated that the Panel needs to be accountable for public quests, including the future trend on the intensity and frequency of tropical cyclones in the region. He also pointed out that significant cyclones recently occurred in the extreme east and west in the region, namely Cyclone Nargis in Myanmar and Cyclone Gonu over Oman and Iran. He mentioned that the ESCAP will continue to support the Panel activities, especially in the area of social and economic perspectives. This includes the ESCAP mechanism of the Second Committee on Disaster Risk Reduction to be held in Bangkok, 29 June to 1 July 2011. At this Committee, ESCAP will propose to develop the second issue of Asian and Pacific Disaster Report to be launched at the next Asian Ministerial Conference on Disaster Risk Reduction to be held in Indonesia in 2012. He invited technical inputs from the Panel to the Report and Committee.

Dr Tokiyoshi Toya

Speaking on behalf of Mr Michel Jarraud, Secretary-General of WMO, Dr Tokiyoshi Toya, Regional Director for Asia and the South-West Pacific, welcomed all the participants and expressed his appreciation and that of WMO to H.E. Shri M. Shashindhar Reddy, Vice-Chairman, National Disaster Management Authority and the Government of India for hosting the thirty-eighth session. He extended his gratitude to Dr Ajit Tyagi, Permanent Representative of India with WMO and his staff for the warm welcome and hospitality and for the excellent arrangements made to ensure the success of the session. By commending the successful performance of the Working Group on DPP in 2010 led by the Department of Disaster Prevention and Mitigation of Thailand, he expressed his confidence that this initiative would lead to the development of the working group activities in other two major components – Meteorology and Hydrology. In referring to the observed unusual weather in 2010 including severe flooding in Pakistan and low global tropical cyclone activity indicated in the WMO Statement on the state of global climate in 2010 at the UN Climate Change Conference 2010 in Cancún, Mexico (COP16) in December 2010, Dr Toya stressed that climate variability and change are real challenges to the Members of the Panel. In ensuring WMO's continued support for the Panel's programmes and activities in areas of Meteorology, Hydrology and Disaster Prevention and Preparedness, he wished the participants a very successful session and an enjoyable stay in New Delhi.

AGENDA

1. ORGANIZATION OF THE SESSION

    1.1 Opening of the session
    1.2 Election of the Chairman and Vice-chairman
    1.3 Adoption of the agenda
    1.4 Working arrangements

2. FOLLOW-UP ACTION ON PTC-37

3. REVIEW OF THE 2010 CYCLONE SEASON

    3.1 Report of RSMC New Delhi
    3.2 Reports of Members on the impact of tropical cyclones

4. COORDINATION WITH OTHER ACTIVITIES OF THE WMO TROPICAL CYCLONE PROGRAMME

5. REVIEW OF THE COORDINATED TECHNICAL PLAN AND CONSIDERATION OF THE WORK PROGRAMME FOR THE NEXT FIVE YEARS

    5.1 Meteorological Component
    5.2 Hydrological Component
    5.3 Disaster Prevention and Preparedness Component
    5.4 Training Component
    5.5 Research Component
    5.6 Publications
        (a) Panel News
        (b) Annual Review

6. REVIEW OF THE TROPICAL CYCLONE OPERATIONAL PLAN

7. PTC SECRETARIAT

8. SUPPORT FOR THE PANEL'S PROGRAMME

9. SCIENTIFIC LECTURES

10. DATE AND PLACE OF THE THIRTY- NINTH SESSION

11. ADOPTION OF THE REPORT

12. CLOSURE OF THE SESSION

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APPENDIX V

Action Sheet on the 37th session of the Panel

Para. No.	Subject	Action Required	Responsible	Deadline	Remarks
4.1	Update of the Global Guide to Tropical Cyclone Forecasting	The updated version of the Global Guide to be published.	WMO (TCP)	ASAP	Ongoing
4.1	Development of the Tropical Cyclone Forecaster Website	The Tropical Cyclone Forecaster Website to be developed in the WMO Website.	WMO (TCP)	ASAP	Done
4.1	Development of Storm Surge Watch Scheme (SSWS)	Establishment of SSWS in the Panel region	WMO(TCP), RSMC New Delhi		Operational
4.2	"Typhoon Landfall Forecast Demonstration Project" on the initiative of East China Meteorological Centre, CMA.	Implementing in the East China Meteorological Centre, CMA. To cover the Panel region in 2012 or later.	WMO (TCP/WWRP)	2012	Ongoing
4.3	North Western Pacific Tropical Cyclones Ensemble Track Forecast Experiment, a 5-year WWRP' Research Development Project (RDP).	Implemented in several Members in the Western North Pacific basin. To cover the Panel region in 2011 or later	WMO (TCP/WWRP)		Ongoing
5.0.2	AOP for the meteorological component	Assessment of the existing observing system as well as related infrastructure.	PTC Secretariat	ASAP	
5.0.3	Application of ensemble prediction techniques into the track forecasting	Use of ensemble prediction techniques in improving TC advisory bulletins	RSMC New Delhi		Ongoing

APPENDIX V

Para. No.	Subject	Action Required	Responsible	Deadline	Remarks
5.0.4	Use of probabilistic forecasts for disaster managers.	Involvement of WG-DPP in this process for best use of probabilistic forecasts for disaster risk management.	Members	ASAP	
5.0.7	AOP for the hydrological component	Promotion of activities including creation of hazard maps and data sharing information systems.	WMO/ICHARM		
5.0.8	Experiments with river-ocean coupled models	Carrying out these experiments by IIT	IIT	ASAP	
5.0.10	AOP for DPP component	Assigning a lead country for each DPP strategic goal. The lead country is responsible for designing concrete activities with achievable goals, plans, deadlines, etc. at the regional and country levels. The inputs from those lead countries should be submitted to the WG-DPP Chair by the end of April 2010.	Leading countries		
5.3.8	Identifying opportunities for strengthening the early warning system capacities linked to tropical cyclone and related hazards in the region	Close collaboration between PTC-WGDPP with DRR Programme and the RA II Working Group on DRR and Service Delivery	PTC-WGDPP		
5.3.15	Second meeting of WG-DPP in 2010	Organization of the meeting.	PTC-WG-DPP		Done

Para. No.	Subject	Action Required	Responsible	Deadline	Remarks
5.5.6	The Third International Conference on Quantitative Precipitation Estimation (QPE) and Quantitative Precipitation Forecasting (QPF) tentatively in Nanjing, China from 18 to 22 October 2010.	Organization of the meeting	WMO (WWRP/TCP)		Done
5.5.7	The Seventh International Workshop on Tropical Cyclones (IWTC-VII) in La Réunion, France from 15-20 November 2010	Organization of the meeting	WMO (WWRP/TCP)		Done

Cyclonic Storms and Depressions over North Indian Ocean – 2010

1. Introduction

During 2010, in all 8 intense low pressure systems (Table 2.1) formed over the Indian seas. These include two Very Severe Cyclonic Storms (Phet & Giri), two Severe Cyclonic Storms (Laila & Jal); one Cyclonic Storm (Bandu), one Deep Depression and two Depressions. Out of these 8 systems, the Very Severe Cyclonic Storm (Phet), the Severe Cyclonic Storm (Laila) and the Cyclonic Storm (Bandu) occurred during the pre-monsoon season and the Very Severe Cyclonic Storm (Giri), the Severe Cyclonic Storm (Jal), two Deep Depressions and one Depression occurred during the post-monsoon season. All the low pressure systems formed over the Bay of Bengal except Phet and Bandu, which formed over the Arabian Sea. No intense low pressure system formed during the southwest Monsoon season. The tracks of these systems are shown in Fig.2.1.

Some characteristic features of cyclonic disturbances formed over north Indian Ocean during 2010 are given in Table 2.2. The frequency, intensity and total life time of cyclonic disturbances formed over the north Indian Ocean and land areas of India during 1997-2009 are given in Table 2.4.

Salient features of cyclonic disturbances during 2010

- During 2010, the north Indian Ocean witnessed formation of eight Cyclonic disturbances including five cyclones. During 2009, out of eight cyclonic disturbances, four had intensified into cyclones.
- The Arabian Sea and the Bay of Bengal was active during pre-monsoon storm season (April-May) with the formation of one very severe cyclonic storm (Phet) and another cyclonic storm (Bandu) and one severe cyclonic storm (Laila) respectively.
- There was no cyclogenesis over either the Bay of Bengal or the Arabian Sea during the monsoon season. This is the second such year in the recorded history, after the year 2002, during which no low pressure area has concentrated into Depression during southwest monsoon season.
- The Bay of Bengal was active during the post-monsoon storm season with the formation of the Very Severe Cyclonic Storm (Giri), Severe Cyclonic Storm (Jal), two Deep Depressions and one Depression.
- Out of five cyclones, three (Laila, Phet and Giri) recurved northeastwards and the remaining two systems moved northwestwards.
- All the three Depressions formed over the Bay of Bengal during the post-monsoon season.

The brief synopses of the intense low pressure systems are given below:

2. Details of the systems

2.1 Severe Cyclonic Storm (Laila) over the Bay of Bengal (17-21 May 2010)

2.1.1 A low pressure area formed over the southeast Bay of Bengal and neighbourhood in the evening of 16. It concentrated into a Depression at 0600 UTC of 17 and lay centered near Lat. 10.5º N/Long. 88.5º E, about 930 kms eastsoutheast of Chennai. It moved northeastwards and intensified into a Deep Depression and lay centered at 1200 UTC, near Lat. 11.0º N/Long. 88.0 º E. Moving in a westnorthwesterly direction, the system further intensified into a Cyclonic Storm (Laila) and lay centered at 0000 UTC of 18, near Lat. 11.5º N / Long. 86.5º E, about 700 kms southeast of Chennai. Thereafter, it moved in a northwesterly direction and at 0300 UTC it lay centered near Lat. 12.0º N/Long. 85.5º E; at 1200 UTC of 18 near Lat. 13.0º N/Long. 83.5º E and near Lat. 13.5º N/Long. 82.0º E at 0300

UTC of 19. The system further intensified into a Severe Cyclonic Storm and lay centered near Lat. 13.5º N / Long. 81.5º E at 0600 UTC of 19. Remaining practically stationary, the system lay near Lat. 14.0º N/Long. 81.5º E at 1200 UTC. Moving in northwesterly direction, it lay near Lat. 15.5º N/Long. 80.5º E at 0300 UTC of 20. The Severe Cyclonic Storm crossed south Andhra Pradesh coast near Bapatla between 1100 & 1200 UTC on 20 and weakened into a Cyclonic Storm at 1200 UTC close to Bapatla (Lat. 16.0º N/Long. 80.5º E). Remaining stationary for some time, it re-curved northnortheastwards and further weakened into a Deep Depression and lay centered over north coastal Andhra Pradesh, about 50 kms north of Machilipatnam (Lat. 16.5º N/Long. 81.0º E) at 0300 UTC of 21. Continuing its northnortheastward movement, it weakened into a Depression and lay centered at 0600 UTC over coastal Andhra Pradesh, about 100 kms west of Kakinada (Lat. 17.0º N/Long. 81.5º E). Thereafter, it rapidly weakened into a low pressure area in the evening of 21 over north coastal Andhra Pradesh and adjoining Telangana.

2.1.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 986 hPa. The maximum estimated mean wind speed was 55 kts. The system moved initially in northwesterly direction and then recurved into northeasterly direction and crossed Andhra Pradesh coast near Bapatla (16.0^0 N/ 80.5^0 E) between 1100-1200 UTC.

Post Cyclone survey report:

Landfall: The Severe Cyclonic Storm appears to have entered the land through the mouth of Nallamada drain (15.8^0 N /80.6^0 E) at Suryalanka coast which is about 12 kms southsoutheast of Bapatla and travelled about 4 to 5 kms over land. It then re-curved in a northnortheasterly direction near Karlapalem village and Satyavathipetha. During its course of recurvature, it remained stationary for 4 to 5 hours.

Wind: As per the report, the maximum estimated wind speed was 55 to 65 kts. Observations of Suryalanka Air force station shows that the maximum surface wind speed was 53 kts at 0000 UTC of 19. As per the local people and fishermen verdict, the wind speed at the time of landfall was 125 to 150 Kmph; whereas the forecast wind at the time of landfall at 0900 UTC of 20 was 100-110 Kmph gusting to 120 Kmph.

Tidal Waves: As per the fishermen's report; at Vadarevu (Prakasam district), height of tidal waves was 6 to 7 meters; at Suryalanka it was 5 to 6 meters and 5 meters at Kothapatnam (Prakasam district). (The forecast of the height of tides was 9-14 meters).

Storm Surge: Storm Surge of 2 to 3 meters was observed at Suryalanka (GNT) coast and 3 to 4 meters at Vadarevu (Prakasam district) coast (forecast storm surge was 1.5 to 3 meters).

Pressure: The lowest mean sea level pressure of 992.8 hPa was recorded at 0900 UTC of 20 at Bapatla.

2.1.3 Weather and damage caused

As per press reports, heavy rains and floods took a toll of 23 people in Andhra Pradesh.Thousands of acres of crops suffered heavy damage in Ongole, Nellore, Guntur, East Godavari and Krishna districts. Many people were rendered homeless. Road and rail traffic was disrupted due to heavy rains and floods in coastal districts of Andhra Pradesh. Hundreds of houses were either fully or partially damaged.

No damage reported from Tamil Nadu. Heavy rain occurred at isolated places in Orissa from 21 to 24 May. Some significant amounts of rainfall (in cms) are:

Andhra Pradesh

20 May: Kothapatnam 35, N. G. Padu 34, Ongole 32, Maddipadu 26, Tangutur 22, Chimakurthy 20, S. Konda 19, Zarugumalli, Narsapur 18, Tanuku 15, J. Pangalur 13, Kandukur, Bhimavaram, Machilipatnam, Inkollu, 12, Chinaganjam, Kondepi, Avanigadda, Kaikalur, Kakinada, Ulavapadu, Vetapalem, 11, Bapatla, Chirala, Korisapadu, Koderu, Kavali, Tadepalligudem, Repalle 10, Nagram, Addanki, S. N. Padu, Bhattiprolu, 9, Parchur, Karamchedu, Yaddanapudi, Gudlur, Darsi, Tallur, Gudivada, Nakirekallu, Kollurru, Karlapalem, Guntur 8, Mudalavur, Anakapalli, Elamanchili, S Magalur, Ponnalur, Pedanandipadu, Chilkavuripet, Amarthalur, and Tuni 7.

21 May: Addanki 52, Maadipadu 28, Chimakurthy, Nurendla, S. N Padu 27, Tallur, Kothapatnam 26, Vinulonda 25, Savalyapuram 23, Bollapalli 20, Machavaram 19, Rompicherla, Tadepalle, Darsi 18, Nakirekkallu, N. G. Padu, Ipur 17, Kondepi 16, Mangalagiri, Korisapadu, Zarugumalli, Kurichedu, 15, Mundlamur, Ongole, Tangutur, S. Konda, 14, Visakhapatnam, Elamanchili, Piduguralla, Bhimunipatnam, Bellamkonda, Duggirala13, Pidugupalla, Kandukur, J. Pangulur, Vijaywada, Kandukur, Donakonda 12, Karempudi, Ballikurava, Vinjamur, Vijayanagaram, Ulavapadu, Pedakakani, Rajupalem, 11, Chebrolu, Thollur, Podili, Narsipatnam, Waltair, Anakapalli, Dachepalli, Podili, Nadendla, 10, Chilkavuripet, Amaravathi, Pedakurapadu, Atchampet, Krosur, Srungavarapu Kota, Chipurupalli, Chodavaram, Bhimadole, Polavaram, Tiruvuru, V.V Palem, K.K Mitla, Tenali, Amarthalur 9, Tadikona, Nandigama, Pathapatnam, Chintalapudi, Guntur, Ranasthalam, Yaddanapudi, S. Magalur, Maripudi, Tenali, Nagram 8, Amalapuram, Sattenapalli, Paderu, Prathipadu, Sompeta, Kalingapatnam Inkollu, Sattenapalli, Vetticharukur Narasaraopet, Drugi, Ponnur, Vemuruand Tuni, 7.

22 May: Tiruvuru 25, Nuzvid 15, Palasa 11, Ichapuram, Chintalapudi, Salur 10, Sompeta 9, Mandasa and Tekkali 7.

Tamil Nadu

19 May: Thozudur 9, Chennai 8, Tiruvarur, Musiri 7.

20 May: Ponneri 17, Cholavaram 13, Chennai, Thamaraipakkam 11, Tiruvallur, Poondi 9, Poonamally, Chembarambakkam, Tiruttani, Arakonam 7.

Orissa

21 May: Parlakhemundi 9.

22 May: Gopalpur 10, Berhampur 9, Chatrapur 8, Purushottampur, Krishnaprasad 7.

23 May: Athagarh 13, Dhenkanal 10, Tikabali 8, Rajkishorenagar 7.

24 May: Jaipur 9, Nilgiri 8.

2.1.4 Satellite and RADAR observations

The system was tracked initially with the help of satellite cloud imageries from 1200 UTC of 16; then by hourly DWR observations; hourly coastal observations and AWS observations of Andhra Pradesh. The maximum intensity of T 3.5 was reported from 0500 UTC to 2000 UTC of 19. It crossed the coast at 0500 UTC of 20 May with intensity T 3.0 and the center was at 15.7N/80.1E. The structure of the system was curved band except for one or two cases when it was observed of Central Dense Overcast (CDO) type.

DWR Chennai: The vortex was first noticed in RADAR scope around 0700 UTC of 18. Spiraling line echoes with EYE could be seen from 1300 UTC of 18 to 0700 UTC of 19. Initially the system moved fairly fast (16 kmph westwards) but eventually slowed down (09 kmph) after gaining northerly component in its motion. Varying features (closed, circular. Elliptical, ill-defined etc) of EYE of the cyclone were seen during the course of the system within the RADAR range. System's centre was closest to the RADAR (130 km) during 0600–0900 UTC of 19.

Maximum radial velocity recorded during the course of the system was around 48 mps at the height of 1 to 2 kms above ground level during the period 0600 to 0900 UTC of 19.

CDR Karaikal: The Cyclonic Storm was tracked form 0900 UTC to 1500 UTC of 19 May 2010 and issued CYREP to ACWC Chennai.

The special features of the storm are as follows:

(i) The track of the system was climatological in nature and recurved northeastwards.
(ii) The system crossed south Andhra Pradesh coast as a severe cyclonic storm

3. Cyclonic Storm (Bandu) over the Arabian Sea (19–23 May 2010)

3.1 The cyclonic storm formed west of Long. 55.0º E and dissipated over Gulf of Aden. As the system did not influence the weather over the Indian Region either directly or indirectly, the description of the system is not included included in Fig. 1 as the area comes under RSMC responsibility.

3.2 Very Severe Cyclonic Storm (Phet) over the Arabian Sea (31 May– 7 June 2010)

3.2.1 Under the influence of an upper air cyclonic circulation over the southeast Arabian Sea, a low pressure area formed over the east central and adjoining west central Arabian Sea on 31 morning. It rapidly concentrated into a Depression and lay centered at 0600 UTC of 31 May near Lat.15.0^0 N / Long. 64.0^0 E and at 1200 UTC near Lat.15.5º N/ Long. 63.5º E. It remained practically stationary upto 0300 UTC of 1 June and in the mean time, intensified into a Deep Depression at 0000 UTC. Then it moved northwestwards and further intensified into a Cyclonic Storm (Phet) and lay centered at 0900 UTC of 1 June, near Lat.16.0º N / Long. 63.0º E. Continuing the northwestward movement, it lay centered near Lat.16.5º N / Long. 62.5º E at 1200 UTC. Subsequently, it intensified into a Severe Cyclonic Storm and lay centered at 0000 UTC of 2 June near Lat.17.5º N / Long. 61.5º E. Moving slightly westwards, it lay centered at 0300 UTC of 2 June near Lat.17.5º N / Long. 61.0º E. Remaining practically stationary, it further intensified into a Very Severe Cyclonic Storm at 0600 UTC of 2. It moved further northwestwards and lay centered near Lat.18.0º N / Long. 60.5º E at 1200 UTC of 2 June; lay centered near Lat.18.5º N / Long.59.5º E at 0300 UTC of 3 and near Lat. 20.0º N / Long. 59.5º E at 1200 UTC. Moving further northwards, it crossed Oman coast near Lat.21.5º N between 0000 & 0200 UTC of 4 June; weakened into a Severe Cyclonic Storm and lay centered at 0300 UTC of 4 over coastal Oman near Lat. 22.0º N / Long. 59.5º E. Continuing the northward movement, it emerged into the northwest Arabian Sea and lay centered at 1200 UTC of 4 near Lat. 23.0º N / Long. 59.5º E. It further weakened into a Cyclonic Storm and lay centered at 0000 UTC of 5 near Lat. 24.0º N / Long. 60.5º E. Re-curving northeastwards, it lay centered at 0300 UTC of 5 near Lat. 24.5º N / Long. 61.0º E and at 1200 UTC near Lat. 24.5º N / Long. 61.5º E. Moving further eastwards, it weakened into a Deep Depression and lay centered at 1800 UTC of 5 near Lat. 24.5º N / Long. 62.5º E. It

further weakened into a Depression at 0300 UTC of 6, near Lat. 24.5º N / Long. 65.0º E and lay centred at 1200 UTC near Lat. 24.5º N / Long. 67.0º E. Moving eastnortheastwards, it crossed Pakistan coast close to south of Karachi (near Lat. 24.7^0 N and Long 67.2^0 E) between 1230 & 1330 UTC of 6 and lay centred at 1500 UTC near Lat. 25.0º N / Long. 68.0º E (about 220 kms northnortwest of Naliya). Further moving eastnortheastwards, it lay centered at 0300 UTC of 7 over west Rajasthan, close to Barmer (Lat. 26.5 º N/Lat, 71.5 º E) and at 0600 UTC of 7 near Lat. 26.5 º N / Long. 72.5º E. It weakened into a well marked low pressure area over east Rajasthan and adjoining northwest Madhya Pradesh in the evening of 7 and became less marked on 8^{th} morning. However, the associated upper air cyclonic circulation extending upto lower tropospheric levels lay over west Uttar Pradesh and neighbourhood on 8 and became less marked on 9.

3.2.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 964 hPa. The maximum estimated mean wind speed was 85 kts. The system moved initially in a northwesterly and then northerly direction before crossing Oman coast as Very Severe Cyclonic Storm in the early morning of 4 June. It then re-curved into northeasterly direction and further moved in an easterly direction and crossed Pakistan coast as a Depression close to south of Karachi. It moved again in a northeasterly direction across Rajasthan, causing heavy rainfall over the region.

3.2.3 Satellite and RADAR observations

The system was tracked mainly with the help of satellite cloud imageries from 1200 UTC of 30 May to 1200 UTC of 6 June. The maximum intensity of T. No. 4.5 was reported from 0800 UTC to 2200 UTC of 2 June.

The intensity of the system was T No. 1.5 reported from 0600 UTC of 31 May. At 0000 UTC of 1 June, the intensity was increased to T 2.0. At 0600 UTC of 1 June, the signs of rapid intensification were observed. Again its intensity was increased to T 2.5 at 0900 UTC of 1 June with center as Lat. 16.3° N / Long. 62.7° E. Its rapid intensification continued and at 1800 UTC its intensity was raised to T 3.0 with center as Lat. 17.0° N/ Long. 61.8° E . The intensity of the vortex was raised to T 3.5 at 2300 UTC, when its EYE was visible. It continued to be visible until 2300 UTC of 2 June and was clearer from 0500 UTC of 2 June, when the system attained the intensity of T 4.0. The system had its first landfall between 0000 & 0200 UTC of 4 June and second between 1230 & 1330 UTC of 6 June.

3.2.4 Weather and damage caused

The system was a Depression when it entered the Indian region. It weakened rapidly and hence no damage was reported. However, fairly widespread rainfall with isolated heavy falls occurred over west Rajasthan on 7 June.

Some chief amounts of rainfall are:

west Rajasthan

7 June: Jaisalmer 11, Phalodi 9.

3.3 Depression over the Bay of Bengal (7- 8 October 2010)

3.3.1 A low pressure area formed over the east central Bay of Bengal and neighbourhood on 4. It moved over to the west central Bay of Bengal off Andhra coast on 6 and concentrated into a Depression at 0300 UTC of 7 and lay centered near Lat. 16.5º N/Long. 84.5º E, about 180 kms southeast of Visakhapatnam. It moved northnortheastwards

and lay centered near Lat. 18.5º N/Long. 85.0º E at 1200 UTC, about 100 kms southsoutheast of Gopalpur. Thereafter, it moved in a northeasterly direction and at 0300 UTC of 8 it lay centered near Lat. 21.0º N / Long. 87.5º E, about 90 kms south of Digha. It moved northeastwards and crossed West Bengal-Bangladesh coasts near Long. 88.5º E between 0500 & 0600 UTC and lay centred at 1200 UTC over Bangladesh, close to Dhaka (Lat. 23.5° N/Long. 90.5° E). The system weakened into a low pressure area over Nagaland-Manipur-Mizoram-Tripura and neighbourhood in the early morning of 9, which subsequently moved over to Arunachal Pradesh and neighbourhood and became less marked in the morning hours of 9.

3.3.2 Other features observed

The lowest Estimated Central Pressure (ECP) was 996 hPa. The maximum estimated mean wind speed was 25 kts. The lowest mean sea level pressure of 998.6 hPa was recorded at Barisal (41950, Bangladesh) at 1200 UTC of 8. The system moved initially in a northnortheasterly direction and then in a northeasterly direction and crossed West Bengal-Bangladesh coasts near Long. 88.5° E of 8.

3.3.3 Weather and damage caused

The system did not cause much damage in India. However, tidal waves wreaked havoc in east Midnapore district and 850 families were shifted to safer places. Monsoon was active or vigorous in Orissa, Gangetic West Bengal, Assam & Meghalaya and Nagaland-Manipur-Mizoram-Tripura. Heavy rainfall occurred at isolated places in interior Orissa on 6 and 7 and extremely heavy rain with heavy to very heavy falls at isolated places occurred in coastal Orissa on 8.

Some significant amounts of rainfall (in cm) are:

Orissa

7 Oct.: Kendrapada 9, Rajkanika 8, Soro, Chandbali, Bhadrak 7.

8 Oct. : Paradip 25, Pattamundai 15, Kakatpur 15, Chandbali, Kendrapara, Bhadrak 14, Rajkanika 11, Balasore, Puri 10, Athgarh, Soro 9, Mundali 8, Nimapara 7.

Gangetic West Bengal

8 Oct.: Canning Town 8, Diamond Harbour, Durgachak 7.

Assam & Meghalaya

8 Oct.: Barapani 46, Cherrapunji 22.

9 Oct.: Cherrapunji 30, Silchar 14, Shillong 4, Dholai, Williamnagar 9, Lumding, Barapani, Gharmura, Amraghat 8, Kherunighat, Jorhat 7.

Nagaland-Manipur-Mizoram-Tripura

8 Oct.: Sonamura 15, Belonia 14, Sabroom, Udaipur 11.

9 Oct.: Agartala 18, Kailashahar 12, Imphal 10.

3.3.4 Satellite and RADAR observations

The system was tracked initially with the help of satellite cloud imageries. The maximum intensity of T No. 1.5 was reported from 0300 UTC of 7 to 0500 UTC of 8. As per the satellite report, the depression crossed the coast around 0600 UTC of 8 Oct.

CDR Paradip: Though the system was tracked by CDR Paradip, no CYREPs were issued. Hourly RADAR observations were taken and reported from 0700 UTC of 7 to 0600 UTC of 8.

DWR Kolkata: DWR Kolkata observed the system since 0000 UTC of 7 at every 15 minutes interval. The initial echoes of the system (WML) were observed in the form of scattered clouds at about 200–300 kms southsouthwest of Kolkata. Amount of convective clouds was increasing in the subsequent observations. Moderate type of clouds were observed with reflectivity about 40 dBz with vertical extension from 6 to 8 kms towards southsouthwesterly and southerly direction of Kolkata at 1900 UTC of 7. The system moved in a northeasterly direction and moderate convective clouds of reflectivity about 42 dBZ with vertical extension upto 12 kms was observed over Kolkata from 2200 UTC of 7 to 0000 UTC of 8. It was observed from subsequent DWR pictures from 0100 UTC of 8 onwards that the system was moving toward Jessore (Bangladesh) at 0300 UTC of 8.

Maximum Wind Observed

The maximum radial wind as observed from PPI (V) was in the range of 22 to 26 mps at a height of 0.5 km above ground level at 2100 UTC of 7 at a distance of 140 kms south/southsouthwest from DWR. The maximum horizontal wind estimated from DWR product VVP_2 is 20 knots at height 6 kms within 50 kms of Kolkata.

3.4 Deep Depression over the Bay of Bengal (13–16 Oct. 2010)

3.4.1 A low pressure area formed over the east central Bay of Bengal and neighbourhood on 12. It became well marked over there on 13 morning and subsequently concentrated into a Depression at 0600 UTC near Lat. 17.5° N / Long. 90.0° E, about 550 kms southeast of Gopalpur. Moving westwards, it lay centered at 1200 UTC of 13 near Lat. 17.5° N / Long. 89.0° E. Subsequently moving northwestwards, it lay centred near Lat. 18.0° N / Long. 88.5° E, about 430 kms southeast of Gopalpur at 0300 UTC and near Lat. 18.0° N / Long 88.0° E at 1200 UTC of 14. Further, it moved northwestwards and intensifiied into a Deep Depression and lay at 0300 UTC of 15 over northwest Bay of Bengal centred near Lat. 19.0° N / Long. 87.0° E, about 220 kms eastsoutheast of Gopalpur. Moving westwards, it lay centred at 1200 UTC over northwest Bay of Bengal, close to Orissa coast near Lat. 19.5° N / Long. 85.5° E, about 50 kms southsouthwest of Puri. It moved westwards and crossed Orissa coast near Gopalpur between 1500 & 1600 UTC of 15. It continued to move in a westerly direction and weakened into a Depression and lay centred at 0000 UTC of 16 over south Orissa and adjoining areas of Chhatisgarh and north Andhra Pradesh, about 50 kms west of Gopalpur (Lat. 19.0° N / Long. 84.0° E). Continuing the westerly course, it weakned into a well marked low pressure area over south Orissa and adjoining Chhatisgarh & north Andhra Pradesh on 16 morning. On 17 morning, it lay over south Chhatisgarh and adjoining Vidarbha and Telangana and over Telangana and neighbourhood in the evening. It continued to move in a near westerly direction as low pressure area and moved across Vidarbha, Marathwada and Madhya Maharashtra and finally became less marked on 20 over the east central Arabian Sea off Maharashtra coast.

3.4.2 Other features observed

The Estimated lowest Central Pressure (ECP) was 995.0 hPa at 1200 UTC of 15. The estimated maximum wind speed was 30 kts during the period 0300 UTC to 2300 UTC of 15. The system moved in a northwesterly direction throughout its course and crossed Orissa coast near Gopalpur between 1500 & 1600 UTC of 15. As per the hourly observation

from Orissa, Gopalpur recorded the lowest pressure of 994.6 hPa (wind 340°/10 kts) at 1000 UTC of 15; which is very close to the estimated central pressure. Puri reported maximum wind speed of 25 kts from 1600 UTC to 1800 UTC of 15.

3.4.3 Weather and damage caused

No damage in Orissa and Andhra Pradesh. Heavy to very heavy rainfall occurred at isolated places over coastal Orissa on 15 and 16. Heavy rainfall occurred at isolated places in Andhra Pradesh on 15.

Some significant amounts of rainfall (in cm) are:

Gangetic West Bengal

15 Oct.: Basirhat 11, Uluberia 8.

Orissa

15 Oct: Paradeep 14, Pattamundai 9, Pipili, Bhadrak, Kendrapara, Rajkanika, Khandapara 8, Nimapara, Mahendragarh, Alipingal 7.

16 Oct. : Kosagumda 24, Junagarh, Umarkote 15, Jaipatna 14, R. Udaigiri 13, Soro 12, Parlakhemundi, Nawarangpur 11, Kalinga, Jeypore 9, Bhawanipatna, Daringibadi 8, Rayagada, Koraput 7.

Andhra Pradesh

15 Oct: Palasa 8.

Chhatisgarh

16 Oct.: Jagdalpur 11, Narayanpur, Kondagaon 8.

3.4.4 Satellite and RADAR observations

The system was tracked initially with the help of satellite cloud imageries. From 0000 UTC of 13 onwards, it was also tracked by DWR. Hourly coastal observations and AWS observations of Andhra Pradesh were also recorded after 0000 of 13. The maximum intensity of T. No. 2.0 was reported from 0300 to 1800 UTC of 15. As per satellite observations, the system crossed south Orissa coast around 1800 UTC of 15 and lay over land with centre near Lat. 19.0° N/Long. 84.7° E.

The system was tracked by CDR Paradip and RAREPs were issued.

3.5 Very Severe Cyclonic Storm (Giri) over the Bay of Bengal (20–23 Oct. 2010)

3.5.1 A low pressure area formed over east central Bay of Bengal and neighbourhood on 19. It concentrated into a Depression at 1200 UTC of 20 and lay centred near Lat. 17.5° N / Long. 91.5° E, about 550 kms southeast of Digha. Remaining practically stationary, it intensified into a Deep Depression at 0300 UTC of 21 and further into a Cyclonic Storm (Giri) at 0600 UTC. It then moved northeastwards and lay centred at 1200 UTC near Lat. 18.0° N / Long. 92.0° E, about 600 kms southeast of Digha. Continuing the northeasterly movement, it further intensified into a Severe Cyclonic Storm at 0000 UTC of 22 and lay over east central and adjoining northeast Bay of Bengal centred near Lat. 18.5° N / Long. 92.5° E. It further intensified into a Very Severe Cyclonic Storm and lay at 0300 UTC 22 over northeast Bay of Bengal centred near Lat. 19.0° N / Long. 93.0° E. Further, it moved north-northeastwards and lay centred at 1200 UTC centered near Lat. 19.8° N / Long. 93.5° E, close to Myanmar

coast, about 100 kms southeast of Sittwe (Myanmar). Taking a northerly course, it crossed Myanmar coast about 70 kms eastsoutheast of Sittwe (Myanmar) around 1400 UTC of 22 and lay at 1500 UTC over coastal areas of Myanmar centred near Lat. 20.0° N / Long. 93.5° E, about 70 kms eastsoutheast of Sittwe (Myanamar). Further, it moved northeastwards and weakened into a Severe Cyclonic Storm at 2100 UTC and lay centered near Lat. 20.5° N / Long. 94.0° E. Weakening further into a Cyclonic Storm, it lay centered at 0000 UTC of 23 centered near Lat. 21.0° N / Long. 94.5° E. It continued to move in a northeasterly direction and lay centred at 0300 UTC of 23 near Lat. 21.5° N / Long. 95.0° E, about 70 kms southsouthwest of Monywa (Myanmar). It weakened into a Depression and lay centered near Lat. 22.0° N / Long. 95.5° E at 0600 UTC of 23. It lay as well marked low pressure area over central parts of Myanmar in the evening of 23 and became less marked thereafter.

3.5.2 Other features observed

The Estimated Lowest Central Pressure (ECP) was 950 hPa from 0900 UTC till the system crossed Myanmar coast. The estimated maximum wind speed was 105 kts.

3.5.3 Weather and damage caused

As the system moved away from the east coast of India, it did not affect the weather over India.

3.5.4 Satellite and RADAR observations

The system was tracked with the help of satellite cloud imageries from 0600 UTC of 20 to 1400 UTC of 22 October. The maximum intensity of T. No. 5.5 was reported from 0900 of 20 till it crossed Myanmar coast.

At 0900 UTC of 22, the cloud pattern indicated sharp improvement in organization and convection around the vortex centre and also decrease in diameter of EYE, which is indicative of explosive intensification. Thus, Very Severe Cyclonic Storm (Giri) gained its maximum intensity with centre near Lat. 19.2° N / Long. 93.1° E and T 5.5 at 0900 UTC of 22.

3.6 Severe Cyclonic Storm (Jal) over the Bay of Bengal (4–8 Nov. 2010)

3.6.1 A low pressure system emerged into the Andaman Sea from the east and lay as a low pressure area over the south Andaman Sea and neighbourhood in the evening of 2. It lay as a well marked low pressure area over the same region in the morning of 3. It concentrated into a Depression and lay over the southeast Bay of Bengal and neighbourhood centred near Lat. 8.0° N / Long. 92.0° E at 0000 UTC of 4. It moved westnorthwestwards and lay at 0300 UTC centred near Lat. 8.5° N / Long. 91.0° E and moving westwards, it lay centered at 1200 UTC near Lat. 8.5^0 N / Long 90.0^0 E. Further moving westnorthwestwards, it concentrated into a Deep Depression at 0000 UTC of 5 and lay centered near Lat.9.0^0 N/Long 88.5^0 E and at 0300 UTC, it lay centred near Lat. 9.0^0 N / Long 88.0^0E. Moving in a northwesterly direction, it further intensified into a Cyclonic Storm (Jal) at 0600 UTC of 5 and lay centered near Lat. 9.0° N / Long. 87.5° E and 1200 UTC of near Lat. 9.5° N / Long. 87.0° E. Taking a westnorthwesterly course, it further intensified into a Severe Cyclonic Storm at 2100 UTC of 5 and lay centred near Lat. 10.0° N / Long. 86.0° E. It moved slightly westwards and lay centred near Lat. 10.0° N / Long. 85.5° E at 0300 UTC of 6. It then moved northwestwards and lay centered at 1200 UTC near Lat. 11.0^0 N / Long. 84.5^0 E. It continued to move in the same direction and lay over the southwest Bay of Bengal at 0300 UTC of 7 centered near Lat. 12.0^0 N / Long.83.0^0 E. It weakened into a Cyclonic Storm and lay centred near Lat. 12.5° N / Long. 82.5° E at 0600 UTC and near Lat. 13.0° N / Long. 81.0° E at 1200 UTC. It

moved westwards and further weakened into a Deep Depression and lay at 1500 UTC centered near Lat. 13.0° N / Long.80.5° E. Moving northwestwards, it crossed north Tamil Nadu-south Andhra Pradesh coasts, close to north of Chennai near Lat. 13.3° N / Long. 80.2° E around 1600 UTC of 7 and lay over coastal areas of north Tamil Nadu-south Andhra Pradesh, centred near Lat. 13.5° N / Long. 80.0° E (about 60 kms northwest of Chennai) at 1800 UTC. It moved westnorthwestwards and weakened into a Depression and lay at 0000 UTC of 8 over Rayalaseema and neighbourhood centred near Lat. 14.0° N / Long. 79.0° E. Moving northwestwards, it lay at 0300 UTC of 8 over Rayalaseema, centred about 50 kms northeast of Anantpur (Lat. 15.0° N / Long. 78.0° E). Moving slightly westwards, it further weakened into a well marked low pressure area over Rayalaseema and adjoining south interior Karnataka by 0600 UTC and over interior Karnataka and adjoining south Madhya Maharashtra in the evening of 8. On 9 morning, it lay over the east central Arabian Sea off south Maharashtra-Goa coasts and over the east central Arabian Sea off Maharashtra coast in the evening. It lay over the northeast Arabian Sea off Gujarat coast in the morning of 10.

3.6.2 Other features observed

The Estimated lowest Central Pressure (ECP) observed was 988 hPa. The estimated maximum wind speed was 60 kts. As per DWR Chennai and DWR SHAR reports, the system started weakening from 0300 UTC of 7 while continuing its northwesterly track and crossed the coast as Deep Depression north of Chennai, close to SHAR around 1800 UTC.

BUOY Observations: The cyclone 'Jal' formed in the south Bay of Bengal was well captured by the 3 data buoys viz. BD6, BD07_Omni & BD06_Omni, which are deployed in the Bay of Bengal; out of which 2 are equipped with sub-surface oceanographical instruments upto 500 meters depth which were deployed on 24 & 26 October 2010 and third buoy BD06 has an indigenize CPU.

The BUOYs (i) BD06_OMNI (Lat. 9.9° N / Long. 88.4° E) Met Sub-Surface Ocean upto 500 meters depth (ii) BD07_OMNI (Lat. 8° N / Long. 88.5° E) Met. Sub-Surface Ocean upto 500 meters depth & Wave and (iii) BD6 (Lat. 17.989° N, Long. 88.089° E) Met and Sea Surface Current. were recently deployed by NIOT.]

The passge of the Jal was along these newly deployed BUOYs. Among these BUOYs, the BD07_OMNI buoy recorded maximum wind speed of 16 mps on 5 around 2000 UTC.

DWR SHAR:

Effect of Cyclone over SHAR and surrounding areas: The high wind force dominated over the precipitation. The prevailing wind speed was of the order of 35-45 kmph on an average and the maximum wind speed was 24 mps at 0500 UTC on 07 (based on the MET-SHAR wind profiler). The tidal waves were in the range of 1-3 meters.

3.6.3 Weather and damage caused

Eleven people died in Andhra Pradesh. Hundreds of houses were damaged and crops over about 15,000 hectares were destroyed. A loss of about 83 crores was estimated.

Five persons lost their lives in Tamil Nadu. About 100 pucca / kutcha houses were either fully or partially damaged. Many boats were damaged and some were also missing due to floods. Rail, road and air transports were affected due to heavy rains. Sea water inundated low lying areas.

Very heavy to heavy rainfall occurred on 8 & 9 in Andhra Pradesh with isolated extremely heavy falls on 8.

Some significant amounts of rainfall (in cm) are:

Tamil Nadu

8 Nov.: Gingee 16, Panruti 15, Ambur 13, Vaniyambadi 12, Tiruvannamalai, Alangayam 11, Tindivanam, Villupuram, Puducherry 10, Cuddalore, Vanur, Thali 9, Chengalpattu, Polur, Krishnagiri 8, Dharmapuri, Palacode, Tirukoilur, Vandavasi, Arakonam, Gudiyatham, Sholinghur, Tirupattur, Vellore 7

Andhra Pradesh

8 Nov.: Palasa 27, Sompeta 14, Ichhapuram 12, Kalingapatnam 10, Tekkali 9, Bheemunipatnam 8, Nellore, Anakapalli, Mandasa, Kandukur, Sullurpet 7 each.

9 Nov.: Ichhapuram 9, Bobbili 7.

3.6.4 Satellite and RADAR observations

The system was tracked by Satellite from 0600 UTC of 2 Nov. till the landfall. The maximum intensity of T 3.5 was reported from 2100 UTC of 5 to 0500 UTC of 7.

DWR SHAR: The RADAR operation recorded hourly observation and transmitted to HQ offices and to user agencies from 0300 UTC of 6. It was observed that the Cyclonic Storm started moving towards the coast in a westnorthwesterly direction. The structure/Eye of the Cyclone was not so well defined as the RADAR echoes did not have the required properties of a cyclone eye. The cloud heights were about 5 to 6 kms; the reflectivity in the wall cloud region was about 35-45 dBz maximum. General maximum velocities recorded are about 20-23 mps.

The likely cloud center locations of the system are presented below along with related description. Arrangement of cloud, radial velocity diagrams are taken in to consideration while trying to fix the Cyclonic system center.

DATE/ TIME(UTC)	Azimuth In deg.	Range in kms			REMARKS
06.11.2010					
0654					Part of the wall cloud region seen in the RDR range
1655					Wall cloud region touched the Stn, centre not clear
07.11.2010					
0000	140	200	12.44	81.49	Estimated from the wall cloud region.
0053	140	180	12.57	81.41	-do-
0153 140		150	12.67	81.12	-do-
0254	140	150	12.67	81.12	-do-
0355	----	-----	------	------	Centre not well defined.
0455	-----	-----	------	------	-do-
0554	140	110	13.06	80.85	Estimated from Wall cloud region.
0656	-----	-----	------	------	Centre seems to dissipated.
0801	135	110	13.04	80.91	Spiral Bands visible.
0859	135	110	13.01	80.83	Spiral bands getting dissipated
0957	----	-----	------	------	Inner last band cloud over

					SHAR.
1054	----	-----	------	------	All Spiral bands appeared to have crossed the SHAR coast.
1200/1300	----	-----	------	------	System appears to be weakened.
1400	130	090	13.22	80.84	Spiral bands re-appeared.
1455	120	060	13.43	80.66	-do-
1554	100	050	13.44	80.63	Centre close to SHAR.
1654	100	025	13.57	80.43	-do-
1755	----	----	------	------	Vortex of the System appears to be over SHAR.

DWR Chennai: The system was tracked from 0400 to 1800 UTC of 7. The vertical wind shear had detrimental effect on weakening the system at sea level. The centre of mass of dense convection area crossed north Cuddalore by about 0600 UTC of 7. Surface wind speed associated with the weak vortex was not more than 25 kts at any time. No bulletin was issued as the intensity of the system as seen by the RADAR had been very weak and deformed.

CDR Karaikal: Hourly special observations were taken from 0000 UTC of 5 to 1500 UTC of 7. Special upper air ascents were taken at 0600 & 1800 UTC in addition to 0000 & 1200 UTC ascents.

3.7 Depression over the Bay of Bengal (7-8 December 2010)

3.7.1 A trough of low at sea level lay over the southeast Bay of Bengal and adjoining south Andaman Sea on 2 and over the southwest Bay of Bengal off Tamil Nadu-Sri Lanka coasts on 3. It organized into a low pressure area over the southwest Bay of Bengal on 4 and persisted there on 5. It became well marked over the same region on 6, subsequently concentrated into a Depression and lay centered at 0300 UTC of 7 over the southwest and adjoining west central Bay of Bengal, near Lat. 14.0^{o} N / Long. 82.0^{o} E (about 230 kms southeast of Kavali). Moving northnorthwestwards, it lay centred at 1200 UTC of 7, near Lat. 15.0^{o} N / Long. 81.5^{o} E (about 150 km eastsoutheast of Ongole). Then it moved northwestwards and crossed Andhra Pradesh coast near Bapatla around 2000 UTC of 7 and lay centred at 0000 UTC of 8, about 50 kms northwest of Bapatla (Lat. 16.0° N / Long. 80.0° E). Subsequently, it weakened into a well marked low pressure area and lay over coastal Andhra Pradesh and neighbourhood in the morning of 8.

3.7.2 Other features observed

The Estimated Lowest Central Pressure (ECP) observed was 1000 hPa. The estimated maximum wind speed was 25 kts. The system moved in a northnorthwesterly direction and crossed Andhra Pradesh coast near Bapatla in the early hours of 8.

3.7.3 Weather and damage caused

Heavy rains claimed 2 lives in Andhra Pradesh. As the Depression did not cross Tamil Nadu coast, there was no serious loss of life and property. However, when it was located over west central Bay of Bengal off south Andhra Pradesh coast; Tamil Nadu received bountiful rainfall almost in all the districts of Tamil Nadu with heavy rainfall over Kanyakumari district in which 4500 huts were damaged and about thousand acres of Paddy field were submerged.

Northeast monsoon was vigorous in Andhra Pradesh from 6 to 8. Widespread rainfall activity with heavy to very heavy falls at isolated places occurred over coastal Andhra Pradesh on 7 & 8. Heavy to very heavy rainfall also occurred over Tamil Nadu from 6 to 8.

Some chief amounts of rainfall are:

Tamil Nadu

6 Dec.: Mahabalipuram 13, Anna University 11, Chennai AP 10, Cheyyur, Chengalpet, Ponneri 9.

7 Dec.: Ponneri, Poonamally, Mahabalipuram 7.

8 Dec.: Kuzhithurai 24, Boothapandi, Pechiparai 17, Tiruchendur 15, Radhapuram 10, Thuckalay 9, Nanguneri 7.

Andhra Pradesh

7 Dec: Bapatla, Narsapur 10, Repalle, Sullurpet 9, Tada 8, Sattenapalli, Kailaur, Machilipatnam, Nuzvid, Gudur, Bhimavaram 7.

8 Dec.: Ranasthalam 14, Tekkali, Cheepurpalli 13, Kakinada, Kalingapatnam, Araku Valley 12, Macherla, Udayagiri, Vinjamur, Cumbum, Visakhapatnam, Salur, 11, Amalapuram, Peddapuram, Patapatnam, Elamanchili, Srungavarapukota, Terlam, Vizinagaram 10.

3.7.4 Satellite and RADAR observations

As per the satellite observations, the system continued to move in northwesterly direction; weakened into a low level circulation at 0000 UTC of 8 and crossed coast at 0300 UTC of the same day centered near Lat. 16.5° N / Long. 80.5° E. The maximum intensity of T 1.5 was reported from 0300 UTC of 7 to 2300 UTC of 8.

Table 2.1: Cyclonic disturbances formed over north Indian Ocean and adjoining land areas during 2010

1.	Severe Cyclonic Storm (Laila) over the Bay of Bengal (17-21 May 2010)
2.	Cyclonic Storm (Bandu) over the Arabian Sea (19–23 May 2010)
3.	Very Severe Cyclonic Storm (Phet) over the Arabian Sea (31 May–7 June 2010)
4.	Depression over the Bay of Bengal (7- 8 October 2010)
5.	Deep Depression over the Bay of Bengal (13–16 Oct. 2010)
6.	Very Severe Cyclonic Storm (Giri) over the Bay of Bengal (20–23 Oct. 2010)
7.	Severe Cyclonic Storm (Jal) over the Bay of Bengal (4–8 Nov. 2010)
8.	Depression over the Bay of Bengal (7-8 December 2010)

Table 2.2: Some characteristic features of cyclonic disturbances formed over north Indian Ocean and adjoining region during 2010

Cyclonic Storm ./ Depression	**Date, Time & Place of Genesis (Lat. ° N /Long. ° E)**	**Date, Time (UTC) & Place (Lat. ° N /Long. ° E) of Landfall**	**Estimated lowest central pressure, Time & Date (UTC) & Lat. ° N /Long. ° E**	**Estimated Maximum Wind Speed (kt), Date & Time**	**Max. T. No. Attained**
Severe Cyclonic	17 May 0600 UTC	Crossed Andhra	986 hPa at 0600 UTC of	55 kt at 0600 UTC of 19	3.5

Storm (Laila) over the Bay of Bengal during 17 – 21 May 2010	near 10.5/88.5	Pradesh coast near Bapatla (16.0/80.5) between 1100 & 1200 UTC of 20	19 May near 13.5/81.5	May	
Cyclonic Storm (Bandu) over the Arabian Sea during 19 – 23 May 2010	19 May 0900 UTC near 10.5/54.0	-	994 hPa at 1200 UTC of 21 May near 12.5/51.5	40 kt at 1200 UTC of 21 May	2.5
Cyclonic Storm ./ Depressio n	**Date, Time & Place of Genesis (Lat. ° N /Long. ° E)**	**Date, Time (UTC) & Place (Lat. ° N /Long. ° E) of Landfall**	**Estimated lowest central pressure, Time & Date (UTC) & Lat. ° N /Long. ° E**	**Estimated Maximum Wind Speed (kt), Date & Time**	**Max. T. No. Attained**
Very Severe Cyclonic Storm (Phet) over the Arabian Sea during 31 May – 7 June 2010	31 May 0600 UTC near 15.0/64.0	Crossed Oman coast Near Lat. 21.5° N between 00 & 02 UTC on 4 and Pakistan coast close to Karachi (24.7/67.2) between 1230 and 1330 UTC on 6.	964 hPa at 1200 UTC of 2 June near 18.0/60.5	85 kt at 1200 UTC of 2 June	4.5
Depression over the Bay of Bengal during 7- 8 October 2010	7 Oct. 0300 UTC near 16.5/84.5	crossed West Bengal-Bangladesh coasts near Long. 88.5º E between 0500 & 0600 UTC of 8.	996 hPa at 1200 UTC of 7 Oct. near 18.5/85.0	25 kt at 1200 UTC of 7 Oct.	1.5
Deep Depression over the Bay of Bengal during 13 – 16 October 2010	13 Oct. 0600 UTC near 17.5/90.0	crossed Orissa coast, close to Gopalpur (43049)betwe en 1500 & 1600 UTC of 15.	995 hPa at 1200 UTC of 15 Oct. near 19.5/85.5	30 kt at 1200 UTC of 15 Oct.	2.0
Very Severe Cyclonic Storm (Giri)	2 0 Oct. 1200 UTC near	Crossed Myanmar coast near 20.0/93.5	950 hPa at 0900 UTC of 22 Oct. near 19.8/93.5	105 kt at 1200 UTC of 22 Oct.	5.5

over the Bay of Bengal during 20 – 23 October	17.5/91.5	about 70 kms eastsoutheast of Sittwe (Myanmar) around 1400 UTC of 22.			

Cyclonic Storm ./ Depression	**Date, Time & Place of Genesis (Lat. ° N /Long. ° E)**	**Date, Time (UTC) & Place (Lat. ° N /Long. ° E) of Landfall**	**Estimated lowest central pressure, Time & Date (UTC) & Lat. ° N /Long. ° E**	**Estimated Maximum Wind Speed (kt), Date & Time**	**Max. T. No. Attained**
Severe Cyclonic Storm (Jal) over the Bay of Bengal during 4 – 8 November 2010	4 Nov. 0000 UTC near 8.0/92.0	Crossed north Tamil Nadu-south Andhra Pradesh coasts, close to north of Chennai (43279) around 1600 UTC of 7.	988 hPa at 1200 UTC of 6 Nov. near 11.0/84.5	60 kt at 1200 UTC of 6 Nov.	3.5
Depression over the Bay of Bengal during 7 – 8 December	7 Dec. 0300 UTC near 14.0/82.0	Crossed south Andhra Pradesh coast near Bapatla (43220) around 2000 UTC of 7.	1000 hPa at 0300 UTC of 7 Dec.	25 kts at 0300 UTC of 7 Dec.	1.5

Table 2.3: Statistical data relating to cyclonic disturbances over the north Indian Ocean during 2010

A) Monthly frequencies of cyclonic disturbances (CI ≥ 1.5)

S. No.	**Type**	**Jan**	**Feb.**	**Mar**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1.	D										*		*
2.	DD										*		
3.	CS					*							
4.	SCS					*						*	
5.	VSCS					*					*		
6.	Su CS												

*Peak intensity of the system

B) Frequency distribution of cyclonic disturbances during 2010 with different intensities based on satellite assessment

CI No.	**≥ 1.5**	**≥ 2.0**	**≥ 2.5**	**≥ 3.0**	**≥ 3.5**	**≥ 4.0**	**≥ 4.5**	**≥ 5.0**	**≥ 5.5**
No. of disturbances	8	6	5	4	4	2	2	1	1

C) Basin –wise distribution of cyclonic disturbances

Basin	**Number of cyclonic disturbances**
Bay of Bengal	6
Arabian Sea	2
Land Depression	-

Table 2.4 Cyclonic disturbances formed over north Indian Ocean and land areas of India during 1997-2010

Year	**Basin**	**D**	**DD**	**CS**	**SCS**	**VSCS**	**SuCS**	**Total**
1998	BOB	0	3	0	1	2	0	6
	ARB	0	1	1	1	1	0	4
	Land	1	0	0	0	0	0	1
	Total	**11**						
111999	BOB	1	3	1	0	1	1	7
	ARB	0	0	0	0	1	0	1
	Land	1	0	0	0	0	0	1
	Total	**10**						
2000	BOB	1	3	2			0	6
	ARB	0	0	0	0	0	0	0
	Land	1	0	0	0	0	0	0
	Total	**6**						
2001	BOB	2	0	1	0	0	0	3
	ARB	0	0	2	0	0	0	3
	Land	0	0	0	0	0	0	0
	Total	**6**						
2002	BOB	1	1	2	1	0	0	5
	ARB	0	0	0	0	0	0	1
	Land	0	0	0	0	0	0	0
	Total	**6**						
2003	BOB	2	2	0	1	1	0	6
	ARB	0	0	0	1	0	0	1
	Land	0	0	0	0	0	0	0
	Total	**7**						
2004	BOB	2	0	0	0	1	0	3
	ARB	0	2	0	3	0	0	5
	LAND	2	0	0	0	0	0	2
	Total	**10**						
2005	BOB	2	3	4	0	0	0	9
	ARB	2	0	0	0	0	0	2
	LAND	1	0	0	0	0	0	1
	Total	**12**						
2006	BOB	5	2	1	0	1	0	9
	ARB	0	1	0	1	0	0	2
	LAND	1	0	0	0	0	0	1
	Total	**12**						

2007	BOB	3	4	1	0	1	0	9
	ARB	0	1	1	0	0	1	3
	Land	0	0	0	0	0	0	0
	Total	**12**						
2008	BOB	1	2	3	0	1	0	7
	ARB	1	1	0	0	0	0	2
	LAND	1	0	0	0	0	0	1
	Total	**10**						
2009	BOB	0	2	2	1	0	0	5
	ARB	2	0	1	0	0	0	3
	LAND	0	0	0	0	0	0	0
	Total	**8**						
2010	BOB	2	1	0	2	1	0	6
	ARB	0	0	1	0	1	0	2
	LAND							
	Total	**8**						

D: Depression, **DD:** Deep Depression, **CS:** Cyclonic Storm, S**CS:** Severe Cyclonic Storm
VSCS: Very Severe Cyclonic Storm, **SuCS:** Super Cyclonic Storm
BOB: Bay of Bengal, **ARB:** Arabian Sea

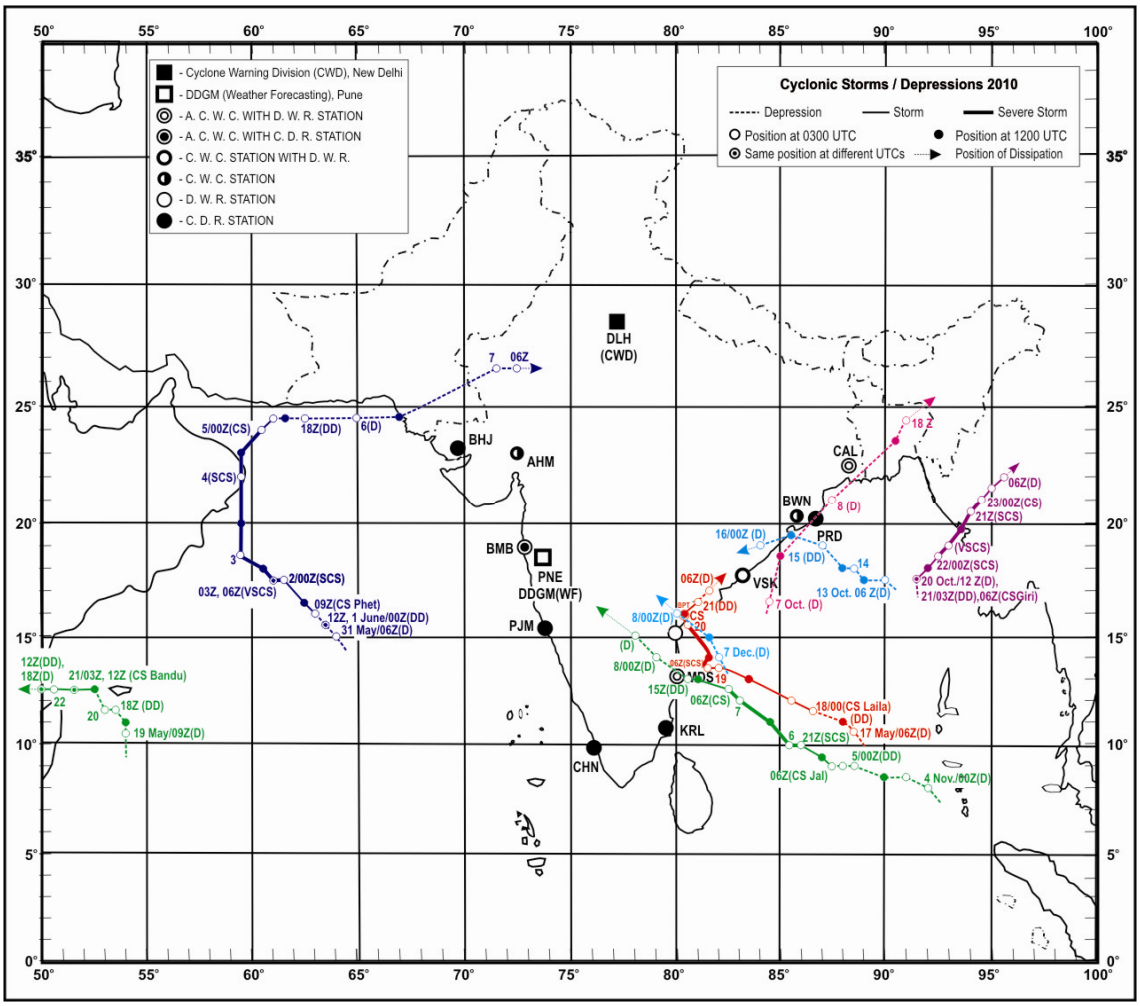


Fig. 2.1 Tracks of the cyclonic disturbances formed over the north India Ocean during the year 2010

Country Report of Members

Thirty-eight session of WMO/ESCAP Panel on Tropical Cyclones (New Delhi, India, 21-26 February, 2011)

SHAMSUDDIN AHMED
ASSISTANT DIRECTOR
BANGLADESH METEOROLOGICAL DEPARTMENT

Country Report on 2010 Cyclone Season Bangladesh

Cyclonic Storm 'Laila' over North Bay during 17-20 May 2010:

A low formed over Andaman Sea and adjoining Southeast Bay at 0600UTC of 16 May 2010. Then it moved west-northwestwards and intensified into a well-marked low over Southeast Bay and adjoining area on 17 May 2010. The system further intensified into Depression at 0900UTC of 17 May 2010 over the same area. Then it moved northwestwards and again intensified in a Deep Depression over same area at 1500UTC of same day.

After that it moved almost northwestwards and intensified further into a cyclonic storm 'Laila' over the same area at 0000 UTC of 18 May 2010. Then it moved continuously northwestwards and finally crossed northeast Andhra Coast of India near Machalipatnum in the afternoon (at about 1200UTC) of 20 May 2010 and lay over Bapatla and adjoining area and weakened afterwards. The track of the cyclonic storm 'Laila' is illustrated in Fig. 1.

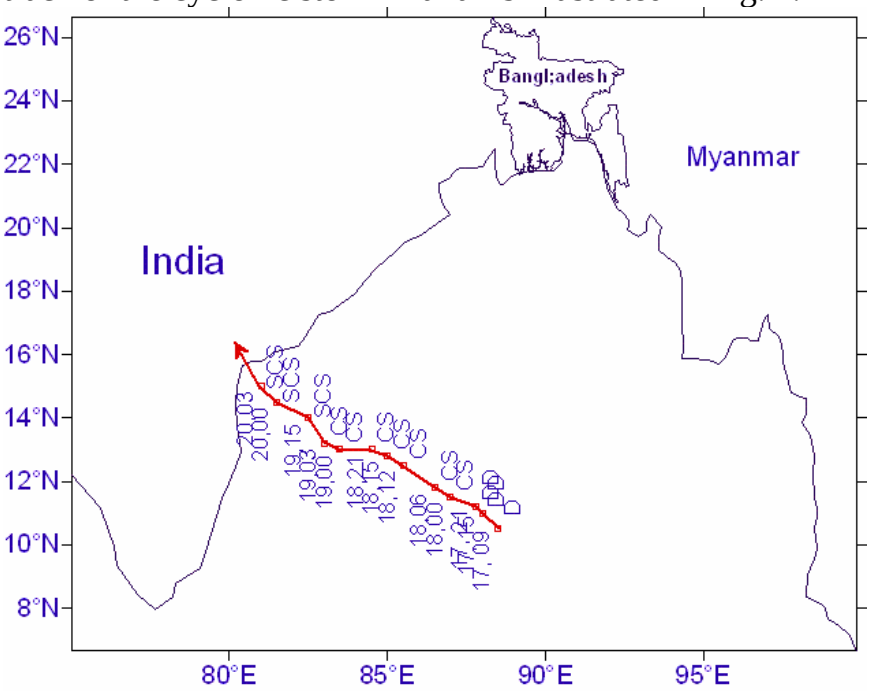


Figure 1: BMD observed track of cyclonic storm 'Laila' during **17-20 May 2010**.

Depression over west central Bay 7-8 October 2010:

A low formed over West Central Bay and adjoining North Bay in the morning of 07 October 2010 and concentrated into a Depression (with central position 17.0°N and long 85.0°E) at 0900UTC of same day. The system moved initially northwards and recurved towards West Bengal-Bangladesh Coast them to Bangladesh coast. Finally it crossed Khulna-Barisal coast of Bangladesh coast

near Mongla in the morning of on 08 October 2010. The track of the depression is given in Fig. 2.

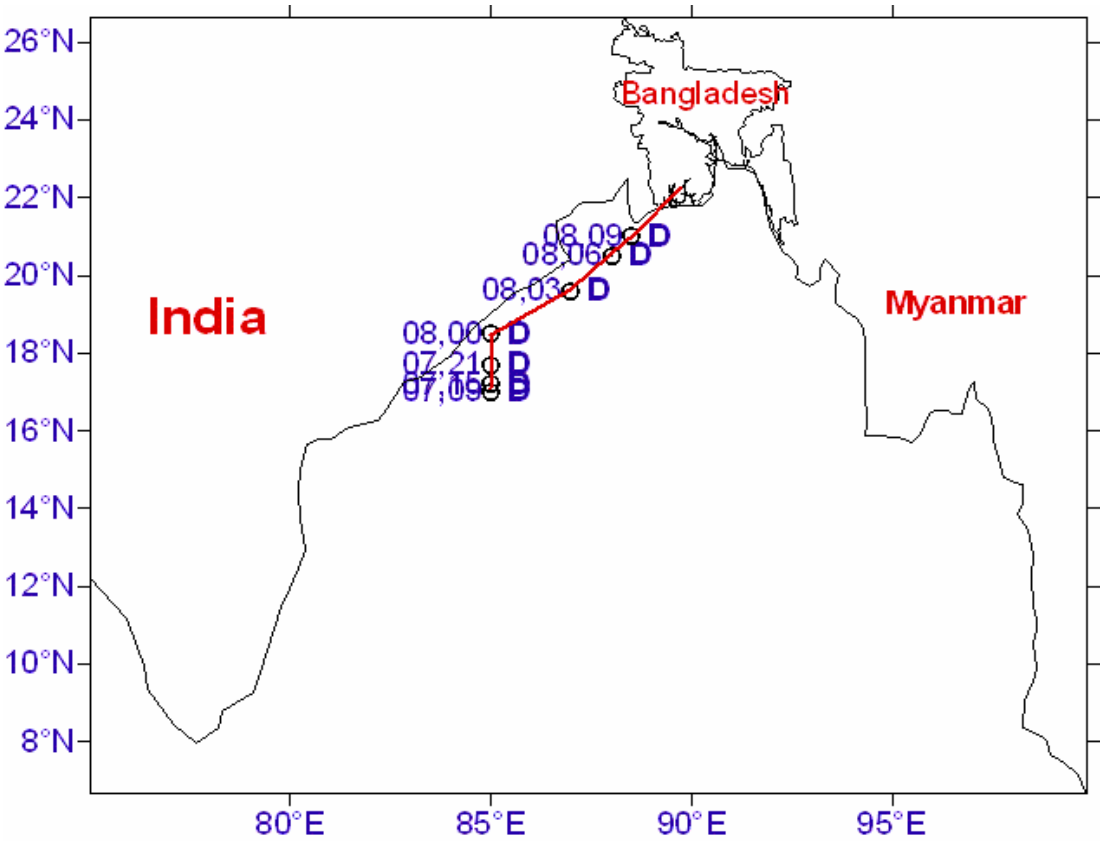


Fig. 2: BMD observed track of Depression during 07-08 October 2010.

Depression over North Bay during 13-15 October 2010:

A low formed over East Central Bay and adjoining area on 12 October 2010. On 13 October the system intensified into a well-marked low over the same area. Then the system moved northwestwards and intensified into a depression at 0000UTC of 13 October and deep depression at 0000UTC of 14 October 2010 over East Central Bay and adjoining West Central Bay and North Bay. After that it moved continuously northwestwards and crossed Orissa coast near Gopalpur (India) at 2100UTC of 15 October 2010 and located over Orissa and adjoining area as a land depression. After that the system moved northwestwards, weakened gradually by giving precipitation and became unimportant. The track of the Deep Depression is illustrated in Fig. 3. During the life time of Deep Depression steep pressure gradient persists over North Bay and deep convection was taking place. Therefore high wind and heavy rainfall were recorded in the coastal districts of Bangladesh.

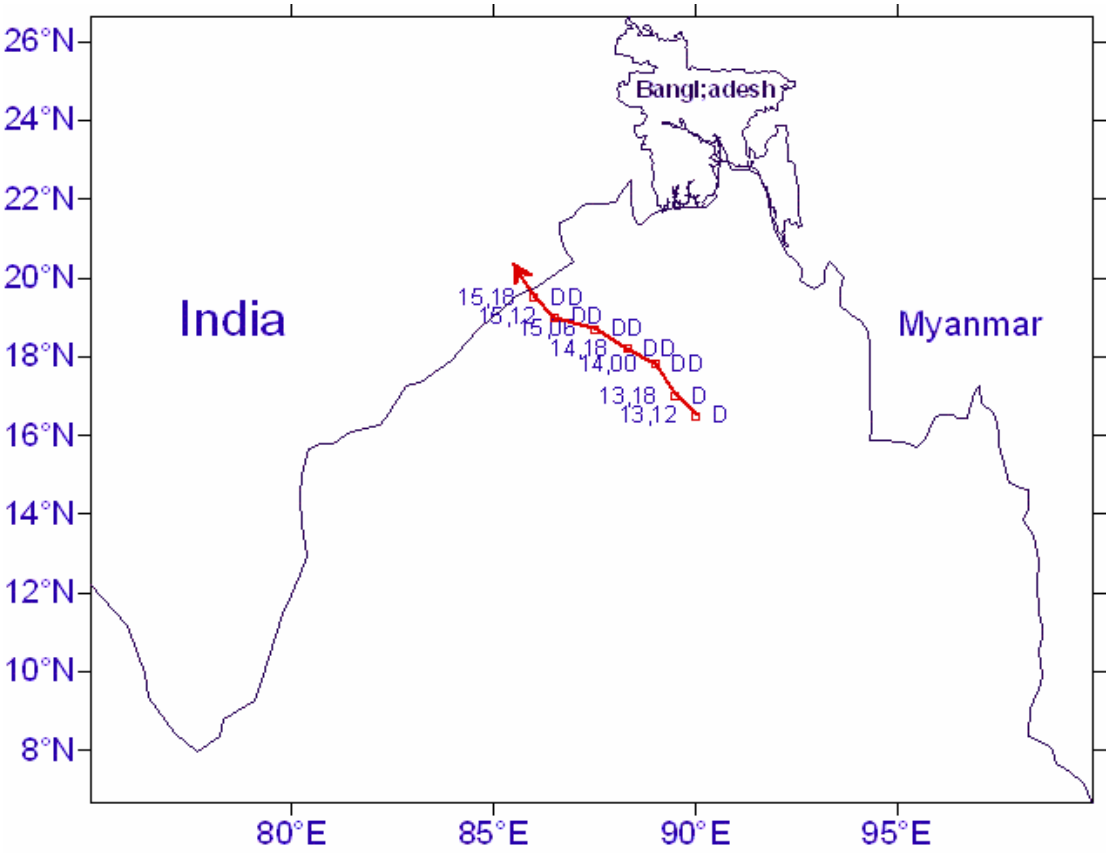
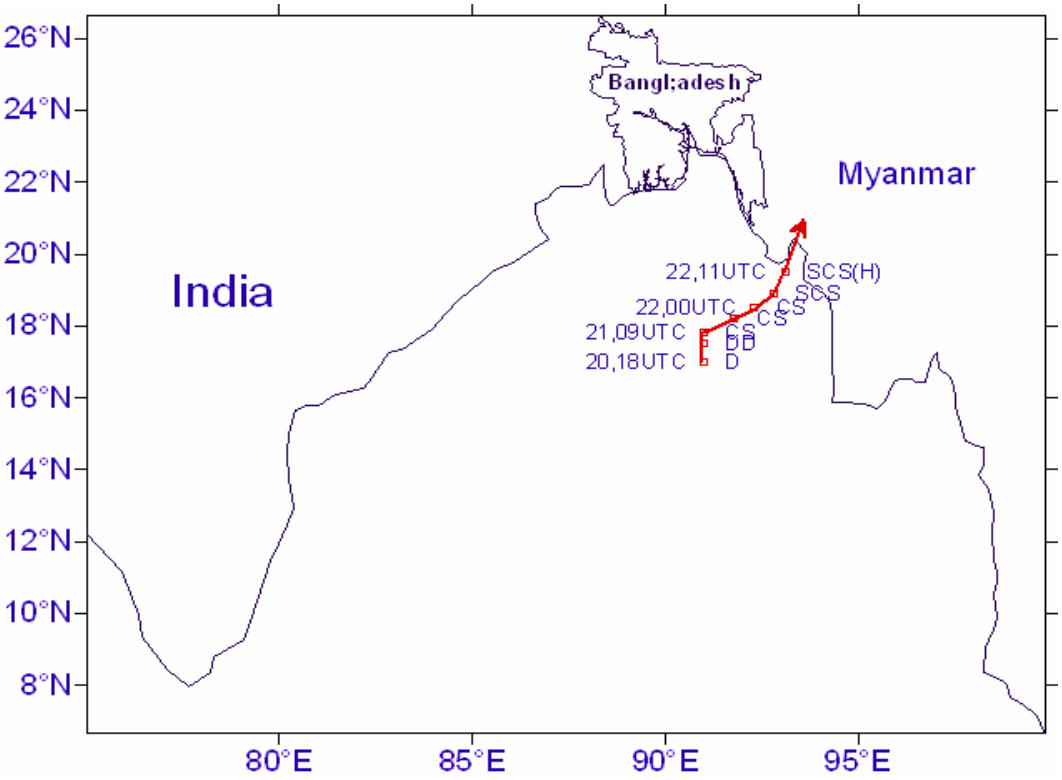


Fig. 3: BMD observed track of Depression during 13-15 October 2010.

Cyclonic Storm 'GIRI' over North Bay during 20-22 October 2010:
A low formed over north Andaman Sea and adjoining East Central Bay on 18 October 2010. Then it moved northwestwards over East Central Bay and adjoining area and intensified into a well-marked low. After that the system moved slightly northwards and concentrated into a depression over East Central Bay and adjoining Northeast Bay at 1800UTC of 20 October 2010. At 0600UTC of 21October 2010, the system intensified further into a Deep Depression over the same area. At 0900UTC of same day the system again intensified into a cyclonic storm 'GIRI' over North Bay and adjoining East Central Bay and moved north-northeastwards. At 0600UTC and 1100UTC of 22 October the system further intensified into a severe cyclonic storm 'GIRI' and severe cyclonic storm with a core of hurricane winds 'GIRI' respectively. At about 1400UTC of 22 October, the system started to cross Myanmar Coast (south of Sittwe) and completed crossing the coast during next 3-4 hours and weakened afterwards. During this period gusty winds were recorded in the southeastern parts of Bangladesh and no casualties were reported. The track of the severe cyclonic storm 'GIRI' is illustrated in Fig. 4.



BMD observed track of severe cyclonic Storm 'GIRI' during 20-22 October 2010 of cyclone 'GIRI' October 2010

Cyclone 'Jal' during 04-07 November 2010:

A low formed over south Andaman Sea and adjoining area on 02 November 2010, moved westwards and concentrated into a depression at 0600UTC of 04 November 2010. Then the system moved mainly westwards into Southwest Bay and adjoining areas and intensified into deep depression at 0300UTC of 05 November 2010. At 0600UTC of same day the system intensified into a cyclonic storm 'Jal' over the same area. Moving continuously towards west-northwesterly or northwesterly direction the system further intensified into a severe cyclonic storm 'Jal' at 0000UTC of 06 2010 over Southwest Bay and adjoining Southeast Bay.

November After that it moved northwestwards to Tamilnadu coast of India over Southwest Bay but remained practically stationary for sometime on the way of its movement. But at 0900UTC of 07 November 2010 when it was slightly away from the Tamilnadu coast of India, the system weakened into a cyclonic storm 'Jal' as it lost it energy by giving high amount precipitation. After that system started to cross north Tamilnadu coast of India and by midnight of same day it crossed Tamilnadu coast of India near Chennai. The observed path of the cyclonic storm 'Jal' is illustrated in fig 5

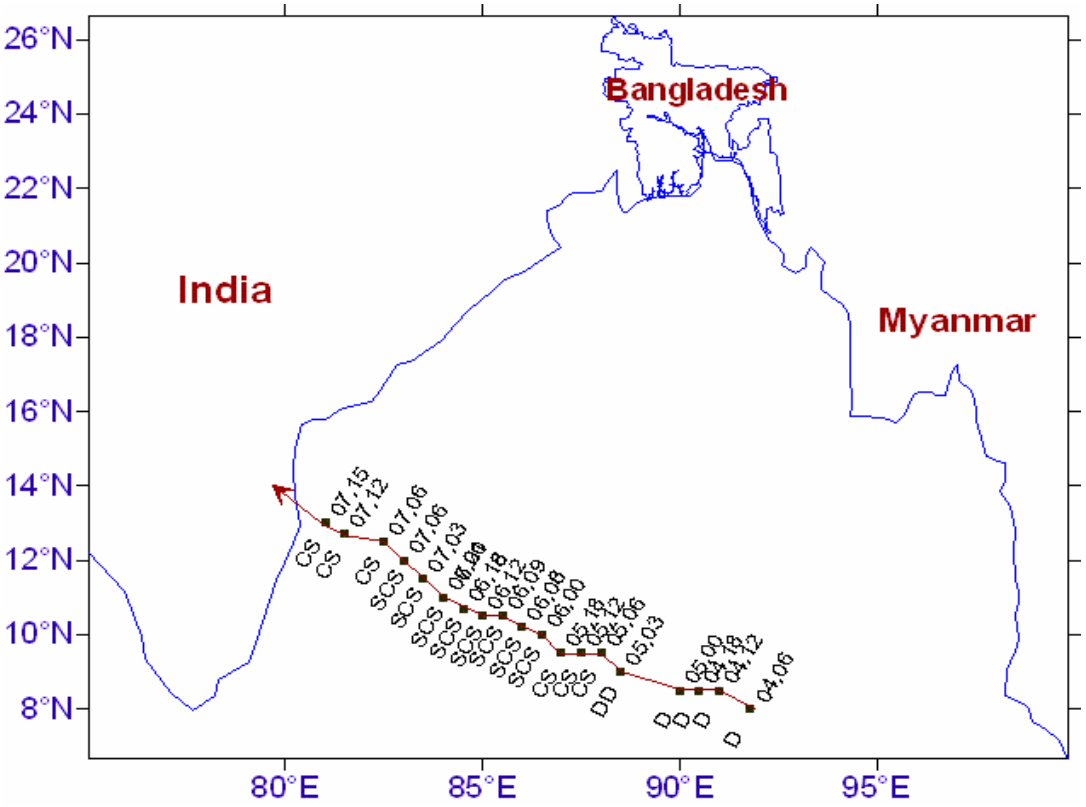


Fig. 5: BMD observed track of cyclone 'Jal' during 04-07 November 2010

Report On the Impact of Tropical Cyclones:

There was no tropical cyclone directly affecting Bangladesh. A Depression over North Bay during 07-08 October 2010 that crossed Khulna-Barisal coast of Bangladesh near Mongla in the morning of on 08 October 2010. Because of the Deep Depression over North Bay during 13-15 October 2010 that crossed Orissa coast near Gopalpur (India), Steep pressure gradient persists over North Bay and deep convection was taking place. Therefore high wind and heavy rainfall were recorded in the coastal districts of Bangladesh. Local Cautionary Signal No. III were also advised to hoist for the maritime ports and fishing boats & trawlers over North Bay and Deep Sea during this period as a precautionary measure.

Meteorological component:

Meteorological Data from RTH New Delhi and 10 synoptic observatories of BMD are exchanged on routine basis through WMO's GTS. All the 35 observatories of BMD have been connected with NMCC Dhaka either by 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 VSAT link. NMCC uses MSS software obtained from WMO/UNDP Regional Computer Network programme for reception and transmission of all meteorological data.

Bangladesh Meteorological Department has been using JMA Global Spectral Model (GSM) for Numerical Weather Prediction since October 2010. The resolution for the surface

is 0.25°x0.25° and for upper air is 0.5°x0.5°. The model out are updated every day accordingly at BMD's website www.bmd.gov.bd

Hydrological Component:

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

Through the completion of the establishment of Meteorological and Hydrological Doppler Radar at the 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.

Disaster prevention and preparedness component:

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

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

Training Component:

Mr. Md. Abdul Mannan, & Mr. Md. Nurul Karim, Meteorologist, participated in the "ICTP Targeted Training activity: statistical methods in seasonal prediction" at ICTP, Italy from 02-13 August 2010

Mr. Md. Hafizur Rahman, Meteorologist, participated in the "seventh post graduate Course in Satellite Meteorology and Global Climate (SATMET-7)" at Ahmedabad, India from 01 August 2010-30 April 2011.

Mr. Md. Shameem Hassan Bhuiyan, Meteorologist, participated in the "USDA Cochran fellowship program" at USA, from 25 October - 02 November 2010.

Ms. Arjumand Habib, Director, participated in the "GEO-VII plenary meeting and 2010 GEO ministerial summit" at Beijing, China from 03-05 November 2010.

Mr. Shamsuddin Ahmed, AD, participated in the "Challenge Programme on Climate, agriculture and development priorities and scenario development workshop" at New Delhi, India from 08-10 November 2010

Research/Publication Activities:

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

- ✓ Analysis of extreme rainfall events
- ✓ Analysis of Tropical cyclone “AILA”.
- ✓ Analysis of significant Nor‘wester events
- ✓ BMD provides information on significant weather and new developments related to meteorology through BMD’s newsletters

Country Report of India-2011

1. A REVIEW OF THE 2010 CYCLONE SEASON

1.1 Report of RSMC- Tropical cyclone, New Delhi

A report on cyclonic disturbances over the north Indian Ocean during the year 2010 has been published by RSMC, New Delhi. However an overall review based on seasonal summary is given in **appendix-I.** Behaviors of individual cyclones and forecast performance of RSMC, New Delhi have been presented in the technical report published by RSMC, New Delhi.

2. COORDINATION WITH OTHER ACTIVITIES OF THE WMO TROPICAL CYCLONE PROGRAMME

Details are given in action taken report.

3. Review of coordinated technical plan and consideration of the work programme for the next five years (2011-2015)

3.1. Meteorology

A brief description of different types of observational network of 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	32	29	17	14	200
II (b), II (c), II (d), III & IV, V, VI Io & EMO (Non Dept.)	108	71	46	32	47	26	330
V (Non Dept. HMO)	64	17	55	21	12	11	180
TOTAL	227	141	133	82	76	51	710

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).

India Meteorological Department is in the process of strengthening of its surface observational network in a phased manner. A network of 125 Automatic Weather Stations (AWS) has been established during the year 2006-07 under the project "Replacement of old and obsolete network of Data Collection Platforms". Their functional status is given below:

Non Functional AWS	**Installed**	**Reporting**
Sutron make 9210: Bonaigarh, Brahmavar, Changlang, Daporizo, Dwarka Kayamkulam, Passighat, Nimpara and Naharlgun and Rajkot	100	90
Astra make: Dhanbad, Jaipur Purulia, Purola Mukteshwar, Ranichawri, Rudraprayag (not reporting)	25	18
Sutron make 8210: GCSC Ahmedabad	01	-
Total	**126**	**108**

Under the IMD Modernization Programme Phase-I, 550 AWS, a TDMA earth station has been installed and so far 382 AWS station have been installed & commissioned. The sensors for parameters Air Temperature, Relative Humidity, Atmospheric Pressure, Rainfall, Wind and Global Solar Radiation are being interfaced with each AWS. Out of 550 AWS planned for installation, 127 will be Agro-AWS with additional sensors for parameters soil temperature, soil moisture, leaf temperature and leaf wetness. Meteorologically unrepresented districts of India are being considered on priority for installation of AWS.

The network is required to meet the needs of diverse services of IMD such as Weather Forecasting, Cyclone Warning and Hydrological Studies etc. The network is planned in such a way that data sparse regions of the country particularly north and northeastern states have uniform distribution of AWS.

There are 253 meteorologically unrepresented districts in India. Typically, one AWS is planned for installation in each unrepresented district. A meso-network of 12 AWS has also been established in and around National Capital Region. Under the modernization project phase-I, a fairly uniform and dense surface observational network of 550 AWS is expected to be available to meet operational forecasting requirements (both synoptic and meso-scale) of the nation.

Under modernization project it is proposed to establish a network of 3600 Automatic Rain Gauge Stations all over India during the period 2007-2012. In order to improve monitoring of districtwise rainfall monitoring a network of 1350 Automatic Rain Gauge Stations is being established during Phase-I of the modernization project. It is planned to install at least two Automatic Rain Gauge Stations in each district of India during Phase-I of the project. Under the project 1350 ARGs, 356 ARG have been installed of which 287 are functional. Out of 1350 ARG, 500 stations are being equipped with additional sensors for temperature and humidity observations. The ARG stations are also being installed on priority in flood prone river basins such as Brahmaputra, Ganga, Mahanadi, Tapi, Narmada, Godavari and Krishna.

Improvement in Maintenance/Servicing of Various Surface Meteorological Instruments

Imparting training to departmental personnel in maintenance and upkeep of the surface airport meteorological instruments has been a regular activity.

Recent Achievements

1. Under the scheme "Up-gradation of standard test facility for barometer and thermometer", various calibration standards were procured. Dead Weight Testers, Digital standard barometers 100 nos., Thermoelectric Pyranometers 5 nos. & Temperature Bath 2 nos., have been procured.
2. Comparison of AWS data received through Kalpana – 1 Satellite with Co-located obsy. data is in progress.

Future Plans

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

- Establishment of a network of 10 Lightening Detection Systems
- Development and supply of Hand Held data logger for Automation of Surface Observatory.

b. Upper Air observatories

In India Meteorological Department (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 kms.

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.

Brief description of ground equipment

Originally India Meteorological Department was maintaining a network of 39 radars. Based on their usage, they are categorized as storm Detection and Cyclone detection radars. 17 Radars out of 39 have become very old and obsolete and are under process of written off and future upgradation.

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

(i) Cyclone Detection Radars (CDRs)

At present there are 10 Nos of S-Band Radars are operational. Out of 10 Radar 7 are Doppler Weather Radar operational at Chennai, Kolkata, Machilipatnam, Visakhapatnam, Sriharikota (SHAR), Delhi (Palam) and Hyderabad. 3 conventional CDRs are working at Kochi, Karaikal and Paradip. SHAR Sriharikota has indigenous DWR developed by ISRO. S-Band radar at Mausam Bhavan was for testing/training purpose and has already been dismantled and in its place C-Band Dual Polarimetric Doppler Weather Radar will be installed. This radar is expected to be commissioned by July 2011.

(ii) Storm Detection Radars (SDRs)

There are at present 5 SDR working at Nagpur, Agartala, Ranchi,Kolkata and Guwahati for the purpose of storm detection. 2 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.

(iii) Wind Finding Radars

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

(iv) 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. Doppler Weather Radar being installed at Mohanbari under Modernization phase-I & likely to be commissioned by 2011.

Status of Radar

S.No.	In working order
1.	Sriharikota, DWR, S- Band
2.	Machilipatnam, DWR, S- Band
3.	Visakhapatnam, DWR, S- Band
4.	Chennai, DWR, S- Band
5.	Kolkata, DWR, S- Band
6.	Delhi (Palam), DWR, S-Band
7.	Hyderabad, DWR, S- Band
8.	**Kochi, CDR, S-Band**
9.	**Karaikal, CDR, S-Band**
10.	**Paradip,CDR, S-Band**
11.	Sriganganagar, SDR, BEL S- Band
12.	Jaisalmer, SDR, BEL S- Band
13.	**Nagpur, SDR, BEL X-Band**
14.	**Agartala, SDR, BEL X-Band**
15.	Kolkata, SDR, EEC X-Band
16.	Ranchi, SDR, EEC X-Band
17.	Guwahati, SDR, EEC X-Band
18.	Machilipatnam, MMR, BEL X-Band
19.	Karaikal, MMR, BEL X-Band
20.	Bangalore, Wind Finder, EEC X-Band
21.	Ahmedabad, Wind Finder, EEC X-Band
22.	Bhubneshwar,Wind Finder, EEC X-Band

Recent Developments

Upper air data of IMD network was doubted for many years by leading Numerical weather Prediction (NWP) centers of the world and observations were rejected by data assimilation systems. IMD is undergoing modernization and has adopted a strategy to

replace the obsolete systems. To achieve the standards of data quality required by the Numerical weather Prediction (NWP) centers, various aspects of modernization including upgradation of observing system and transmission of data to central data centre in real time have been planned covering representativeness, accuracy of observations, achieved heights & timeliness. Apart from the data quality, regularity of observations, completeness and timeliness of the collection of observational data at the center concerned, is very important. To enable this, all TEMP data generated from GPS stations had been broadcast to GTS through SOCKET transmission. Web based portal for on line monitoring of Upper air network has also been started. Performance of the ascents, achieved heights, message dissemination time, Total number of ascents taken, MISDA reported, comparative performance of the all stations, stock statement etc can be monitored.

To improve the performance of pilot balloon observation, new optical theodolites have been installed at all 62 locations. Hand held data loggers have also been implemented at all 62 locations for computation. All the PB observations are now working on semi automatic computation system.

In recent years, the Upper Air Radiosounding System based on Global Positioning System (GPS) is used as an effective method resulting to improved observation accuracy and allowing simplification of ground equipment. Accordingly, in the first phase of modernization, ten stations have been upgraded with new GPS based Upper air systems in 2009. After the introduction of new systems, data quality has improved substantially at these stations, which has been validated by ECMWF. Recently another GPS system has been installed at New Delhi to facilitate the nowcasting during Commonwealth Games in October'2010.

At present the RS/RW network comprised of GPS system at 11 places, 10 IMS-1500 Radiotheodolites installed in 2002 & at remaining stations Ground System of indigenous make installed in 1992-93. Details of Ground systems used in IMD upper air network

Future Plans

(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 end of April, 2011.

(b) Commissioning of 12 Nos. of DWRs

In first Phase of modernization plan of IMD, 12 Nos DWRs 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.

All the 12 Nos DWRs procured from M/s Metstar China have reached at respective stations. Out of 12 Nos, two DWRs have already been commissioned. Schedule for the installation of rest 10 Nos DWRs at Agartala, Nagpur, Patna Mohanbari, Patiala, Lucknow, Bhopal, Goa, Paradip, and Karaikal.

(c) Procurement of 2 C-band DWRs

IMD is procuring 2 C-band dual polarized DWRs for installation in the IMD's radar network. These C-band DWR will be installed at Delhi (HQ), Mausam Bhawan and at M.C. Jaipur. Supply order has already been placed in May, 2010 and L /C already opened. FAT will be conducted 21-25 February, 2011 at Vaisala, Finland. Both these radars are expected to be installed / commissioned by July, 2011.

(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 0f 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. These are expected to be installed / commissioned by September, 2011.

(e) Procurement of Mobile Radar

IMD is procuring one no. Mobile radar . Tender inquiry has already been issued on the basis of Request For Proposal prepared by the committee approved by competent authority.

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 installation 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 submitted. EFC for the establishment of NWROC has also been prepared.. The scheme has been included in the IInd phase of modernization under networking of radars.

(f) Meteorological Satellite

(i) Current status:

At present IMD is receiving and processing meteorological data from two Indian satellites namely Kalpana1 and INSAT-3A. Kalpana-1 was launched on 12th September, 2002 and is located at 74 ^{0} E. INSAT-3A was launched on 10th April, 2003 and is located at 93.5^{0}E. Kalpana-1 and INSAT-3A both have three channels Very High Resolution Radiometer (VHRR) for imaging the Earth in Visible (0.55-0.75 um), Infra Red (10.5-12.5um) and Water vapour (5.7-7.1um) channels having resolution of 2X2 kms in visible and 8X8 kms 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 (0.77-0.86um) and Short Wave IR (1.55-1.77um) bands of Spectrum. The Resolution of CCD payload in all the three channels is 1km X 1km. At present about 48 nos. 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.

INSAT 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 Satellite Data derived products from the processed data as follows:

- Cloud Motion Vectors (CMVs) are derived using three consecutive half hourly images from the operational Kalpana-1Satellite. CMVs are generated at 00, 03, 06, 09, 12, 15 & 18 UTC using IR imagery data.
- Water Vapor Winds (WVWs) are derived using three consecutive half hourly images from the operational Kalpana-1 Satellite. WVWs are generated at 00, 03, 06, 09, 12, 15 & 18 UTC using water vapour imagery data.
- Sea surface Temperatures (SSTs) are computed at 1^0 x 1^0 grid intervals from all Kalpana-1 data on half hourly /daily /weekly/monthly basis.
- Outgoing Longwave Radiation (OLR) are computed at 0.25^0 x 0.25^0 grid intervals from Kalpana-1 data on half hourly /daily /weekly/monthly basis.
- Quantitative Precipitation Estimates (QPE) are 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 automization of this technique. Automated Dvorak technique is running in experimental mode at Synoptic Application Unit, Satellite Meteorology Division.

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 emmissivity
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)

From 2007 onwards, Satellite Application Unit of IMD is getting half hourly satellite imageries throughout day and night. Using the half hourly satellite imageries, Satellite Application Unit of IMD is involved in interpretation of satellite imageries and issuing different types of Satellite Bulletins: - Satellite bulletins based on 3-hourly INSAT cloud imageries are prepared and transmitted to all the forecasting offices on Global Telecom Service (GTS) through RTH. New Delhi, Special hourly satellite bulletin in case of cyclone over Bay of Bengal or Arabian Sea, heavy rainfall advisory bulletins are also transmitted & uploaded on IMD website in addition to routine bulletins.

The proper monitoring and tracking of cyclonic storm, thunderstorm, Fog (day and night) and other Severe weather phenomena's using half hourly imageries of Kalpana-1 and products from NOAA/MODIS/METOP are quite useful in issuance of timely warning/advisory to the users and thus saving property and life.

With the Web Archival System-A system developed at IMD KALPANA-1/INSAT-3A data products and imageries are being archived for one month.

On 23rd September 2009 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 height for early detection of Tropical cyclones.

(ii) Digital Meteorological Data Dissemination:

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

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, TIR1, TIR2, & 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 2011 and will provide much improved capabilities to the meteorological community and users. In preparation for the reception and processing of

these 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:

1. Outgoing Long-wave Radiation (OLR)
2. Quantitative Precipitation Estimation (QPE)
3. Sea Surface Temperature (SST)
4. Snow Cover
5. Snow Depth
6. Fire
7. Smoke
8. Aerosol
9. Cloud Motion Vectors (CMV)
10. Water Vapour Winds (WVW)
11. Upper Tropospheric Humidity (UTH)
12. Temperature, Humidity profile & Total Ozone
13. Value added parameters from sounder products
    a) Geo-potential Height
    b) Layer Precipitable Water
    c) Total Precipitable Water
    d) Lifted Index
    e) Dry Microburst Index
    f) Maximum Vertical Theta-E Differential
    g) Wind Index
14. Fog
15. Normalized Difference Vegetation Index
16. Flash Flood Analyzer
17. Himalayan Snow Cover Analysis System (HSCAS)
18. Tropical Cyclone Intensity/position

Cyclone Warning Dissemination:

A specially designed Cyclone Warning Dissemination System (CWDS), which works via the INSAT Satellite, provides area-specific service even when there is a failure of conventional communication channels. A set of 252 analog and 101 digital CWDS receivers have been deployed in vulnerable coastal areas in the east and west coast. This network will be replaced shortly by 500 new CWDS, which are modern and easy to maintain.

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.

Meeting

Meeting of Coordination Group for Meteorological Satellites (CGMS) –38 was held in New Delhi from 8th –12th November 2010. Various agencies like EUMETSAT, NOAA, JMA, KMA, delegates from Russia and various other countries participated in the meeting.

A bilateral meeting between officers of IMD and EUMETSAT was held in DGM office, New Delhi on 9th Nov'2010. EUMETSAT agreed for one EUMETCAST receiving station and also agreed to help IMD becoming a centre of excellence of WMO.

For Technical and scientific cooperation related to INSAT-3D satellite data applications between the Ministry of Earth Sciences (MoES) / India Meteorological Department (IMD) and the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS) an Implementing Arrangement regarding INSAT-3D Satellite Data (IA-3D) has been signed by Director General of Meteorology and ,Assistant Administrator for Satellite and Information Services , National Oceanic and Atmospheric Administration (NOAA) at Washington D.C. on 6th October, 2010.

Prediction Models in Operational Use During the Year 2010

IMD operationally runs three regional models WRF(NMM), MM5 and Quasi-Lagrangian Model (QLM) for short-range prediction during cyclone condition. MM5 model is run at the horizontal resolution of 45 km with 23 sigma levels in the vertical and the integration is carried up to 72 hours over a single domain covering the area between lat. 30^{o} S to 45^{o} N long 25^{o} E to 125^{o} E. WRF (NMM) is run 4 times a day at the horizontal resolution of 27 km.

IMD also makes use of NWP products prepared by some other operational NWP Centres like, ECMWF (European Centre for Medium Range Weather Forecasting), GFS (NCEP), JMA (Japan Meteorological Agency), UKMO etc. A multimodel ensemble (MME) technique for predicting the track of tropical cyclones for the Indian Seas is developed and implemented in the operational mode. The MME is developed applying multiple linear regression technique using the member models MM5, QLM, GFS (NCEP), ECMWF and JMA. All

All these NWP products are routinely made available on the IMD web site www.imd.gov.in.

Operational NWP Support for Cyclone Warning Service

(i) Current Status

(a) Global Forecast System

With the commissioning of High Performance Computing System (HPCS), National Centre for Environmental Prediction (NCEP) based Global Forecast System (GFS T382) has been made operation at the H/Q of IMD, incorporating Global Statistical Interpolation (GSI) scheme as the global data assimilation for the forecast up to 7 days. Currently, it runs twice in a day (00 UTC and 12 UTC).

(b) Regional Forecast System

The meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is being operated daily twice, at 27 km and 9 km horizontal resolutions for the forecast up to 3 days using initial and boundary conditions from the IMD GFS-382. The WRF (ARW) 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, the outer model domain covers the area between lat. 25^{o} S to 45^{o} N long 40^{o} E to 120^{o} E. At ten other regional centres, very high resolution mesoscale models (WRF at 3 km resolution) are made operational.

Future Plan

IMD has the plan to implement latest version of NCEP HWRF for the Indian basins with the assimilation of local observations. The model has the provision for vortex re-location

and moving nesting procedure. In this direction action has been already initiated and the model is exceeded to be available in the operational mode by the end of 2011.

Research and Development

Like operations, research is another priority area to transform research to operation. Some our research publications on improving cyclone forecasts are given below:

Kotal, S.D., Roy Bhowmik, S.K. and Mukhopadhaya, B., 2010, Real-time forecasting of the Bay of Bengal Cyclonic Storm "RASMI" of October 2008 – A statistical dynamical approach, Mausam, 61, 1-10

Kotal, S.D., Kundu P.K. and Roy Bhowmik S.K. , **2009**, An analysis of cyclo-genesis parameter for developing and non-developing low pressure systems over the Indian Sea, **Natural Hazards,** 50,389-402

Kotal, S.D., Kundu P.K. and Roy Bhowmik S.K. , **2009**, An analysis of Sea Surface Temperature and Maximum Potential Intensity of Tropical Cyclone over the Bay of Bengal, **Met Application,** 16,169-177

Kotal S.D., Roy Bhowmik S.K. and Mukhopadhaya B., **2009**, Performance of IMD NWP based Objective Cyclone Forecast System during 2008-2009, IMD **Met Monograph No. Cyclone Warning 4/2009**

Pattanaik D.R., and Y. V. Ramarao, 2009, Track Prediction of Very Severe Cyclone 'Nargis' Using High Resolution Weather Research Forecasting (WRF) Model. **Journal of Earth System Sciences,** 118, 309-330.

Roy Bhowmik SK, Sen Roy Soma, Srivastava K, Mukhopadhaya B., Thampi SB, Reddy YK, Singh Hari,. Venkateswarlu S and Adhikary Saurav, 2011,

Processing of Indian Doppler Weather Radar data for meso-scale applications, Meteorl. Atmos Phy, DOI.1007/s00703-010-0120-x

Roy Bhowmik S.K. and Kotal S.D. 2010, A dynamical statistical model for prediction of a tropical cyclone, Marine Geodesy, 33, 412-425

Sen Roy Soma, Roy Bhowmik, SK, Lakshmanan, V, and . Thampi S.B., **2010**,

Doppler Radar-based Nowcasting of the Bay of Bengal Cyclone – Ogni of October 2006, **J., Earth SCI. Sys,** 119(2),183-199

Srivastava Kuldeep, Gao Jidong, Brewster K, Roy Bhowmik S.K. Xue Ming AND Gadi Ranu, Assimilation of Indian radar data with ADAS and 3DVAR techniques for simulation of a small scale tropical cyclone using ARPS model, Natural Hazards, DOI 10.1007/s11069-010-9640-4.

(E) Telecommunication Network in IMD

India Meteorological Department 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, VHF / Walkie-Talkie have been installed at various locations dispersed throughout the

country & neighbourhood. A new Transmet (RTH) System an Automatic Message Switching System (AMSS) to receive, check and route the meteorological data and products according to WMO standards/ requirements & Central Information and Processing System (CIPS) High end database management system having task centre to develop, test and operationalise meteorological tasks for real time generation of meteorological products have been installed and are operational. Telecom System has (GTS Ten links) and five circuits through internet connectivity.

The details of communication facilities at RTH New Delhi are given below:

(1) VPN Link (2 mbps) …. For National Links.
(2) RMDCN Link (1 mbps) … For connectivity with four countries.
(3) 64 Kbps IPLC and VPN over Internet .. For connectivity with 11 countries.
(4) Internet Link (45 mbps) – From Tata communication Ltd.
(5) Internet link (45 mbps) – From Bharti Airtel.
(6) E-mail
(7) FAX
(8) Digital Met. Data Dissemination through INSAT
(9) Telephone
(10) IMD Web sites http : www.imd.gov.in & http://www.mausam.gov.in IMD INTRA Portal metnet.imd.gov.in
(11) VSAT
(12) IVRS at 26 locations / cites.

- 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.

- 52 (44 commissioned + 8 to be commissioned) Stations have been provided VPN Connectivity, and are functioning for operational purpose.

- 27 Stations have been equipped with 64 kbps high speed data terminals.

- A network of 26 V-SATs is being installed at selected seismological observatories, Cyclone Detection Radar stations, Cyclone Warning Centres for reception of observational data utilizing communication Transponder of INSAT. Out of 26 stations, 23 stations have been installed and commissioned.

- 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 Proving data in GRIB/BUFR format for Wind/Temperature and Sig. WX. Charts.

3.2 Hydrology

The Hydrometeorological Division at New Delhi was established for 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, hydrometeorological analysis of different river catchments for project authorities and provides 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 hydrometeorological activities. The main activities of the Division are;

Rainfall Monitoring

(i) Real time monitoring of dsitrictwise daily rainfall is one of the important functions of IMD. A network comprising a large number of raingauge stations is utilized under Districtwise Rainfall Monitoring Scheme (DRMS). Based on real time daily rainfall data, weekly districtwise, sub-divisionwise and statewise rainfall statics are prepared on weekly,monthly and seasonal basis in the form of rainfall tables and maps. Districtwise and sub-divisionwise rainfall statistics provides important information useful to the agricultural scientists, planners and decision makers.

(ii) The software used for preparation of districtwise rainfall summary has been modified in all the six hundrad forty districts of India on rainfall bulletin.

(iii) Preparation of weekly sub-divisionwise/districtwisse / statewise rainfall reports including the statistics for the country as a whole as well as for the four regions viz, North-West India, South Peninsula, Central India and North East India. During the Monsoon Season 2010 daily sub-division rainfall report (169 reports including Oct.) were prepared and supplied to the Cabinet Secretary and other users

(iv) Week by week progress of rainfall for the districts and subdivisions were put up on the website.

Flood Meteorological Service

Flood Meteorological Service of IMD provides the following inputs to Central Water Commission (CWC) through their 10 Flood meteorological Offices (FMO estabhlished in different parts of India for operation flood forecasting. FMO's are located at Agra, Ahmedabad, Asansol, Bhubaneswar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi and Patna in the flood prone areas which caters to the river catchments Lower Yamuna, Betwa, Ken and Chambal, Narmada, Tapi, Deman Ganga, Sabarmati, Banas and Mahi, Ajoy, Mayuraksi and Kangasbati, Mahanandi, Brahmani and Subernarekha, Brahmaputra, Dehand, Lohit, Subansiri, Manas, Dhansiri and Barak, Godavari and Krishna, Teesta, Upper Ganga, Ghaghra, Gomati, Rapti and Sharada, Upper Yamuna and Sahibi, Lower Ganga, Kosi, Baghmati, Gandak, Burhi Gandak and Sone respectively.

15372 QPF;s were issued by FMO's during the Flood 2010, and supplied to Central Water Commission for flood forecasting purposes. From this year lead time of QPF is enhanced and now it is issued at 0930 IST instead of 1200 IST earlier. 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 2009 and 2010 by using IMD's MME forecast and IMD's WRF(9kmX9km) model was also partly utilized in the flood season 2010 with 48 hours lead time.

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., Private Agencies, design storm values (Standard Project Storm, Probable Maximum Precipitation along with Time Distribution) are being provided for users as main

input. For Govt. agencies, these studies are being carried out free of cost and for private / profit earning agencies on payment basis. The detailed project reports are being sent in respect of the projects completed on payment basis.

During the year 2010, design storm studies of thirty six (36) projects have been completed and results communicated to the concerned project authorities. An amount of Rs.16,56,800/- (Rupees Sixteen Lakh Fifty Six Thousand Eight Hundred only) has been deposited in IMD's A/c for carrying out the design storm studies in respect of projects received from private/profit earning agencies. The work of preparation of PMP Atlas for Krishna Basin has been initiated. Two JRF's have been posted for the purpose.

International Hydrology Programme Unit (IHP)

The activities of IHP are taken care by Indian National Committee of Hydrology (INCOH) located at NIH Roorkee. IMD is the member of INCOH. The activities of IHP are coordinated by Hydromet Division. Shri N. Y. Apte, Scientist 'F' attended the meeting of Hindu Kush- Hydrological Cycle Observation System (HKH-HYCOS) at International Centre for Integrated Mountain Development(ICIMOD), Kathmandu, Nepal for Development of Flood Information System from 23-25 June 2010 and Dr. (Mrs.) Surinder Kaur, Scientist 'F' attended the 7th meeting of International Coordination Group (ICG)) of Asia Water Cycle Initiative (AWCI) in Tokyo, Japan from 5-6 Oct,2010 under Global Earth Observation System of Systems(GEOSS) which is a regional effort in Asian region.

Storm Analysis Studies

For designing medium and small structures like bridges, culverts, drainage structure etc. depth duration frequency analysis is carried out. For this purpose India have been divided into hydrometeorological homogeneous 7 zones and 26 sub-zones.

For the purpose of railway and road bridges construction a committee has been formed viz, "Flood Estimation Planning & Co-ordination Committee" and the work is carried out jointly by the 4 departments viz, India Meteorological Department (IMD), Central Water Commission (CWC), Research Design Standard Organisation(RDSO), under Ministry of Railway and Ministry of Transport. This study has been carried out for 24 sub-zones and published in the form of CWC's Reports.

An Atlas of State-wise Generalised Isopluvial Maps of India has been prepared in four parts containing 2,5,10,25,50 & 100-year 24-hour return period maps of all states of Indian mainland.

World Bank Funded Hydrology Project

Ministry of Water Resources had conceived hydrological project with the assistance of World Bank. The objective of the project is to generate Reliable, Comprehensive, User Friendly, Quality data base of various hydrological components under Hydrological Information System. The project is planned to be implemented for a period of 6 years. The Hydrology Project Phase – II commenced on 05.04.2006 and its target date of completion is 30.06.2012. IMD is to look after all aspect of Hydrometeorology under the project and assist the 13 participating states to:

a. Establish Hydromet Network by undertaking joint inspection tours for site selection.
b. Capacity Building of state personals by imparting training in Hydrometeorology.
c. Validation of the Hydromet Data collected by the states under the project.
d. Establish data centres in participating states.

Central Hydromet. Observatory (CHO)

A Central Hydromet Observatory is situated at IMD, New Delhi for taking observations and for demonstration as a Model observatory to visitors. During the year 2010 about 2512 students and teachers from various schools/Govt./Private Institutions visited the Central Hydromet Observatory to get familiarization of India Meteorological Department and working of C.H.O. During Commonwealth Games, CHO supplied observatory data to MFI (Meteor France International) to Met. Safdarjung for forecasting of Weather. This practice is still continuing four times a day i.e; at 03, 06, 09, and 12 UTC. to Met. Safdarjung and two times a day i.e; at 03 and 12 UTC to NHAC.

Contribution of Central Water Commission in India

Central Water Commission (CWC) has been entrusted the responsibility of flood forecasting in the country. CWC maintains 878 stations for hydro-meteorological observations and issues flood forecasts for 175 stations in the country. During the year 2010, 7508 forecasts were issued. Out of this 6489 were stage forecast and 1019 inflow forecast to reservoirs. Out of the 7508 forecasts issued, 7369 were found to be within the permissible limits of accuracy. The percentage of accuracy is 98.15%.

Modernisation of Flood Forecasting Network of CWC

In view of requirement of real time flood forecasting for undertaking measures by the State Governments like evacuation of people during floods from flood affected areas to the safer places as well as optimum reservoir operations for mitigating flood damages, CWC has undertaken modernization of its flood forecasting and data collection network. So far, telemetry system has been installed at 221 stations and 2 Earth Receiving Stations have been set up at Jaipur and Burla. During XI Plan, the works are in progress for installation of telemetry system at 222 stations, 1 Earth Receiving Station with new TDMA technology at New Delhi and setting up of 10 Modelling Centres besides 11 Modelling Centres which have already been set up. Under the modernized system, the data collection is being done with sensor-based equipments, transmission of data is done through satellite and VSAT systems, the flood forecasts are formulated using state-of-the-art mathematical model like MIKE-11 and the flood forecasts are disseminated expeditiously to the local administration reducing the human errors and time taken in earlier manual processes. CWC has also planned to install telemetry stations at remaining 234 stations so that the entire network of 175 flood forecasting stations and their Base Stations including rainfall stations is covered.

Classification of Various Flood Situations

Danger level Fixed in consultation with beneficiary, i.e., the concerned State Authorities based on risk to properties in the area.

Warning Level Generally 1 m or as deemed fit below Danger Level fixed in consultation with the beneficiary.

HFL Highest Flood Level-ever recorded

Category of Flood	Criteria	Colour code
Low	When Water Level touches or exceeds the Warning Level	Yellow Bulletin
Moderate	When Water Level touches or exceeds the Danger Level but remains below 0.5 m of HFL	Yellow Bulletin
High	When Water Level is less than previous HFL but within 0.5 m of HFL **even if it is equal to or below danger / warning level**	Orange Bulletin

Unprecedented	When Water Level touches or exceeds previous HFL **even if it is equal to or below danger / warning level**	Red Bulletin

Flood situation in the year 2010

During the period from 15th May to 15th October, seven stations namely Karimgunj on river Kushiyara in Karimgunj district of Assam, Basua on river Kosi in Supaul District of Bihar, Haridwar, Kannauj, Ankinghat, Kanpur on river Ganga in Dehradun District of Uttarakhand, Kannauj District, and Kanpur District respectively of Uttar Pradesh, Moradabad on river Ramganga in Moradabad District of Uttar Pradesh crossed the previously recorded HFL.

(a) Unprecedented Flood Situation

Assam

The river Kushiyara at Karimgunj crossed the previous HFL during the period 1600 hours of 10th June 2010 to 1400 hours of 11th June 2010. It attained a peak level of 16.57 m on 10th June 2010 at 2300 hours which was 2 cm above the previous HFL of 16.55 m observed on 9th September 2007. Afterwards, it fell below the unprecedented flood situation.

Bihar

The river Kosi at Basua in Supaul district of Bihar crossed the previous HFL on 3 occasions on 20th, 21st and 24th August 2010. It attained a peak level of 48.89 m on 20th and 21st August 2010. However on 25th August 2010 at 0700 hours, the river attained a peak level of 49.17 m between 0600 and 0900 hours which was 30 cm above its previous HFL of 48.87 m attained on 11th July 2004.

Uttarakhand

The river Ganga at Haridwar in Dehradun district of Uttarakhand crossed the previous HFL on one occasion on 19th September 2010 between 8 and 10 hours. It attained a peak level of 296.30m between 08 to 10 hours of 19th October 2010 and then fell below the previous HFL. The peak attained at Haridwar was 7 cm above the previous HFL of 296.23 m attained on 02.09.1978.

Uttar Pradesh

The river Ramganga at Moradabad in Moradabad District of Uttar Pradesh crossed the previous HFL of 192.68 m recorded on 03.09.1978 by 2300 hours of 20th September 2010 and attained a peak level of 192.88 m between 02 and 03 hours of 21st September 2010 and then fell. It fell below previous HFL by 0600 hrs of 21st September 2010.

The river Ganga at Kannauj in Kannauj district of Uttar Pradesh crossed the previous HFL of 126.24 m attained on 29th August 1998 by 1400 hours on 23rd September 2010. It attained a peak level of 126.78 m between 0700 and 1200 hours of 27th September 2010. It fell below the previous HFL by 1000 hours on 30th September 2010. The peak attained in this flood was 0.54 m above the previously recorded HFL.

The river Ganga at Ankinghat in Kanpur district of Uttar Pradesh crossed the previous HFL of 124.31 m recorded on 9th September 1978 by 0500 hrs of 26th September 2010. It attained a Peak level of 124.49 m between 05 and 06 hours of 28th September 2010 and fell below the previous HFL by 24 hours of 28th September 2010. The peak attained in this flood was 0.18 m above the previously recorded HFL.

The river Ganga at Kanpur in Kanpur District of Uttar Pradesh crossed the previous HFL of 113.48 m recorded on 2nd September 1967 by 0700 hrs of 25th September 2010. It attained a peak level of 114.075 m between 14 and 18 hours of 29th September 2010 and then started falling. It fell below the previous HFL by 16 hours of 2nd October 2010. The peak attained in this flood was 0.595 m above the previously recorded HFL.

(b) High flood situation

Assam

The river Kushiyara at Karimgunj in Karimgunj District of Assam was flowing in High flood situation during the period 8th June 2010 to 12th June 2010, from 15th to 22nd June 2010 and from 21st to 22nd September 2010.

The river Beki at Road Bridge was in High Flood situation on 27th June 2010, 11th July 2010, 18th July 2010 and 21st July 2010.

The river Kopili at Kampur was in High flood situation was in High Flood Situation during the period 10 hours of 10th October 2010 to 05 hours of 11th October 2010.

Bihar

The river Kosi at Basua was in High flood situation on 21st July 2010 to 23rd July, 1st and 2nd August 2010 and from 22nd August 2010 to 27th August 2010. It was again flowing in High Flood Situation on 29th August, 8th and 16th September 2010.

The river Bagmati at Benibad is in High Flood situation from 26th August 2010 to 30th August 2010.

Uttar Pradesh

The river Ghaggra in Elgin Bridge in Barabanki District was flowing in High Flood situation from 25th August 2010 to 27th August 2010. The river Ghaggra at Ayodhya in Faizabad District was flowing in High Flood situation from 25th August 2010 to 5th September 2010.

The river Yamuna at Mawi was flowing in High Flood Situation on 10th September 2010 and from 21st September to 22nd September 2010.

The river Ramganga at Moradabad and Bareilly was in High Flood Situation from 20th September to 22nd September 2010 and from 20th September to 24th September 2010 respectively. The river Ganga at Kannauj was flowing in High Flood Situation from 27th August 2010 to 3rd September 2010 and from 18th September 2010 to 1st October 2010. The river Ganga at Kanpur was flowing in High Flood Situation from 27th August 2010 to 4th September 2010 and from 19th September 2010 to 3rd October 2010. The river Ganga at Ankinghat was flowing in High Flood Situation from 22nd September 2010 to 1st October 2010. The river Ganga at Dalmau in Rae- Bareilly District was flowing in High Flood Situation from 28th September 2010 to 2nd October 2010.

Uttarakhand

The river Ganga at Rishikesh in Dehradun district was flowing in High Flood Situation on 19th September 2010. The river Ganga at Haridwar was flowing in High Flood Situation on 19th September 2010.

National Capital Territory, Delhi

The river Yamuna at Delhi Railway Bridge was flowing in High Flood Situation on from 22nd September to 23rd September 2010.

(c) Moderate Flood Situation

The rivers in Brahmaputra and its tributaries, Barak, Tista and its tributaries, River Godavari and its tributary of Indravathi and river Krishna and its tributary of Tungabhadra experienced moderate flood situation during the year 2010.

(d) Low Flood Situation

Other than the rivers which experienced moderate flood situation, low floods were also witnessed in Rivers Mahanadi, Burbhalang, Vamsadhara in Orissa and Andhra Pradesh.

Reservoir Inflow Forecast

Most of the reservoir in the country is having very good storage as on the 15th October 2010. During peak floods heavy inflows were received in Narora Barrage on river Ganga and Hathnikund Barrage on river Yamuna. These two barrages have recorded the heaviest releases on record during the spell of floods in September 2010. Other than this, good inflows have been recorded in other reservoirs in Godavari, Krishna, Mahanadi, Tapi basins also.

Formulation and issue of Flood Forecast during 2010

The field Divisions of CWC are responsible for formulation and issue of flood forecasts whenever the river stage is touching or crossing the Warning Level or the inflow exceeds the criteria for issuing the inflow forecast. They formulate the forecast taking into account the flow in the base stations as well as the rainfall in the intervening catchment and the travel time available for the water to reach the downstream areas. The forecasts are then disseminated to concerned beneficiaries through the fastest communication mode. The performance of these forecasts is assessed by having certain criteria for accuracy. In the case of stage, the stage forecast is within permissible limit, if the actual level is within +/- 0.15 m of the predicted stage. In the case of inflow forecasted, the forecast is within permissible limit if the actual inflow attained at the reservoir is within +/- 20% of the forecasted inflow.

During the year 2010, 7508 forecasts were issued. Out of this 6489 were stage forecast and 1019 inflow forecast to reservoirs. Out of the 7508 forecasts issued, 7369 were found to be within the permissible limits of accuracy. The percentage of accuracy is 98.15%. In the case of stage forecast out of 6489 issued, 6393 were found to be within permissible limit with a percentage accuracy of 98.52%. While for inflow forecast, out of 1019 forecast issued 976 were within permissible limit of accuracy with a percentage accuracy of 95.8%.

5.3. Disaster prevention and preparedness

5.3.1. Cyclone Warning Services

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

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

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

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 Meteorological Offices).
(12) Bulletins for ships in the high seas through Navtex Coastal Radio Stations.

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

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

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

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

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

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

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

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

Disaster Management

(i) Organisational structure of disaster management

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

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

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.

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

(iii) 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.

(iv) 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

(v) 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.

(v) 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.

(vi) 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.

(vii) 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.

3.4 Training

The training activities at Regional Meteorological Training Centre (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
iii) Senior Level refresher course

III) Future Plans:

Annual Training Calendar for the Year 2010 – 2014 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)	Four months	Second Monday of March, July 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. (MT) 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 passed

Courses under Hydrology Project Phase II

S.N.	**Name of the Course**	**Number of batches to be conducted**
1	Basic Hydromet Observer's Course under	3
2	Hydromet Supervisor Course under	2
3	Senior Level Refresher Course under	1

Three Refresher Courses in a year, on the thematic topics.

Familiarization training on tropical cyclones monitoring at RSMC New Delhi

- One official each from Sri Lanka and Myanmar had received familiarization training on tropical cyclones monitoring at RSMC New Delhi during 1-12 February, 2010.
- Standard Operational Procedure(SOP) on Tropical Cyclones has been prepared and published by RSMC, New Delhi.

Future Plan:

1. Attachment of cyclone forecasters training in RSMC, New Delhi has been completed for the year 2010 and same will be conducted in 2011.
2. The seminars/workshops will be conducted for the cyclone forecasters in India during March and September 2011 as pre-cyclone exercise.
3. A refreshers course in cyclone monitoring & prediction will be conducted in March 2011.
4. A workshop on FDP- Cyclone (pre-pilot phase) will be conducted in May 2009 and for the pilot phase will be conducted in year 2010.

Other Trainings

- Training course for Linux Operating, System was conducted during 1-11 Feb at NDC by MFI in association with Focus Training Services, Pune as a part of Clisys implementation.
- An orientation programme of training of 10 observers of Part time Observatory of Tamilnadu was held at RMC Chennai during the period 8-12 March 2010. The observers were issued certificate by RMC Chennai.
- A training course on Oracle was conducted at NDC from 10 to 21 May 2010 for 10 officials by Meteo Franc International in association with Focus training Services, Pune as a part of CLISYS implementation at NDC.
- Synergy Basic User Training was imparted to 16 officers/staff of RMC Mumbai by Mr. Hubert Brunet, Chief Forecaster, Meteo France International from 31 May to 4 June 2010.
- Intermediate Course (Instrumentation) batch XXXV commenced on 20 May 2010 and concluded on 17 September 2010 and Advanced Course (Instrumentation) batch XXII also commenced on 20th September 2010.
- MFI experts. from France imparted raining to officers on MFI at RMC Chennai during the period 7-11 June, 2010.
- One week training in forecasting using Synergie System was organized at NWFC during 9-13 August 2010 for the forecasters from RMC, New Delhi. Dr. M. Mohapatra, Scientist 'E' (CWD), Shri M. Duraisamy, Director and Dr. Naresh Kumar, Meteorologist delivered lectures on various aspects.
- A two weeks CLISYS Users Training Course was conducted for NDC officers & staff by MFI officials from 13 to 24 September and CLISYS Administrator's Training Course was conducted for NDC officers from 2 to 14 September 2010.
- An International School on Applications with the newest Multi-spectral Environmental Satellites was organised by scientists from SSEC Madison (USA) during 30th January to 5th February 2011 at New Delhi. There were trainees from Indian organisations e.g. IMD, NCMRWF, IITM, INCOIS, IIT-Delhi, IISc-Bengaluru, and Indian Air Force.
- Three officers were deputed to Madison, USA for training on visual display, navigation, retrieval of temperature and moisture profile from INSAT-3D sounder.

3.5 Research:

(i) Forecast Demonstration Project (FDP) on landfalling cyclones over the Bay of Bengal

An FDP on landfalling tropical cyclones over the Bay of Bengal has been taken up. Its main objective is to minimise the error in prediction of tropical cyclone track and intensity forecasts, at least 48 hrs in advance. The programme has been divided into three phases

(i) Pre- pilot phase : 15 Oct- 30 Nov. 2008 and 2009
(ii) Pilot phase : 15 Oct- 30 Nov. 2010
(iii) Final phase : 15 Oct- 30 Nov. 201, 2012

Like last year, the pre-pilot phase was conducted during 15 Oct - 30 Nov, 2010. Several national institutions participated for joint observational, communicational and NWP activities. There were one very severe cyclonic storm, GIRI, one severe cyclonic storm JAL and a deep depression over the Bay of Bengal during the FDP comparison of 2010. There were 10 days of intense observation period conduced during this phase. However, the data and information collected during this period could used for finding out the role of various dynamical and thermodynamical parameters associated with intensification and movement of cyclones over the Bay of Bengal during 15 October to 30 November 2010. Compared to 2008 & 2009, there were four additional observations viz. (i) on board observation from Sagarkanya cruise (ii) oceanset observation of surface wind (iii) observations from five buoys (iv) microwave imageries and products.

(ii) Cyclone hazard prone districts of India

National Disaster Management Authority (NDMA) NDMA constituted a sub-committee for the purpose of preparing list of cyclone hazard prone districts based on some scientific criteria as it is found that there are some anomalies in the list of hazard prone districts prepared by Building Material Technology Promotion Council (BMTPC), ministry of Urban Affairs, Govt. of India. The BMTPC, based on Hazard Vulnerability of India identified cyclone prone districts of India taking into consideration cyclone hazards of the coastal districts. These districts are also listed in cyclone guidelines published by NDMA. These lists have included some inland districts of a few states in northeast India which do not experience full impact of cyclone. Also, while preparing such list it appears that no weight was given for the number as well as intensity of cyclones crossing coast. Considering all the above, sub-committee constituted by NDMA subsequently suggested to prepare the first draft by Dr. G.S. Mandal, Specialist, NDMA and Dr. M. Mohapatra, Director, Cyclone Warning Division, IMD, New Delhi to be considered by the sub-committee. A report on cyclone hazard prone districts of India has been prepared and sent to the sub-committee for consideration. An attempt has been made to prepare a list of cyclone hazard prone districts by adopting hazard criteria.

(iii) Verification of Cyclone Warning

Systematic verification of operational cyclone track and intensity forecasts issued by IMD has been introduced. The verification of forecasts issued by RSMC, New Delhi has been included for the first time in the 'Report of Cyclone disturbances over the north Indian Ocean during 2008' which is published by RSMC-Tropical Cyclone New Delhi during January, 2009. The skill score of the IMD has also been calculated alongwith the bias like along track and cross track errors, latitudinal & longitudinal errors for the period of 2003-2010 as per international standard.

(iv) Seasonal prediction of cyclonic disturbances over the north Indian Ocean

The preliminary study has been completed to find out the potential predictors. The findings have been published in the Journal, Mausam. Further work is in progress to develop a regression model for prediction of frequency of cyclonic disturbances during monsoon season.

(v) Modulation of genesis and intensity of cyclonic disturbances by Madden Julian Oscillation

A study has been completed to find out the modulation of genesis and intensity of cyclonic disturbances over north Indian Ocean by Madden Julian Oscillation. The findings have been sent to the Journal Mausam for consideration of publication. The results of this study will be utilized for extended range prediction (10-20 days) of genesis of cyclonic disturbances over the north Indian Ocean.

(vi) Web enable version of IMD's Storm Track Atlas (e-Atlas):

The project of electronic version of IMD's Storm Track Atlas(e-Atlas) was undertaken by CWRC, RMC Chennai and was completed successfully with help software. Digital database of the tracks of cyclones and depressions that formed over Indian seas during the period 1891-2006 was generated in-house. Now the project to make web enable version of IMD's Storm Track Atlas (e-Atlas) has also been taken up : CWRC, RMC Chennai for use of scientific community. The work is in progress and will be completed by the end of year 2011.

(vii) Individual Research

A number of papers are published every year in various journals and proceedings. Five research papers were published in national journals, three in Meteorological Monograph/ reports and twelve in proceedings of seminar/symposia/workshop. The detailed list is given below.

Papers published in Mausam

The research paper(s) published in the journal, **'Mausam'** Vol. 61, during the year 2010 are as follows

Real time forecasting of the Bay of Bengal cyclonic storm "RASHMI" of October 2008 – A statistical–dynamical approach. S. D. Kotal, S. K. Roy Bhowmik and B. Mukhopadhyay

Diagnostic study of a recurving cyclone – 'MALA' over the Bay of Bengal. Ramesh Chand and M. Mohapatra

An account of low level wind shear over Chennai airport – Part I : Observation and forecasting aspects .R. Suresh

Fractal analysis : Annual rainfall in Chennai. R. Samuel Selvaraj, R. Gayathri and S. Tamilselvi

Meteorological factors associated with July 2005 floods in river Jhelum. B. P. Yadav and S. C. Bhan

Large scale fluctuations of the Continental Tropical Convergence Zone (CTCZ) during pilot CTCZ phase-2009 and the evolution of monsoon drought in 2009D. R. Sikka, Ajit Tyagi and L. C. Ram

Technical feasibility on reception of VHRR signals from Kalpana-1 satellite in the event of contingency with the existing operational ground receiving system. J. K.S. Yadav, A. K. Chakarborty and R. K. Giri

Utilization of 'Aerostat' Doppler Weather Radar in nowcasting of convective phenomena. P. K. Arora and T. P. Srivastava

Performance evaluation of precipitation prediction skill of NCEP Global Forecasting System (GFS) over Indian region during summer monsoon 2008. V. R. Durai, S. K. Roy Bhowmik and B. Mukhopadhyay

Study of rainfall features over Goa state during southwest monsoon season. S. M. Metri and Khushvir Singh

Recent winter warming over India – spatial and temporal characteristics of monthly maximum and minimum temperature trends for January to March. A. K. Jaswal

Semi-quantitative precipitation forecasts for Kosi/Mahananda catchment by synoptic analogue method. K. M. Singh, M. C. Prasad, G. Prasad, R. Prasad and M. K. Jha

Study of rainfall departure over catchments of Bihar plains. T. N. Jha and R. D. Ram

Effect of broadcast and precise satellite orbits in the estimation of Zenith tropospheric delay and integrated precipitable water vapour from GPS. J. K. S. Yadav, R. K. Giri and D. K. Malik

Precipitable water vapour monitoring using ground based GPS system. N. Puviarasan, R. K. Giri and Manish Ranalkar

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. Y. E. A. Raj

Evaluation of Indian summer monsoon rainfall features using TRMM and KALPANA-1 satellite derived precipitation and rain gauge observation. V. R. Durai, S. K. Roy Bhowmik and B. Mukhopadhaya

Semi quantitative forecasts for Baghmati/Adhawara Group of rivers/Kamala Balan catchments by synoptic analogue technique. K. M. Singh, M. C. Prasad and G. Prasad

Signatures of northeast monsoon activity and passage of tropical cyclones in the integrated precipitable water vapour estimated through GPS technique

An indigenous state-of-the-art High Wind Speed Recording (HWSR) system for coastal meteorological observatories. R. D. Vashistha, K. N. Mohan and P. S. Biju

Seasonal prediction of cyclonic disturbances over the Bay of Bengal during summer monsoon season : Identification of potential predictors. M. Mohapatra and S. Adhikary

Statistical analysis of monsoon rainfall distribution over West Bengal, India. Avik Ghosh Dastidar, Sarbari Ghosh, U. K. De and S. K. Ghosh

Weather-based crop protection stewardship at Pattambi, Kerala. R. P. Samui, K. Karthikeyan and J. P. Sabale

Rainfall variability and probability pattern for crop planning of Roorkee region (Uttrakhand) of India. A. K. Bhargava, P. K. Singh, Vasu Mitra, Awadhesh Prasad and M. Jayapalan

Probability distribution functions of weekly reference crop evapotranspiration for Pune station of Maharashtra state, India. D. T. Meshram, S. D. Gorantiwar, H. K. Mittal and R. C. Purohit

A quantitative assessment of KALPANA-1 derived water vapour winds and their improvement from the use of NCEP first guess forecast fields. A. K. Mitra, P. K. Kundu, A. K. Sharma and S. K. Roy Bhowmik

Unprecedented rainfall over Bangalore city during October, 2005. M. Mohapatra, Naresh Kumar and B.K. Bandyopadhyay

Erraticness of the rainfalls in different regions of India. R. P. Kane

Impact of AMDAR observations from Lufthansa aircraft on Global Analysis-Forecast System. Surya K. Dutta, Munmun Das Gupta and V. S. Prasad

Stochastic modeling of the occurrence of rainfall over some districts of Assam during 1987-1992. G. N. Raha and S. C. Kakaty

Rainfall models – a study over Gangtok. K. Seetharam

Climatological and synoptic aspect of hailstorm and squall over Guwahati Airport during pre-monsoon season. G. K. Das, R. P. Samui, P. A. Kore, L. A. Siddique, H. R. Biswas and B. Barman

A severe hailstorm over Guwahati airport and its vicinity on 2nd April 2006 : Synoptic and thermodynamic perspectives. H. R. Biswas, D. Chakrabarti, P. A. Kore and G. K. Das

3.6 Publication

Annual Review of Tropical Cyclones

The Annual Review for the year 2008 has been completed and has been sent to WMO for publication. The Annual Review for the year 2009 is also been completed and will be handed to Chief of PTC during 38th Session of WMO/ESCAP Panel on Tropical Cyclones during 21-25 February, 2011 in India. 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 2010.

4. Review of Tropical Cyclone Operational Plan

Tropical Cyclone Plan for 2010 has been given to WMO for publication. India was rapporteur for this purpose. India would like to continue to act a rapporteur for the year 2011.

5. Technical Support Unit

No action from RSMC, New Delhi

6. Support for the Panels' Programme

India has paid its annual contribution US $ 2000 to Trust Fund for WMO/ESCAP Panel on Tropical Cyclones and the contribution for the year 2010.

UNDP UNDP was the major donor of substantial support to the Panel's activities. Now UNDP is not in a position to make any commitment

with regard to the functioning due to sharp decline in their allocation of funds and changes in the UNDP programme and implementation procedure.

VCP India has been providing training facilities at its RMTC to foreign candidates under various programme including VCP of WMO Fellowship.

Bilateral Assistance INSAT Digital Meteorological Data Dissemination System (MDD) at Nepal has been commissioned/installed on gratis basis by Govt. of India during January 2009. Maldives and Sri Lanka have also been upgraded by a new digital Meteorological Data Dissemination system on gratis basis by Govt. of India during 2009. At present the systems are working satisfactory.

It is also propose to commission/ install new Digital Meteorological Data Dissemination System in Bangladesh, Afghanistan and Myanmar in near future on gratis basis by Govt. of India.

No activity took place during 2009-2010 under TCDC programme. We could consider the training requirements of the Panel countries under VCP. Under this programme, financial support is either provided by WMO or by the country concerned and at our end, we provide the training facilities free of cost.

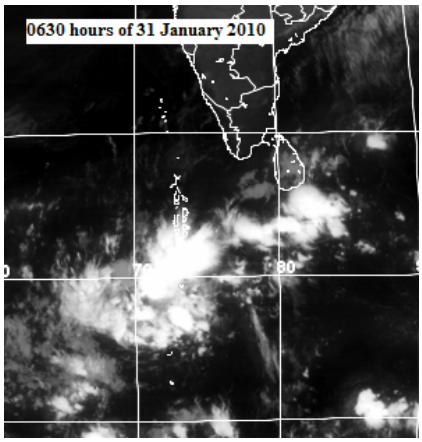
Maldives

1. Report on the impact of Tropical Cyclone season 2010 ***(agenda item 3.2)***

January

A low pressure trough formed over southern atolls on January 16. The axis of this trough moved slightly southward and intensified into a low level circulation on 23rd. intense convective clouds associated with this system caused flooding mainly in Seenu Atoll. Heaviest fall recorded was 148 mm in *Hithadoo*, 130 mm in *Hulhumeedhoo* and 127 mm in *Gan*. More than 8 hours of continuous rain brought water levels up to 1 foot in *Hithadhoo* on 24th.

Another low pressure trough formed over southern atolls on January 30. Combined effect of this system and wind convergence caused fairly widespread rain with isolated heavy showers and thunderstorms in southern and central parts of the country. Heaviest rainfall recorded was 93 mm in *Thaa Hirilandhoo* followed by 66 and 56 mm at Meteorological Office *Kaadedhdhoo* and S. Gan respectively. Apart from heavy rain, the average wind speed of 21 miles per hour were also sustained over the Male' area for nearly 13 hours.



Lightning and thunderstorms were continuously reported in southern atolls for nearly 15 hours on January 31 and even recorded 95 mm of rain in *Meemu Mulee* before the trough of low pressure retreated back.

February

As the NE Monsoon progress further in to Maldives, hazy condition became predominant in northern atolls reducing the visibility to 800 – 500 meters on 9th February.

March

The low pressure trough formed over the Maldives on 11 March brought a violent shower measuring 38.5 mm within half an hour in *Laamu Kahdhdho*. The same trough gave continuous lightning and thunder over *Huvadhu* atoll for about 11 hours on 18 March then 8 hours on the 19th.

April

Occasional heavy showers and thunderstorms occurred over a fairly widespread area of southern atolls due to a low pressure trough over that area. This system gave 70 mm of

rain in *Meemu Muli* on 5th April and became stronger on 12 April giving heavy falls of 89 mm in *Kadhdhoo* and 67 mm in *Dhaalu Kudahuvadhoo* on 13th.

May

The Inter Tropical Convergence Zone (ITCZ) was active in the south on May 5 giving a heavy fall of 87 mm to *Seenu Gan*. The ITCZ gradually propagated northward causing monsoon to be well established over southern atolls on 9 May. Thus, fairly widespread rain showers and average winds of 20 – 26 miles per hour sustained in *Addu Atoll* for nearly 5 hours. The maximum gust wind speed was 44 mph over *Gan* Island. The strong monsoon gave a heavy showers of 107 mm, in *Dhaalu.Kudahuvadhoo*, followed by 66 in *Meemu Muli* and 61 mm in *Thaa.Veymandoo* on May 15th.

A Depression formed in the Bay of Bengal intensified into a Tropical Cyclone 'LAILA' on 17 May. Even the monsoon over the Maldives became stronger in association with this system. Strong winds and heavy rain was experienced in central and northern atolls with a very heavy down-pour of 165 mm recorded in *Thaa Veymandoo*. Continuous lightning and thunderstorms were also experienced in north *Thiladhunmathi* from 1100hrs of May 20 until 12 pm of the next day.

June

After a short break in monsoon, fairly warm and humid weather prevailed during first week of June, registering high temperatures of 34.6° Celsius at the Meteorological Office, *Kadhdhoo*. However, monsoon became active again on 9 June causing 111 mm in *Hanimaadhoo*. Gale force winds lashed over the same area with maximum gusts of 56 mph.

During this week flash flooding was reported from south *Thiladhunamthi*. Reports from *Kulhudhuffushi* stated damage of 38 households and 8 households at *Nolhivaram* on 12 June. Swell waves also hit *Nolhivaram* and schools had to be closed the following day as well.

A low pressure system persisted over the Maldives from 25 till the end of June causing occasional gusty winds of 45 - 50 mph and 89 mm of heavy rain during this period. The trough then moved away northwards.

July

On 22 July, winds near Somalia got intensified tremendously and generated large swell waves of 15 -18 feet high at their coast. These waves got merged with northerly ocean currents and reached our coasts. Approximately, 10ft high swell waves were observed in Northern part of Maldives area. The Eastern harbor of *Male'* was severely hit by the waves inundating marine drive. Many islands from north and central atolls reported inundation of about 100 to 500 feet.

Severe monsoon activities were experienced in central atolls on 28 July when the effect of the trough of low pressure over the Maldives and the strong winds at upper-levels over the Arabian Sea got combined. Gale force winds accompanied with squally showers lashed the central atolls in the afternoon. Strong winds of 30 mph lasted nearly 3 hours, gusting to 62 miles per hour in *Male'* area. Several marine disasters were reported in that afternoon, among them were, sinking of a fishing vessel in the east of *Hulhule'*, a boat with 11 crew members sunk near *Donveli Beach Resort*. In another incident, a cargo carrier wrecked on *Hulhule'* reef, some ferries slipping off while being anchored at the harbor. Apart from this, many structural damages such as flinging of roofs, uprooting of trees in the capital *Male'* were also reported. The Coast-Guard described this day as 'the day that it received the highest number of reports lately'.

August

From 12th August onwards, the country have experienced very heavy rain accompanied by strong winds. It was an intense low pressure trough that brought devastation to northern atolls. Heavy falls recorded were 125, 100, 75 and 73 mm in *Shaviyani Funadhoo*, *Haa Alif Kelaa*, *Male'* and *Hanimaadhoo* respectively. Average winds were 15-25 miles per hour in central and northern atolls on both 14th and 15th August with maximum gusts of 50 mph recorded during this period. According to media reports, some islands in the north were flooded and few palm trees were uprooted.

September

A Gale force wind of 60 miles per hour was generated on 17th September when the effect of south-west monsoon and the low pressure trough got combined and enhanced. A violent shower measuring 110 mm within 3 hours brought flash flood in *Addu Atoll* on the 18th September. Rough seas disrupted ferry services for as long as two weeks' time.

October

Under the influence of an upper air cyclonic circulation, fairly strong winds of 17 - 24 miles per hour recorded in central atolls on the 8th of October. Gusty winds were reported mainly from Southern Province.

November

The central Maldives experienced strong winds again when the severe cyclone 'JAL' made landfall near Tamilnadu coast on 7th November.

December

The trough of low pressure extended over the Maldives caused heavy showers in central atolls on 4th December with a rainfall record of 84 mm at the National Meteorological center. The trough became stronger over the central atolls bringing fairly widespread rain,

squally showers with strong winds on the 6th. The prevailed average winds were at the order of 20 – 30 mph, gusting to 50 mph at the National Meteorological center.

A series of high swell waves hit central and northern atolls inundating up to 1300 feet in *Shaviyani Funadhoo* and about 200 feet in *Thilafushi* on 22 December.

2. Meteorological Component *(agenda item 5.1)*

Upper air Observation

Radio-sonde observations at the Meteorological Office, Gan (WMO # 43599) that were discontinued in 2009 were resumed in 2010 when UK Met Office graciously donated consumables sufficient for 1 year.

Like last several years, no upper-air observations were made at Male' (WMO # 43555) in 2010 as well. There is no upper air sounding equipment in Male'.

The location of Maldives in the Indian Ocean happens to be a data sparse area, upper air observations from the south and central Maldives are very important to us as well as the entire meteorological community in the region. Hence, Maldives urge assistance from WMO/ ESCAP and Panel members to consider rebuilding of our upper air network.

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) surface
- Male' (43555) surface
- Kadhdhoo (43577) surface
- Kaadehdhoo (43588) surface
- Gan (43599) surface + radiosonde

Total of 23 Automatic Weather Stations (AWS) has been installed up to 2010 and are in operation.

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 and Doppler Weather Radar

Digital Meteorological Data Dissemination System

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 during 2010 and IMD is taking measures to repair the system.

Maldives' Satellite Data receiving ground station GEOSAT 500.

System components:

- Antenna (with L-band feed)
- Satellite receiver (input 50ohm,frequency 130-145MHz,Demondulation FY2C HiRID)

The High Resolution Satellite Image Receiving System GEOSAT 500 made by Australians and the Doppler Weather Radar received as part of Multi-hazard Early Warning System are currently not functioning. Local technicians were unable to diagnose or rectify the problem or fault.

Numerical Weather Prediction

Maldives Meteorological Service continues to run WRF model as a trial basis and although planned to expand this service last year, could not achieve that goal due to budget constraints.

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.

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

MESSIR-COMM message switching system developed by COROBOR is a TCP/IP based multi-channel communication link that is capable of handling vast amount of data. Although this GTS is in operation throughout 2010, Maldives received many complains from other countries of not receiving our radio-sonde observation (TEMP) message through GTS. Likewise, the monthly CLIMAT report sent via GTS is also reported not received by users. Therefore, we request India to look into this matter and to work with us closely to solve this problem.

Forecaster's Workstation

MICAPS (meteorological data analyzing) System donated by China Meteorological Administration (CMA) is being used as an important in the Forecasting Office.

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.

3. Hydrological Component *(agenda item 5.2)*

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

4. Disaster Prevention and Preparedness Component *(agenda item 5.3)*

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

Warnings and advisories

The National Multi-Hazard Early Warning 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 and Indian Tsunami Early Warning Centre through internet and GTS were also disseminated to public satisfactorily in time.

Under the Standard Operating Procedures (SOP) of the Department, the warnings were additionally dispatched through cooperate SMS and Hotlines to designated authorities.

5. Training *(agenda item 5.4)*

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 and storm-surge modeling.

TRAINING REQUIREMENT FOR 2011- 2014

Overall Priority	COURSE NAME	LEVEL	Number	YEAR				No. Being Trained	Estimated Costs (MVR)	Training Required	
				2011	2012	2013	2014			Local	Overseas
1	Adv Meteorology	Adv Cert	6	2	2	1	1	1	**78,900.00**	□	□
2	Climatology Adv	Cert	1	1	-	-	-	-			□
3	Climatology Intermediate	Cert	1	1	-	-	-				□
4	Climatology	B.Sc	1	1	-	-	-	0			□
5	Electronic & Elec Eng	Dip	2	1	-	1	-	0		□	
6	Multi-Media	B.Sc	1	1	-	-	-	-	**105,000.00**	□	
7	Software Eng	B.Sc	2	-	1	1	-	-			□
8	Electronic Eng	B.Sc	2	1	-	-	-	1	**550,000.00**		□
9	Meteorology	B.Sc	2	1	1	1	-	-	**2,50,000.00**		□
10	Seismilogy	Dip	2	1	1	-	-	-		□	
11	Intermediate Met	Cert	2	1	1	-	-	-		□	

6. Research *(agenda item 5.5)*

Research projects on air-pollution were carried-out in the Climate Observatory of Hanimaadhoo.

Maldives Climate Observatory

Location in an Island called Hanimaadhoo (≈ 6N, ≈ 73 E)

Major purpose Monitoring Transboundary Air pollution

Measurement Techniques Remote sensing mainly Passive, In situ Technique Passive

Equipments Microtops and Cimel Sun photometer for Aerosol optical depth and for Ozone, Condensation Particle Counter (CPC) to measure number of particles, Sample mobility Particle Seizer (SMPS) to measure particle size, Aethelometer for Black carbon, Nephelometer for Scattering and pyranometers with sun tracer, for direct , diffusive radiation, Wet only collectors for collecting rain water for pH , EC, and ion analysis.

DATA shows the country experience high concentration of Aerosols in North east Monsoon compare to South West Monsoon and also rain analysis DATA shows increased acidity (pH<5) in rain water in some months in the north east monsoon.

7. Publications *(agenda item 5.6)*

Panel News

Maldives contributed information on significant weather and new developments in the meteorological service to *Panel's News Letters.*

Annual Climate Report

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

Country Report of Myanmar

1. Review of 2010 Cyclone Season

During the year 2010, ten low pressure areas were formed in the Bay of Bengal. Out of these ten LPAs, three LPAs intensified into tropical depressions and three LPAs into severe cyclonic storms. According to the average data of (1877-2005) period, ten cyclones formed annually. During the year 2010, altogether six storms occurred in the Bay of Bengal.

1.1 LAILA

A low pressure area formed over South Bay on 17th May and intensified step by step into a cyclonic storm named "Laila" on 18th May. Then it moved to Southwest Bay and adjoining West central Bay and finally crossed the southern Andhra Pradesh coast on 20th May. Although it crossed the coast, it still persists as a land depression up to 22nd May and become unimportant on 25th May. Because of the formation of "Laila" in the early monsoon period, there was continuous onset of Southwest monsoon over Southern and Deltaic areas of Myanmar on 18th and 21st of May respectively.

1.2 GIRI

In October, two depressions occurred over North Bay and Central Bay, and finally crossed to the Indian coast respectively. Next to these two depressions, a low pressure area formed over Central Bay on 19th October and further intensified into depression on 20th October. It systematically intensified to cyclonic storm "GIRI" on 21st October and finally it reached to very severe cyclonic storm with wind speed of above (120) mph at some places. On (15:30) hours of 22nd October, the severe cyclonic storm "Giri" crossed Rakhine (Myanmar) coast between Kyaukpyu and Sittwe. After that it still persist as a land depression and passed through Magway, Lower Sagaing and Mandalay divisions of Myanmar. Strong wind with (80) mph and heavy rain were occurred along the passage of this land depression. According to the post survey data, storm surge of about (12) feet was observed at Rakhine coast.

DMH received Cyclone Advisory, Cyclone Warning and Storm surge guidance from RSMC New Delhi and other International Forecast Center. Upon the acceptance of DMH issued storm warnings, Myanmar State Media immediately broadcast color coded Cyclone Warning and Special Cyclone Warning round the clock. Radio station aired every 10 minutes during the Red color emergency time (cyclone is expected to cross within 12 hours).
Cyclone warnings were accompanied with Advisories for local people and fishermen by informing the possibilities of very rough sea, heavy rainfall, landslide and (100) to (120) mph strong wind. National Disaster Preparedness Central Committee closely supervised and linked to local authorities and other related Ministries to evacuate the people from risky areas.

The six townships: Myay Pone, Min Pya, Pauk Taw, Kyauk Phyu, Ann and Sittwe were affected by GIRI. The death toll numbered 35 and the missing 10 were very less compared to the destructive intensity of storm and 4 meters storm surge, due to close cooperation of all responsible agencies with coastal community by learning lessons from storm NARGIS in 2008.

The estimated cost of losses and damages amounted as 24024 Million Kyats. The damages of cultivated land were reported as 72540 acres, and the damages of dam and dike as 12. The shrimp breeding ponds 49426 acres and 1148 fishing boats were damaged.

1.3 JAL

On 2nd November, a low pressure area was formed over South Andaman Sea and it became depression on 3rd November. At the beginning, it moved westwards slowly and its intensification did not significantly change up to 5th November. In the early morning of 6th November, the depression intensified to Cyclonic storm "Jal" and reached to the southwest Bay. On the same day it became severe cyclonic storm and located (330) miles southeast of Chennai. Then it downgraded to cyclonic storm on 7th November. On the next day, 8th November, it crossed between Southern Andhra Pradesh and Northern Tamil Nadu coasts of India near Chennai.

In December, a low pressure area formed over south west Bay on 5th December and it intensified to tropical depression on 7th December. Then it crossed Andhra Pradesh coast of India on 8th December.

2. Meteorological Component

2.1 Advancement / withdrawal of Southwest Monsoon

The advancement of Southwest monsoon to Southern, Deltaic, Central and whole Myanmar areas were late about (13) days, (6) days, (4) days and (5) days respectively. Contrary to onset phase, the withdrawal dates are as early as (19) days from Northern and Central areas, (15) days from from Deltaic as well as the whole country. (details in table 1 & 2).

Table (1) - Onset dates of Southwest Monsoon

No.	*Areas*	*Onset dates (2010)*	*Normal*
1	Southern Myanmar Area	18.5.2010	5 May
2	Deltaic Area	21.5.2010	15 May
3	Central Myanmar Area	24.5.2010	20 May
4	Northern Myanmar Area	6.6.2010	1 June

Table (2) - Withdrawal dates of Southwest Monsoon

No.	*Areas*	*Withdrawal dates (2010)*	*Normal*
1	Northern Myanmar Area	13.9.2010	2 Oct
2	Central Myanmar Area	19.9.2010	8 Oct
3	Deltaic Area	26.9.2010	11 Oct
4	Southern Myanmar Area	28.9.2010	14 Oct

2.2 Recorded Highest Maximum Temperature in May

Especially, during the month of May 2010, almost the whole country experienced the inconvenience hot weather caused by the increase of day temperature. Out of 75 reporting meteorological stations, 20 stations observed the highest maximum temperatures, which set new record compare to the previous 40 to 50 years data. Most of those stations located in Central Myanmar areas as shown in the table below.

Table (3) – List of the stations observing highest recorded Maximum Temperature in May, 2010

State/Region	Station	New Record (☐C)	Old Record (☐C)
Mandalay	Pyinoolwin	35.5	34.5 (1998)

	Mandalay	45.0	44.2 (2010)
	Meikhtila	44.0	43.2 (1998)
	Moekok	35.7	33.8 (1995)
	Myingyan	46.5	45.6 (2010)
	Nyaungoo	45.2	45.0 (2003)
	Yamethin	43.6	43.0 (2010)
	Pinmana	44.5	44.0 (2010)
	Yezin	44.0	42.0 (2007)
Magway	Magway	45.5	45.3 (1998)
	Pakokku	45.1	44.5 (2010)
Sagaing	Monywa	45.7	45.0 (2010)
	Myinmu	**47.2**	**47.0** (2010)
	Kalewa	45.0	43.8 (2009)
Yangon	Kaba Aye	42.5	42.0 (1998)
	Khayan	42.0	41.5 (2005)
Bago	Pyay	44.0	43.6 (2010)
Rakhine	Ann	42.6	41.7 (2010)
Mon	Theinzayat	43.5	43.0 (1998)
Tanintharyi	Kawthaung	39.5	38.5 (1998)

2.3 Meteorological Satellite Reception and data Processing System (MTSAT)

Based on the report of WMO Facts Finding Mission in February 2009, the Government of Japan provided the valuable Meteorological Satellite Reception and data Processing System (MTSAT), worth of USD (175,000) to Myanmar, in order to promote the tasks on daily weather issues, forecasts and early warnings of Department of Meteorology and Hydrology. Under the program of Japan International Cooperation Agency, MTSAT system was installed successfully by four engineers from the manufacturing company, at Nay Pyi Taw in January 2011. Data received from MTSAT are also sent to weather forecasting sections of Yangon (Kaba Aye) and Yangon International Airport through Internet network.
However the Fung Yun Cast receiving system had been no longer operational since November 2009 due to the expiry of software license, the satellite imageries are able to receive now through the MTSAT receiver.

2.4 Forecasting Services of DMH

National Meteorological Center Yangon, Nay Pyi Taw issues day-to-day routine weather forecasts and cyclone warnings. The forecast, warning, bulletin and news issued by DMH are as follows:

Daily, Dekad, Monthly and Seasonal Weather & Water level forecast
Aviation weather forecast,
Squall wind weather forecast
Sea route forecast
Storm warning, Storm surge warning
Untimely rainfall warning

Heavy rainfall warning
Strong wind warning
Fog warning
Bay bulletin
Agro-meteorological bulletin

2.5 Storm News, Warnings and Dissemination

24x7 Storm Watch Centers: Nay Pyi Taw Multi Hazard Early Warning Centre, Yangon Forecasting office, Mingladon International Airport Aviation Forecasting office and all coastline observatories watch the storms whenever cyclones develop in the Bay of Bengal. Moreover various meteorological websites like TMD,IMD, JTWC, NCEP, JMA etc., are used for cyclone monitoring. Storm news and warnings are issued at frequent intervals for national and international users in various sectors. Special storm warnings accompanied with color code and possible storm affected specific areas are issued hourly to all news media. National televisions televised all hourly news continuously in footnote rolling format frequently. The dissemination of cyclone information such as cyclone forecasts and warnings are an important task for disaster preparedness in Myanmar. DMH plays an important role by initiating the warning related to the formation of tropical disturbances in the Bay of Bengal and transmitting the warnings to National Disaster Management Committee (NDMC), National Disaster Risk Committee (NDRC) and other higher authorities, NGOs, UN Offices and etc. Cyclone warnings are transmitted without delay to the local authorities through telephone, fax, mobile phones, VHF, emails, Port wireless, websites, radio and TV.

2.6 DMH's Website:

DMH's new website (http://www.moezala.gov.mm) is going to operational from 23 March 2011. It will link with the existing website (http://www.dmh.gov.mm), which was launched since 2005 WMO Day. The forecasting products like daily weather reports, weather analysis maps and warnings are created and timely up dated in DMH website.

3. Hydrological Component

3.1 Occurrences of Floods in 2010

During 2010, there were floods in Dokhtawady river, Bago river and Kaledon river. In August, flood occurred at Myitnge in Dokhtawady river and it exceeded the danger level by ½ foot and stayed 3 days above danger level. The another flood at August was at Bago in Bago river and it exceeded the danger level by ½ foot and stayed 2 days above danger level. This flood caused the inundation about 2-6 feet at 9 wards at Bago and also flooded 2 feet depth on highway road between milepost No. 48/7 and 49/2 but there was no remarkable destruction. This flood was 7th highest flood at Bago by historical record (1965-2010). In October, the flood occurred at Kyauktaw of Kaledon and it exceeded about 1 foot above danger level and stayed about 1 day above danger level. This flood was also 6th highest flood at Kyauktaw by the historical record (1987-2010). This flood affected the 50 houses and 200 acres of paddy field by inundation. During October, another flood occurred at Myitnge in Dokhtawady river and this was second flood for Dokhtawady river for the year 2010. It exceeded 1½ feet above danger level and stayed 8 days above danger level. It inundated some roads, houses and agriculture crops from low land area. DMH has issued (4) flood warnings and (14) flood bulletins during 2010 flood season. At the year 2010, there were less flooding by historical record.

No flood occurred along Ayeyarwaddy, Chindwin, Sittoung, Thanlwin and Shwegyin rivers. But the water level of Hinthada, which is the lower station of Ayeyarwady river, reached 10 cm below danger level and the water level of Homalin, which is the upstream of

Chindwin river reached 60 cm (about 2 feet) below danger level. Similarly, the water level of Hpa-an of Thanlwin river reached 30 cm (about 1 foot) below the danger level.

Apart from river flood, inland flood and severe landslide occurred at Buthitaung Township of Rakhine State, due to the continuous heavy rain which amounted (35.53) inches within (6) days during the second dekad of June 2010. It caused (76) death toll and affected (29) Wards and villages in Buthitaung Township.

The peculiar urban floods were also encountered in Central Myanmar during the first dekad of October, due to the locally heavy fall in the areas for (2) to (3) days, caused by the formation of depression in the North Bay. The rain enhanced overflowing of the small streams and inundated (2) to (5) feet in low land areas and streets of Mandalay and villages and wards of nearby townships.

3.2 Hydrological services

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

RFS of D.M.H is using both simple and advanced techniques for issuing flood warning and bulletin to the users and public, and is also applying empirical models based on single and multiple regression analysis for forecasting peak flood level along Ayeyarwady and Chindwin rivers. The lead time for issuing flood warning is about one to two days for short range forecast and about 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 45 years' observation, severe flood years were noted as 1973, 1974, 1976, 1979, 1988, 1991, 1997, 2002, 2004 and 2007.

3.3 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 2010, measurements of discharge, sediment discharge and bed profile were implemented at Sagaing and Pyay for Ayeyarwady river and Monywa for Chindwin River.

3.4 Acid Deposition Monitoring

As a national monitoring center of EANET (acid deposition monitoring network of East Asia), DMH is responsible to monitor acid deposition of Yangon rain water. After the installation of Ion chromatograph and Ultra pure water production system in August 2009 with the support of JICA, the Laboratory of DMH has been able to analyze the ion contents such as Cation NH_4^+, Na^+, K^+,Ca^{2+},Mg^{2+} and Anion SO_4^{2-}, NO_3^-,Cl, in addition to pH and EC.
During the end of October 2010, the experts from Asia Center for Air Pollution Research – ACAP(former ADORC) has 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 institutional arrangement on the acid deposition monitoring of EANET in Myanmar; to discuss and exchange information on technical issues, especially QA/QC activities and data

reporting, including check on condition of analytical instrument; to discuss the maintenance of sampling instruments, and Others.

3.5 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 2010, DMH has developed flood hazard analysis and flood simulation by using IFAS for upper parts of Chindwin river, Ayeyarwady river and Shwegyin river. Development of river catalogue for Chindwin river basin is now in processing. Moreover, DMH is also implementing the flood hazard map for Bago township at Bago river basin by technical assistance by ICHARM and financial support by JICA.

3.6 Myanmar National Committee for International Hydrological Programme

By the organization of DMH, Myanmar National Committee for International Hydrological Programme was formed in 2003 and the government assigned the Minister for Transport as Chairman, Deputy Minister for Transport as Vice Chairman and Director General of DMH as the Secretary of the National Committee. Chairmen of Yangon and Mandalay City Development Committees and Heads of Departments related to hydrology are members of the committee. Under the National Committee, five Working Groups are formed to implement research and task according to the guideline of International Hydrological Programme and also to participate and contribute in the meeting conducted by National Committee. Up to 2010, Myanmar National Committee for International Hydrological Programme had conducted five meetings including paper reading session.

4. Disaster Prevention and Preparedness Component

The main DPP measures of DMH are on two main components (1) Issuance of Early Warning from Multi-Hazards Early Warning Center - MEWC (2) Public Education and Awareness Program.

4.1 Issuance of Early Warning

The warnings issued by MEWC are as follows:

a) Storm warning, Storm surge warning
b) Strong wind warning
c) Heavy rainfall warning
d) Untimely rainfall warning
e) Flood warning
f) Minimum water level alert
g) Significant rise of water level
h) Tsunami warning

4.2 Public Education and Awareness Program

Myanmar was actively involved in IO Wave - 2009 Exercise conducted on 14 October 2009 (World Disaster Reduction Day) with Functional Exercise, which including evacuation. It was conducted at tsunami prone coastal areas with the close cooperation of Local Authorities and DMH as below:

i. Palungtonetone village, Kawthaung Township, Tanintharyi Region
ii. Daminseik (Setse) village, Mon State
iii. Letkhukkone village, Kunchiankone Township, Yangon Region
iv. Leyinkwin village, Pinsalu Township, Ayeyarwady Region

v. Sanpya Ward, Sittwe, Rakhine State

Apart from this kind of drill, DMH has closed collaboration with Relief and resettlement Department (RRD), the focal point of Disaster Management. DMH Staff always participate as trainers in Disaster Management trainings, conducted by RRD. Regarding public education, 6 articles on weather phenomena and behavior of storm were printed in State media, *New light of Myanmar* and the *Mirror* during 2010. Moreover, the functions and activities of Multi-hazard Early Warning Center also appeared in those newspapers as interview.

4.3 Preparation of Project Proposals

DMH was actively participated in preparation of Myanmar action plan on disaster risk reduction (MAPDRR), and under this plan DMH has prepared priority project proposals, which to be implemented with cooperation of other related agencies as below:

a) Improved Meteorological, Hydrological and Seismological observation and forecasting (duration - 18 months, estimated budget – 2130 million Kyats)
b) Up-gradation of Early Warning Center (duration – 24 months, estimated budget – 1595 million Kyats)
c) Risk Assessment of Myanmar (duration - 18 months, estimated budget – 180 million Kyats)
d) Hazard Maps of Myanmar (duration - 36 months, estimated budget – 305 million Kyats)
e) Multi-Hazard end to end early warning dissemination system (estimated budget – 175 million Kyats)

5. Training Component

5.1 Trainings conducted in Myanmar

Meteorological course Grade III was conducted from 15 November 2010 to 31 January 2011 with 30 trainees, 15 from DMH and another 15 from Military. IFAS application training was conducted by the guidance of two Experts from ICHARM and 20 trainees from DMH had an opportunity to attend the course during the last week of June 2010.

5.2 Expert dispatch program

In order to improve the disaster risk reduction in Myanmar, JICA had been provided short-term experts dispatch program on the Improvement of Tropical Storm Forecasting and Warning to DMH. Mr. Kunio AKATSU, a well experienced expert of Japan has been dispatched to DMH from December 2009 to April 2010 for the first term, and technical transfer seminars have been conducted to improve the capacity of DMH weather forecasters.

Mr. AKATSU's second-term four months assignment was started again since mid December 2010, and the achievement of MTSAT installation can be counted as one outcome of his dispatch assignment. Another outcome is enabling to provide mobile AWOS, which will be very efficient for instrument calibration, through JICA program. JICA dispatched another two Lecturers from Japan Meteorological Agency – JMA and conducted Technical Guidance Seminar on MTSAT Data Utilization from 19 to 25 January 2011. About 17 DMH staffs have attended the seminar and received technical transfer from the Lecturers.

JICA will also dispatch third batch and fourth batch expert on Improvement of Storm Surge 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.

5.2 Short Term Abroad Trainings

During 2010 several DMH staff had having an opportunity to be trained under the below short term trainings conducted in abroad.

Sponsor	Training	Country	Duration	Participant
JICA	Cyclone & Disaster Warning Technology Training for Broadcast Engineer	Japan	1-19 February	3
	Reinforcement of Meteorological Services	Japan	14 Sep – 18 Dec	1
	Acid Deposition Monitoring	Japan	17 Oct – 18 Dec	2
TICA	On job training of Meteorological Instruments	Thailand	4 -27 July	3
	GIS & Remote Sensing	Thailand	19 July – 6 Aug	4
	Heavy Rainfall Surveillances And Early Warning's during the south west monsoon	Thailand	7 June – 2 July	5
	Training Program on Crop Weather Modeling	Thailand	10 – 29 October	5
KOICA	Training Program on Climate Change &Disaster Prevention	Korea	9 – 27 March	1
	Training Program an Analysis of COMS Data	Korea	26 Aug – 18 Sep	2
KMA	Training Workshop on Meso- scale Numerical Weather Predication – Phase 1	Korea	27 Sep – 8 Oct	2
MTCP	4th International Course on Flood Mitigation and Storm Weather Management 2010	Malaysia	4 October – 22 Oct	1

5.2 Long Term Abroad Trainings/ Degree

Sponsor	Training/ Degree	Country	Duration	Participant
WMO	M. Sc (Meteorology)	Philippine	2 years	1
	M. Sc (Hydrology)	India	2 years	1
JICA	Operating Management of Earthquake, Tsunami and Volcano Eruption observation system	Japan	5-7-2010 to 31.3.2011	1
	Seismology Earthquake Engineering and Disaster Management Policy	Japan	2-9-2010 to 17.9.2011	1
TICA	Remote Sensing & GIS	Thailand	2years	1

6. Research Component

Under the control of DMH, Research and Development Section is establish recently in 2010 with the purpose for building capacity of younger generation, without having the proper facilities. The titles of research currently carrying out are mentioned below.

a) Dryness and wetness during 1970 to 2099
b) Drought Index for dry Zone of Myanmar in 21st Century
c) Storm track shift due to climate change over SE Asia
d) Climate change in Myanmar during 21st Century by ECHAM 5 Model with Global Warming Experiment
e) New definition of monsoon onset and withdrawal for Myanmar
f) Analyzed the Evapotranspiration in Dry zone

To equip this Section with proper facilities, which enable to run the Regional Climate Model, the cost is estimated as USD 50000. This required budget is still in seeking.

Annual Report on Activities in Meteorology In the Sultanate of Oman During the year 2010

Review of the 2010 Cyclone Season

1. Meteorological Events

1.1 Cyclones

Three years after being affected by tropical cyclone Gonu in June 2007, Oman was affected again by another powerful tropical cyclone (Phet) during the period between 2nd to 5th of June 2010.

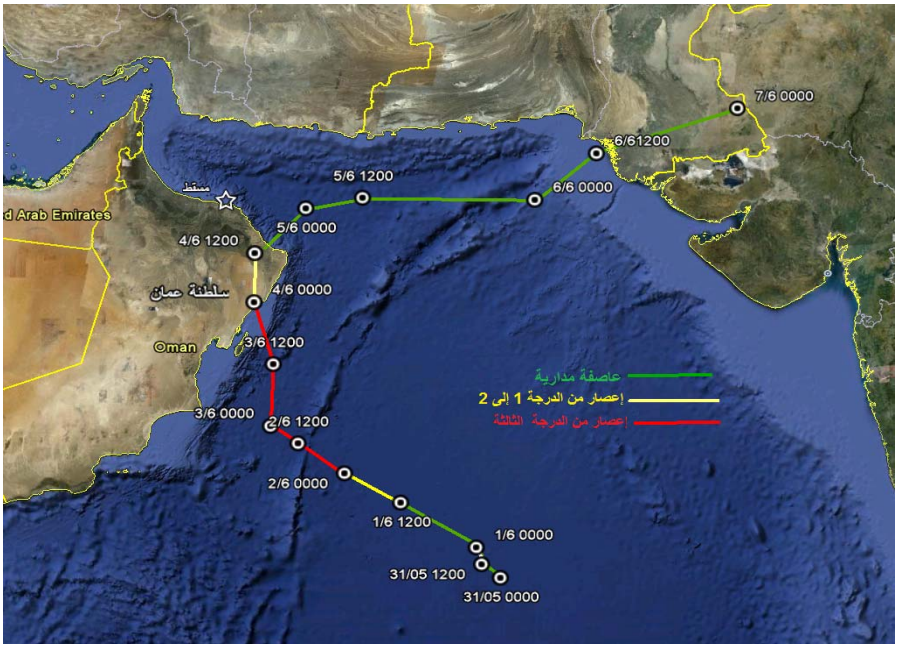


Figure 1: Path of Tropical Cyclone Phet.

The Meteorology department has issued several warnings well ahead of the cyclone arrival and the national plan for the disaster management was activated in coordination with the National Committee for Civil Defence (NCCD).

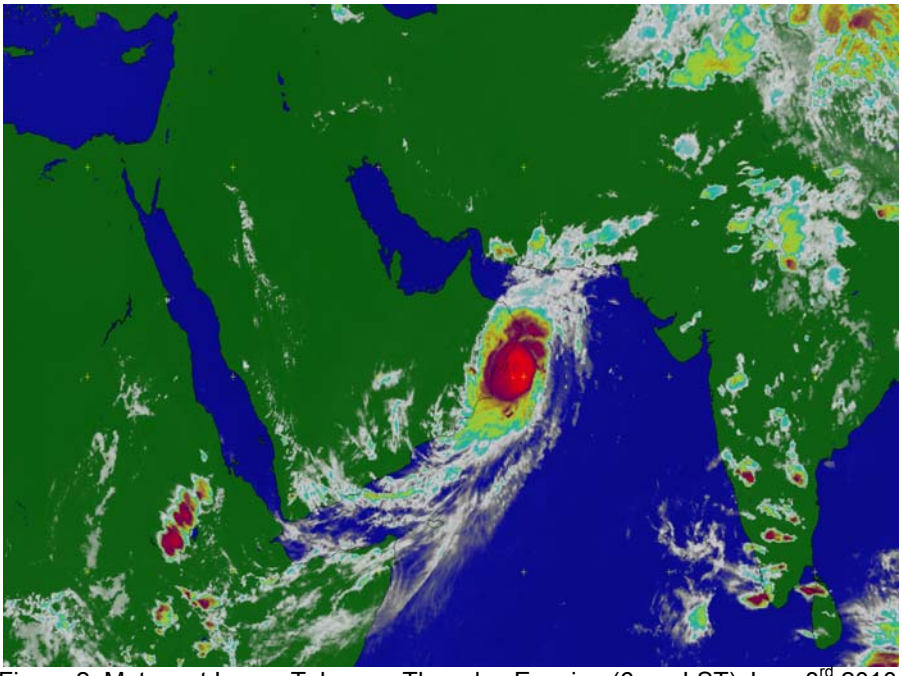


Figure 2: Meteosat Image Taken on Thursday Evening (6 pm LST) June 3rd 2010.

Figure 3 below shows maximum precipitation and wind speeds recorded by Oman Met stations during the period from 2nd to 5th June 2010. The highest precipitation accumulation was recorded in Masirah island with more than 175 mm. However, Qurayat (a mountainous place near Muscat) recorded 603 mm according to rainfall data from rainfall gauges operated by the Ministry of Regional Municipalities and Water Resources. The same source also reported 472 mm in Masirah island and 444 mm in hilm mountain in Sur. Masirah recorded the strongest winds with 85 knots.

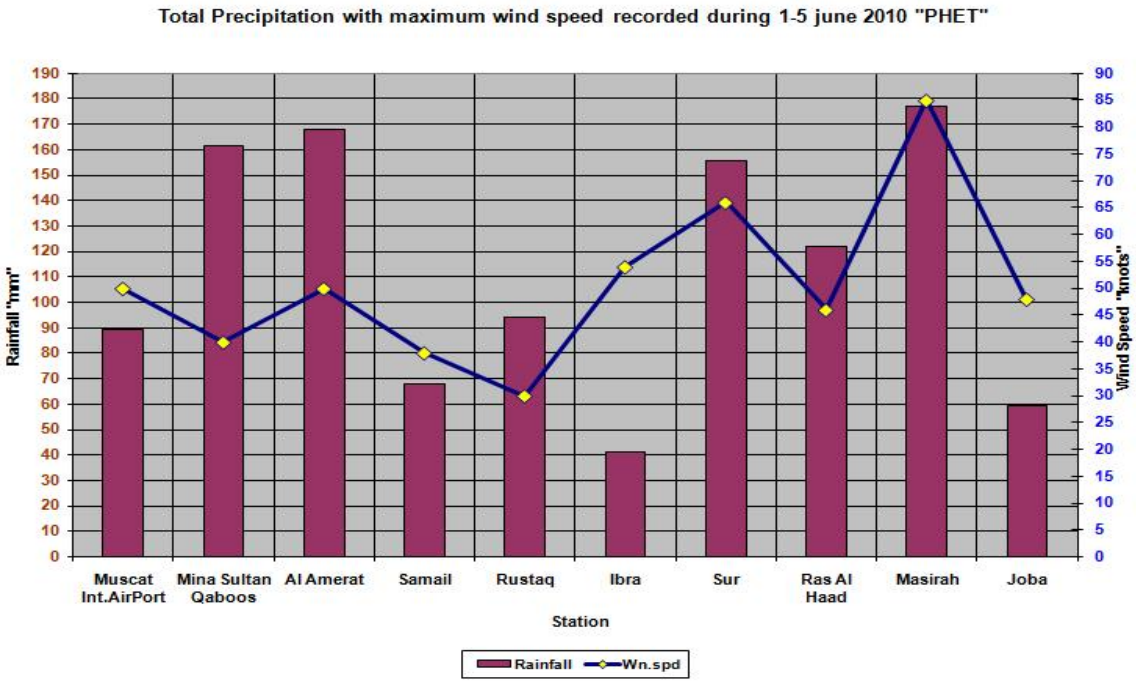


Figure 3: Total precipitation (mm) recorded and Maximum wind speeds (Knots) at Oman Met Stations during the period from 2nd to 5th June 2010.

As shown in figure 4 below, the lowest mean sea level pressure was almost 980 hpa which was recorded at Masirah island.

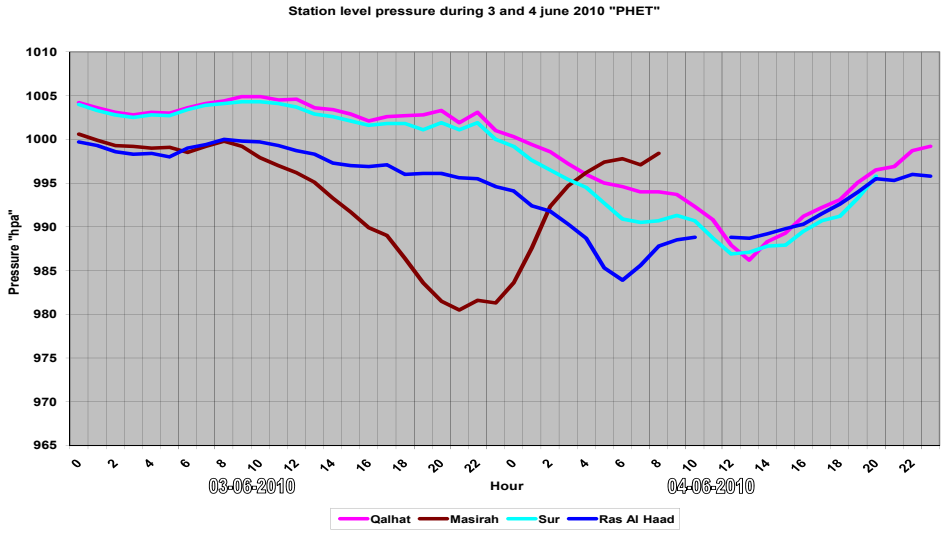


Figure 4: MSLP recordings at various Met stations.

Although Phet was a very powerful cyclone, Oman has managed to reduce its impact very well. This success was due to the early warnings issued by the Meteorology Department as well as the excellent coordination with the National Committee of Civil Defence (NCCD) which lead to the activation of the national disaster management plan well ahead of the cyclone arrival. According to the NCCD, 12870 people were evacuated to 91 shelters which were set up before the cyclone arrival. The NCCD reported a death toll of 16 people.

Review of the Coordinated Technical Plan

2 Meteorological Facilities

2.1 Upper Air Observation

The Sultanate of Oman operates two upper air-observing stations, located at Muscat (41256) and Salalah (41316) respectively. Both these are equipped with Vaisala's Digicora GPS wind finding system. The radiosonde was up graded to Visalla RS92 equipment. One flight is launched at 00Z from each of these stations on a daily basis.

2.2 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.

2.3 Wave Measurements

One wave radar measurement station was installed offshore of Qalhat (Sur)- another two wave measurement stations located offshore Sohar Station and Mina Salalah Station.

2.3.1 Synoptic Land Stations

The number of Synoptic Land Stations being inserted into the GTS still remained at 32 stations. Thirty Six Additional AWS stations were procured in 2010 and installation is expected to be completed in 2011.

2.3.2 Weather Radars

Five S-Band Dual Polarization Doppler Weather Radars was Tendered and Awarded to a German Firm Selex (Gematronix). The installation and commissioning of these Weather Radars will be completed in 2012.

2.3.3 Telecommunication (Ref to Diagram next page)

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

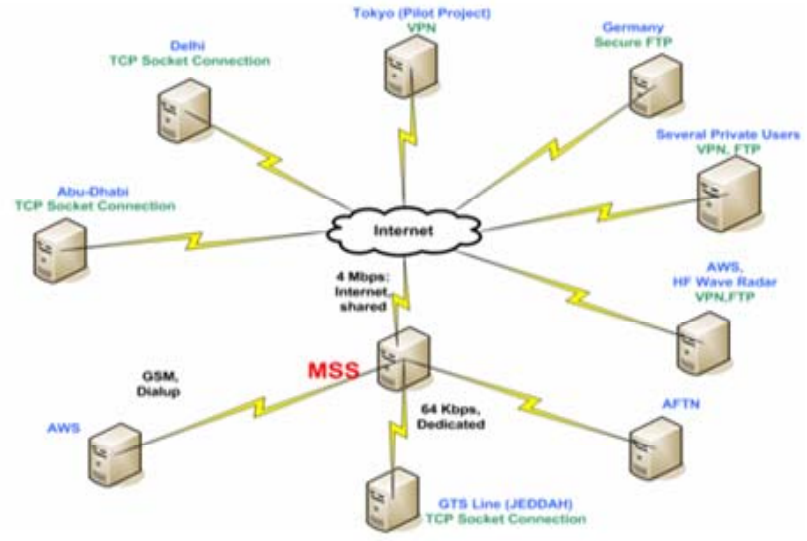
The MSS is connected to the RTH Jeddah by a dedicated link at 64 kbps based on TCP/IP protocol.

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.

Beside 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.

Oman Meteorological Telecommunication Network



2.6 Satellite reception

2.6.1 There are two locations with Ground Receiving Satellite Stations Muscat and Salalah.

2.6.2 These include HRPT Polar Orbiters operated by USA and China as well as Metop by Eumetsat.

2.6.3 Geostationary Satellites including Eumetsat MSG with DWDsat in addition to Eumetsat MFG seven as well as to the Chinese FY2 satellite.

2.7 Data Visualization

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

2.8 Computer Workstations

2.8.1 Data Processing System

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

Current operational processing capabilities consist of a PC Cluster of 20 nodes with total of 40 processors. Dual AMD Opteron 3.0 is used for each node. All nodes are connected via very fast Interconnection network using 24 Infiniband switch with guarantees 3Gbps full duplex.

Recently, new processing element under pre-operational status is being tested. It consists of 72 nodes with total of 756 threads. Quad-core AMD 3.2 processor are used and interconnected using 144-port Infiniband switch.

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

A] High Resolution Model HRM is Hydrostatic limited-area numerical weather prediction model for meso-α and meso-β. Main prognostic variables are: Surface pressure (ps), Temperature (T), Water vapour (qv) Cloud water (qc), Cloud ice (qi), Ozone (optional), Horizontal wind (u, v) and Several surface/soil parameters. More details are available on the model website (http://www.met.gov.om/hrm/index.php).

DGMAN runs HRM with two model resolutions:

ORM_28: 28x28 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 0.25 degree. There are 193x114 grid points and 40 vertical layers. The model is running on 20 nodes from the PC Cluster. It produces up to 78-h forecast at 00 and 12 UTC. The following figure shows the domain area.

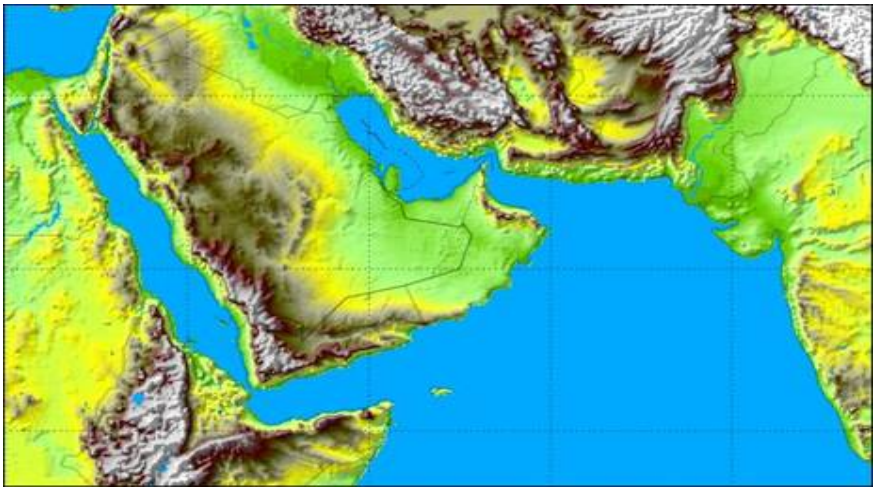


Figure 1: ORM_28km resolution domain

ORM_07: 7x7 km resolution. The operational version of the model covers the area between 48.5.0 E, 14.0 N (lower left corner) to 63.5E, 29.0 N (Upper right corner) with mesh size of 0.0625 degree. There are 241x241 grid points and 40 vertical layers. The model is running on 20 nodes from the PC Cluster. It produces up to 78-h forecast at 00 and 12 UTC. The following figure shows the domain area.

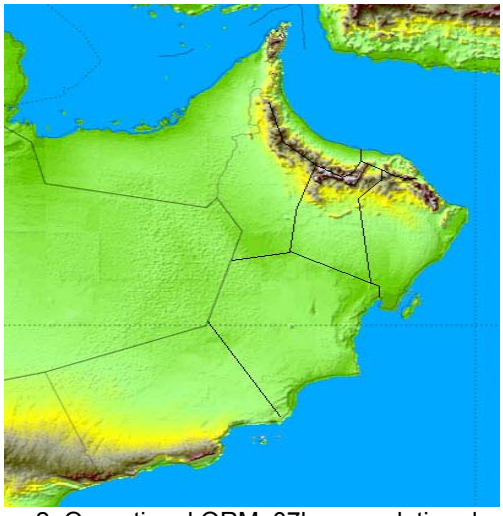


Figure 2: Operational ORM_07km resolution domain

Under the new processing element, ORM_07 is run over the domain shown in Figure 1. On this configuration there are 769x453 grid points and 60 vertical layers.

B] Consortium for Small-scale Modeling COSMO is a non-Hydrostatic limited-area numerical weather prediction model for meso-α and meso-β. Main prognostic variables are: pressure perturbation (p‘), Temperature (T), specific humidity (qv) Cloud water (qc), Cloud ice (qi), Horizontal/virtical wind (u, v) and Several surface/soil parameters. More details are available on the model website (http://cosmo-model.cscs.ch)
DGMAN COSMO model with kind cooperation with DWD. The operational version of the model runs on 7x7 km covers the same domain of ORM_07 as shown in Figure 2. 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.
Under the new processing element, COSMO model is run using two different model resolutions. The first resolution is 7km and covers the model domain shown in Figure 2.

C] A WAM based wave model was established with the kind cooperation of GKSS of Germany, which covers the Arabian Sea, gulf of Oman and Arabian gulf. WAM model run of 28km resolution and it runs on a single processor on the PC cluster.

Under the new processing element WAM is run over the domain shown in Figure 1 using 14km resolution and close to the Omani coast with 3.5km resolution.

D] Tsunami Model for the Oman Sea and India Ocean: Comit Model from IOC is used to develop some hypothetical experiments to simulate tsunami waves propagation and indentation.

2.8.2 Module Output Statistics (MOS)

The Directorate General of Meteorology and Air Navigation (DGMAN) successfully established a MOS based on ORM_07. 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.

2.8.3 Verification Package

The Directorate General of Meteorology and Air Navigation (DGMAN) managed successfully to develop its own verification package. The developed system verifies the continuous weather parameters such as T_2m, TD_2m and for the categorical weather parameters such as Total precipitation. The system generates different statistical scores such as Hit rate with a margin of error, Bias, Root Mean Squared Error (RMSE). The package provides a friendly UGI to allow the user to select different choices (Model type, stations list, observation time, weather element and statistical score) to be verified. This system will help find the systematic errors in the Model output, which can be tuned.

The package is being in several countries such as UAE, Brazil, Jordan, Malaysia, Hungary, Vietnam, Iran, University of Berlin, Kenya and Madagascar. Panel Members may get a copy also if they request Oman's P.R.

3 Aeronautical Services

In order to meet ICAO recommended practices and to fulfill the requirements for Aviation the Directorate General of Meteorology and Air Navigation (DGMAN) installed a SADIS workstation as early as 1996. The Department pay’s to the UK Met Office the annual contributions for obtaining SADIS data and Products. In addition all the SADIS data and products are also received thru an FTP Server from UK as a back up.
A new service was also established for the provision of en-route flight folders for all Airlines operating in the Sultanate which is accessed thru a Web Portal.

4 Training

Workshops, Seminars and Training Courses attended by the Met personnel during the year 2010 were as follows:-

Workshop/Seminar/Training Course	Country	No. of Persons
PhD. In Climate change	UK	1
PhD. In Storm Surge Forecasting	India	1
PhD. In wind power	Oman	1
PhD. In Network	Oman	1
Master in Statistics	Oman	1

Master in environment	Oman	1
EUMETSAT Satellite Application Course	Oman	10
Tropical Cyclone Workshop	France/Reunion Island	2
Dust Forecasting Course	Spain	1
database systems CLDB	Slovakia	1
moving weather system	Slovaki	2
numerical weather forecasts	Germany	1
Production of weather graphics for TV	Oman	4
programming languages	Oman	3
Total		30

5. Hydrological Component

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 2010, a measurements of all hydrological parameters were measured through (4681 monitoring stations).Station includes (rain gauges, wadi gauges, flow peaks, aflaj, springs and water level) in addition to 32 dams distributed all over the Sultanate.

Rainfall:

There are 304 rain gauges, of which 219 Automatic and 85 of standard type. About 30 of these rainfall stations are fitted with telemetry using GSM modems.
During the year 2010 the coastal area of the country was exposed with exceptional rainfall as a result of tropical cyclone Phet. The maximum annual accumulated rainfall was 603 mm in Quryat, while 472 mm were recorded in Al-Sharqyah region. Mhoot in AlWusta region recored 68 mm. The other areas of the country recorded rainfall lesser the annual average.

Wadi flow and floods:

There are 137 wadi gauge stations to measure wadi flow and to compute flood volumes. In addition to 25 stations to measure the peak height of the wadi flow. The year 2010 is considered the largest year where high discharge rates were recorded since 1997. The total flood volumes during 2010 (712 Mm^3) which is about 3 times of the annual average. The highest recorded was (390 Mm^3) in Muscat region.

Groundwater level measurements:

The Ministry of Regional Municipalities & Water resources operate a network of 2107 groundwater wells measured for water levels. 1700 of them are measured every month and the rest measured every three months. Analysis of data showed that as a result of increase in recharge there is a gradual increase in water levels in most areas of the Sultanate, particularly for the shallow alluvium aquifer which represents the main supplied source of irrigation water.

Recharge Dams:

There are 3 types of Dams in Oman. 61 surface retention dams, 32 recharge dams and 11 flood protections dams. On the 32 recharge dams stations for measuring flow and sedimentation. A total of 78.5 Mm^3 was retained by recharge dams during 2010. In addition to this the Wadi Dayqah dam in Muscat region a total of 133 Mm^3.

Events:

The Ministry arranged 2 main water resources related conferences during 2010 these were:

- WSTA 9th Gulf Water Conference, Sultanate of Oman, 22-25 March, 2010 Water Sustainability in the GCC Countries, The Need for a Socio-economic and Environmental Definition.
- Training Workshop on Application of GIS and RS in Water Resources Management 19nd to 22th December 2010, Muscat, Sultanate of Oman

Achievements:

Some of the main Ministry achievements are listed below:

- The Ministry has completed the work of Wadi Dhaiqa Dam its one of the biggest dams in Oman the storage capacity of it 100 Mm3, Water of this dam is allocated for agriculture and drinking. During June of 2010 as a result of Phet cyclone the dam exceeded its maximum capacity and overflowed.
- The Ministry has also completed 5 other 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 the year including; dams construction, study of the increase groundwater level in some part of the country, study the water situation, use of gray water in desert, drilling of exploration wells, rehabilitation of monitoring wells, wadi gauges and rain gauges effected by cyclone.
- In surface water the ministry completed many studies including; identification of flood prone areas , preparation of hydrogeological map for the whole country.

Training:

The Ministry of Regional Municipalities and Water Resources is very keen in training the staff. During the year 2010 the Ministry arranged for both local and overseas training and workshops :

Future Plans:

The Ministry of Regional Municipalities and Water Resources is working on implementation of the five years plan starting from this year. The plans include exploration of new water resources in the country through drilling. Construction of more dams to store water and recharge the groundwater aquifers. Plans also include expansion of hydrological network and upgrade of automatic stations and including the telemetry systems. The other Ministry plans includes:

- 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).

6. Disaster Prevention and Preparedness Component

The National Committee of Civil Defense is the government unit responsible for disaster preparedness and response. It is chaired by H.E the Inspector General for Police and Customs (the equivalent of the minister of interior in most countries). It has 21 members from government and nongovernment agencies. The Committee is responsible for formulating national policies and strategies in regard to risk prevention and preparedness.

The National Committee for Civil Defence (NCCD) keeps an excellent coordination and cooperation with the Meteorology department. During Phet, the national plan for disaster management was activated. Figure 1 below shows the main sectors which were activated to run operations during Phet.

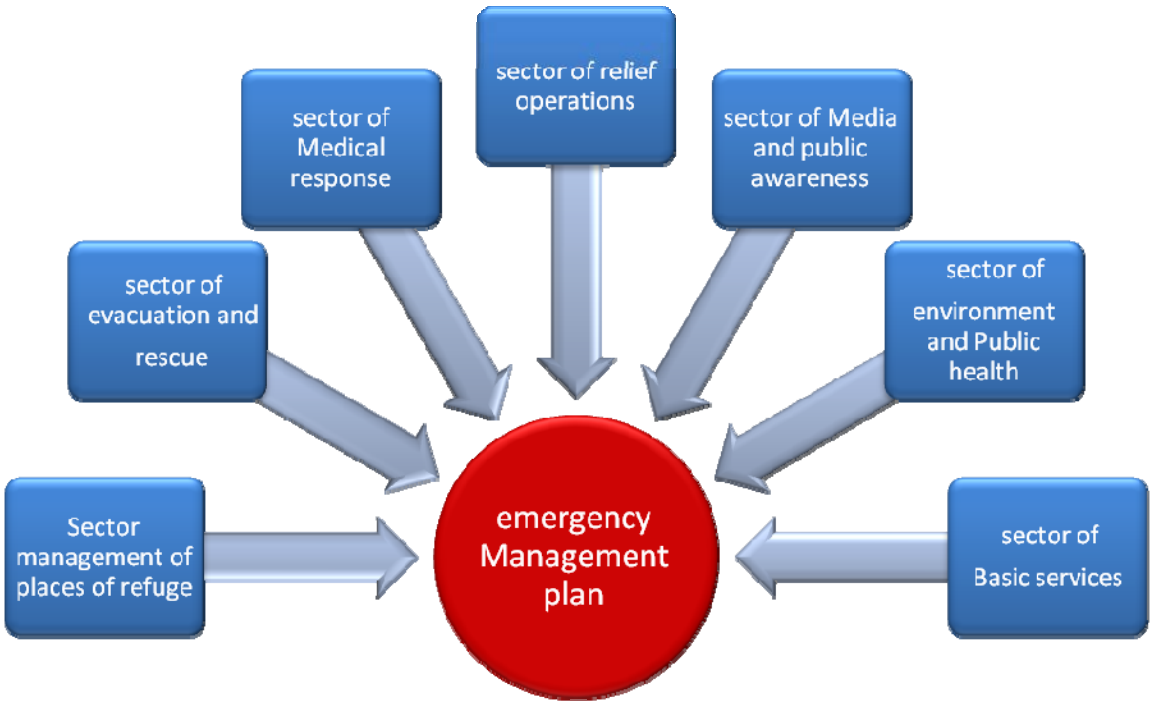


Figure 1: Main NCCD sectors during Phet

Table 1 below shows a summary of major NCCD operations and statistics during Phet.

Table 1: Tropical Cyclone Phet NCCD Statistics

1	**Shelters**	91
2	**Number of people using shelters**	12 870 people
3	**Logistical support**	23843
4	**Emergency medical response**	16 hospitals and health center
5	**The number of deaths**	16 people

6	**The number of missing**	2 people
7	**The number of flights**	3558
8	**The number of Land Trips**	17
9	**The number of Communication stations affected**	1997
10	**The number of routes affected**	59

- **Main Events/Activities organized by the Executive Office of the NCDD**

1. The executive office of the NCCD hosted an international workshop on information management in crises and emergencies.
2. A workshop on how to deal with radiation, chemical and biological accidents.
3. Symposium on the national system for crisis management with participation from ministries focal points and other related government agencies.
4. Training program for representatives of government agencies and coordinators of subcommittees on how to prepare contingency plans and crisis management in cooperation with a number of experts and specialists.
5. Participation in the crisis and disaster management course organized by the Royal Air Force of Oman in cooperation with the University of Bournemouth.
6. Participation in the planning for crisis and disaster management organized by the University of Bournemouth in collaboration with the British Royal Oman Police.
7. Regional volunteer teams.
8. Launching a website for the National Commission of Civil Defense (on experimental basis for now).
9. Participatations in the evacuation drill at Oman's Petroleum Development Company in port of Al-Fahal.

- **Future Plans**

There are royal directives to further improve the national plan for disaster management. Some of the main objectives to achieve that include:

1. Working towards establishing a fully equipped emergency management centre whose design needs to take into consideration all the physical and geographical features.
2. Building up-to-date databases for the civil establishments, roads, physical features and Geographical Information Systems (GIS).
3. Relocating the food reserve stores all over the Sultanate's Governorates and Regions in order to expedite the emergency-related administrative procedures and support provision and develop a national system to distribute relief supplies in the affected areas.
4. Activating the special plan developed by NCCD on how to deal with disasters related to hazardous materials.
5. Establishing quickly deployable hospitals which can be airborne.
6. Furnishing the emergency shelters with the necessary equipment and ervices, including the food supplies.
7. Providing water reserves to the main hospitals for use in the event of desalination plants failure.

---END---

PMD

Country Report of Pakistan

(2010-2011)

for

38th Session of WMO/ESCAP
Panel on Tropical Cyclones for the Bay of Bengal
& the Arabian Sea
(New Delhi, India, 21 – 25 February, 2011)

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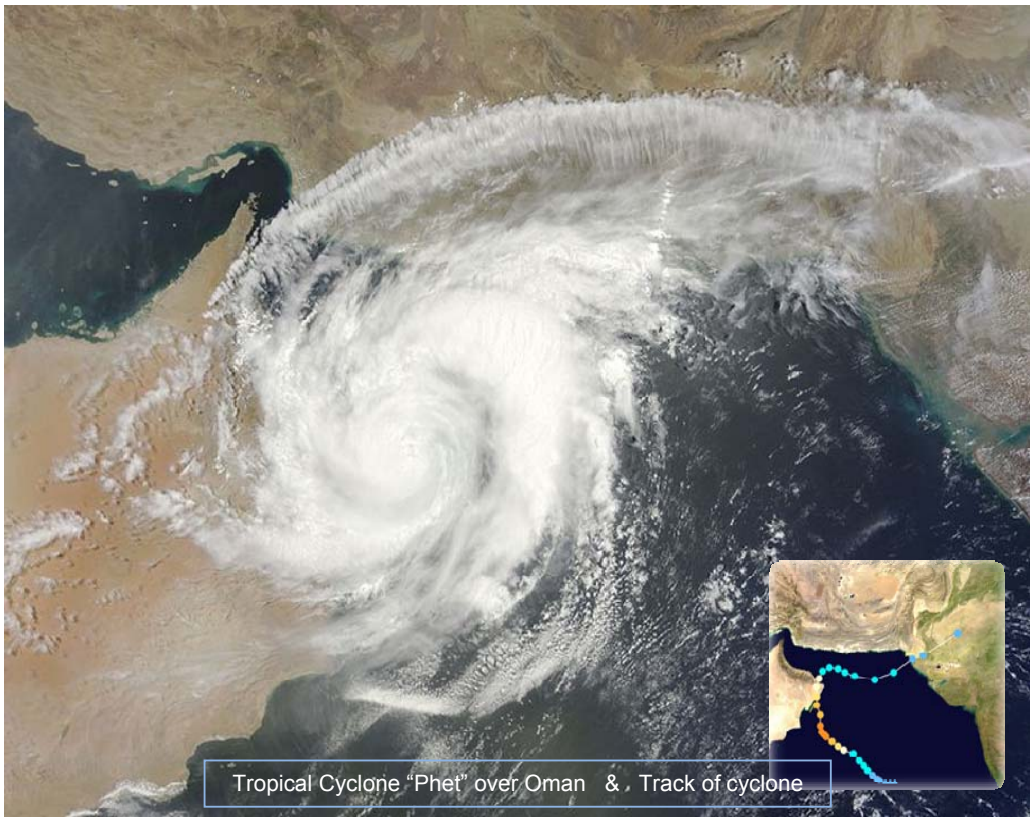
1. Tropical Cyclone activity:

On 31st May 2010, a low pressure area with deep convection and an organized Low Level Circulation Centre (LLCC) formed in the central Arabian Sea at around 15°N and 63.9°E which later accentuated into a depression and then intensified into a tropical cyclone on 1st June at 0000 UTC laying centered at 15.7°N – 63.8°E about 1100 Km south-southwest of Karachi.

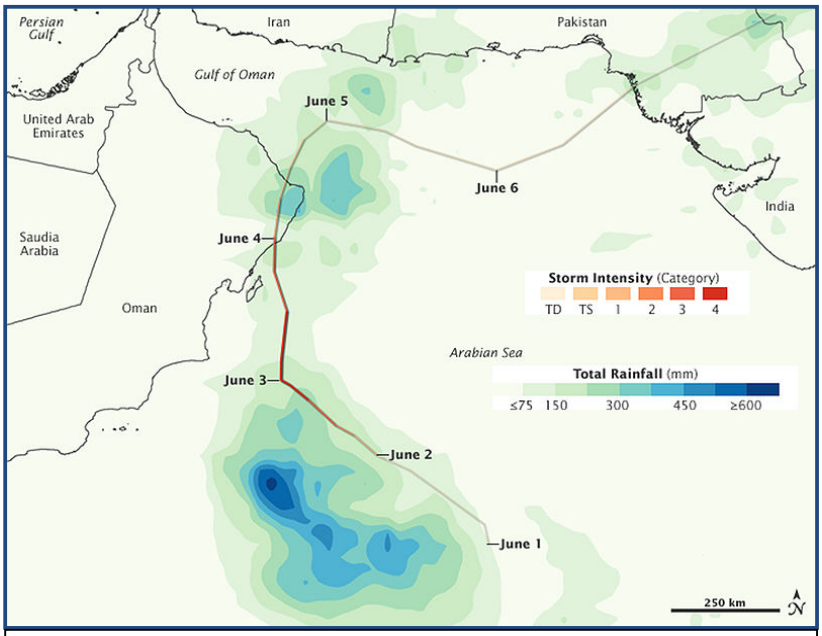


Tropical Cyclone "Phet" over Oman & Track of cyclone

On 2nd June, the tropical cyclone was named "Phet" (a Thai word pronounced as "Pet" meaning diamond). On the same day, the "Phet" having drifted initially in northwesterly direction further intensified into a severe tropical cyclone with centre at 17.5°N - 61°E about 950 Km southwest of Karachi and it kept its pace slow (at a speed of 6 Kts/hour) along northwest and by the evening it underwent further intensification from severe tropical cyclone to a very severe tropical cyclone and lay centered around 18.2°N – 60.0°E. On 3rd June, having sustained its severity, the cyclone kept moving north-northwestwards, struck the northeastern tip of Oman during night and weakened into a severe tropical

cyclone centered around 21.5°N – 59.5°E. It remained almost stationary over there for about 12 hours. After crossing the Oman coast on 4th June (1200 UTC) it crested the subtropical ridge (STR), entered the west North Arabian Sea and started recurving towards northeast as a severe cyclonic storm with centre at 23.5°N – 59.5°E. Keeping its course east-northeastwards on 5th June (0600 UTC) it centered around 24.0°N - 61°E at about 80 Km south of Gawadar and it was the time when Makran coast of Pakistan came under the grip of very heavy downpour accompanied with strong winds over 40 Kts with Jiwani recording the maximum surface wind of 45 Kts.

Record breaking torrential rains were observed along Pakistan coast. The rainfall recorded at different stations were 370 mm at Gawadar, 208 mm at Jiwani, 140 mm at Pasni, 60 mm at Ormara and 63 mm at Turbat. Widespread very heavy rainfall also occurred in southeastern parts of Pakistan (comprising mainly the lower Sindh province). The principal amounts of rainfall recorded were 152mm at Karachi, 154 mm at Thatta and 101.6 mm at Hyderabad. From 5th June (mid-night) onwards, the "Phet" started moving eastward with a speed of 10 Kts per hour and on 6th June at 0600 UTC its centre was around 23.4°N – 65.6°E. It weakened gradually before the landfall and finally made landfall in the evening of 6th June over Sindh coast (at about 24.6°N – 67.3°E) just south of Karachi. After landfall, the system weakened rapidly to become a well marked low pressure area and moved towards Rajasthan (India).



TRMM satellite rainfall estimate map (8th June 2010) shows Cyclone Phet's heaviest rainfall (600 mm or 23.6 inches or more) occurred over open waters of the Arabian Sea (blue) Northeast Oman received as much as 450 mm (17.7 inches), while Pakistan received between 150-300mm / 5.9-11.8 inches. The colored line indicates storm track and intensity according to the Saffir-Simpson hurricane scale.

2. Meteorological Component

2.1 Strengthening of AWS Observational Network in Pakistan

During 2010-2011, PMD have established 10 AWS and 45 precipitation monitoring stations to strengthen its observational network making the total number of AWS and precipitation monitoring stations 35 and 500 respectively. These stations have been established mostly in the arid/ semi arid regions of the country. Further, PMD also started generating Drought Monitor for the entire country fortnightly (using GIS) which is also updated on PMD's website.

2.2 Numerical Weather Prediction at PMD

Pakistan Meteorological Department has been using High resolution Regional Model (HRM) of DWD (the National Meteorological Service of Germany) as an operational model for numerical weather prediction since January, 2007. Initially the model was run with 28 Km resolution, however, from March 2008 on wards, the model was started to run with 22 Km resolution and the simulations are being performed twice a day by using GME data of 0000UTC and 1200UTC. Further, the model output (prognostic charts) are also uploaded at PMD's website www.pakmet.com.pk. In 2009, PMD procured additional servers/hardware with processing power of 1.7 T-FLOPS to upgrade its existing computer system and run the model with the resolution of 7 km. However, the upgradation of HRM at 7 km resolution was not successful for Pakistan due to complex topography. The HRM, a hydrostatic model is limited in representing the full spectra of waves (e.g., trapped lee waves), which are connected to steep slopes. Therefore, after upgradation of hardware, the model with 11 km resolution has been operational since September 2010. Now PMD is planning to implement a non-hydrostatic model with higher resolution. In this regard, PMD is seeking support of DWD (Germany) and WMO for capacity building in NWP based on COSMO model (COnsortium for Small-scale MOdelling), a non-hydrostatic regional atmospheric model.

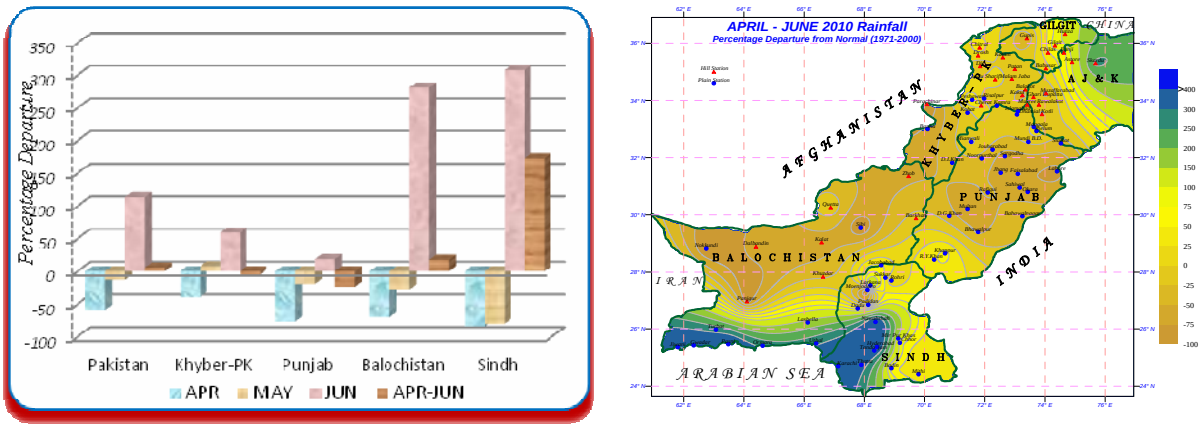
2.3 Weather Summary

2.3.1 Heat Wave Sweeps Major Parts of the Country

The intense heat wave swept major parts of the country during 16th – 25th March, 2010 especially affecting the northern and central regions of the country. The temperatures remained above normal at as many as 32 Met Stations of PMD. The highest maximum temperature during the month was of 42.6°C recorded at Sibi on 21st March, 2010 as against of 41.5°C, the previous highest. Karachi, the cosmopolitan coastal city, also experienced the ever hottest recorded day of March with maximum temperature being 42.2°C on 19th March. In Punjab province, Rahim Yar Khan was the hottest place where maximum temperature was recorded as 42.3°C.

2.3.2 Pre-Monsoon Season (April- June) 2010:

On country basis, rainfall recorded during the pre-monsoon season (April-June) has been close to normal. On monthly basis, the rainfall has been observed to be below-normal in the months of April and May and above-normal during June (mainly due to the tropical cyclone "PHET" that struck Oman and Pakistan coasts during first week of June). However, on province basis, the seasonal rainfall has been found to be quite variable as shown in the following figure.



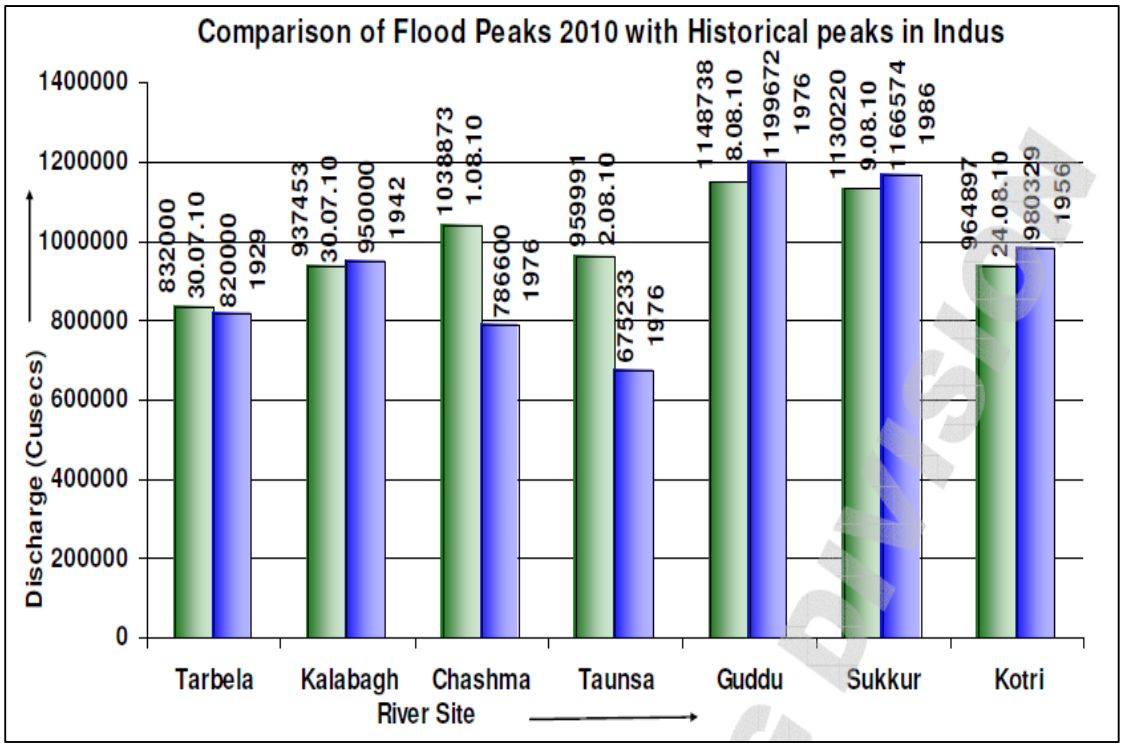
The percentage departure and spatial distribution of rainfall during Pre-Monsoon Season (April-June) 2010

3. Hydrological Component

3.1 2010 Super Floods:

Pakistan suffered from history's worst extremely high floods during 2010-Monsoon season. Heavy rainfall spell during 28-30 July, 2010 in the north of Pakistan especially in Khyber Pukhtunkhwa (KPK) province and adjoining upper Punjab caused firstly severe flash flooding and then history's extreme high riverine flooding in Pakistan. The second wave of the flood in the Indus River and its tributaries was caused by the rainfall spell which occurred during 5-9 August 2010.

PMD issued weather forecasts for these precipitation events a few days earlier. The second flood wave aggravated the already flooded fields of Punjab, KPK, Sindh and Balochistan provinces. This second flood wave practically merged



The comparison of 2010 flood peaks with historical peaks at different dams/barrages along the Indus

with the first flood wave below Taunsa barrage (on the Indus River in Punjab) and created havoc in the surrounding areas and downstream Taunsa and the phenomenon is referred to as the "2010 Super Flood." The flood affected several areas in all provinces.

Losses & Damages *(Source: NDMA, Pakistan)*	
Deaths	1,985
Injured	2,946
Houses damaged	1,744,471
Population affected	20,184,550
Crop areas (Hectares)	2,244,644
Districts Affected	78

In terms of the number of people affected, the United Nations rated the flood as the greatest humanitarian crisis in recent history.

The riverine floods were predicted reasonably well by PMD's Flood Forecasting Division (FFD).

3.2 Pakistan Floods: WMO and ESCAP Actions

3.2.1 Establishment of Task Force on Pakistan Floods on 27th August, 2010

WMO has established a Secretariat Task Force on the Pakistan floods at WMO on 27th August, 2010 which is led by senior officials of WMO.

3.2.2 WMO ad hoc liaison office at PMD, Islamabad 14th October to 13th November, 2010

In order to address hydrometeorological disaster risk reduction (DRR) challenges in Pakistan, WMO has offered its assistance to PMD. WMO ad hoc liaison office was opened at PMD Headquarters, Islamabad with Dr. Jaser Rabadi (WMO Representative for West Asia) to work as liaison officer from 14th October to 13th November, 2010.

3.2.3 WMO Expert Mission to Pakistan 4th to 8th November, 2010

In order to make assessment of the damages to hydrometeorological infrastructure and to further strengthen the hydrometeorological system in Pakistan, a six-member WMO fact-finding and needs-assessment Mission comprising of experts in hydrology and DRR from UNESCAP, WMO, JMA, USA visited Pakistan from 4th to 8th November, 2010

In light of the recommendations of the WMO Expert Mission, it has been proposed to restore and strengthen the capacities of PMD with phased approach including: (i) short term needs (within less than one year), (ii) medium term needs (2-3 years) and (iii) long term needs (5-10 years).

Some of the main items of the recommendations/proposal include:

- Restoration of damaged meteorological and hydrological observational network;
- Establishment of around ten (10) localized Flash Flood Warning Systems for small rivers and streams (replica of Flash Flood Warning System for Nullah Lai basin (twin cities of Rawalpindi and Islamabad);
- Establishment of Regional Flood Forecasting Centers in KPK, Sindh and Balochistan provinces;
- Strengthening of Radar Network to give radar coverage to the whole country;
- Improvement in hydrological/flood forecast model and NWP model;
- Capacity building/human resource development.

The report of the WMO Expert Mission will be sent to the potential donors by WMO Secretariat for consideration of the support needed in the identified areas as per recommendations of the Mission in order to affectively address hydrometeorological DRR challenges in Pakistan.

3.2.4 UNESCAP organized an Expert Group Meeting on Reducing Flood Risk Reduction in Islamabad-Pakistan on 9-10 November, 2010

In wake of 2010-Super Floods in Pakistan, ESCAP organized a one-day preparatory Meeting in Nanjing, China in September, 2010 for hosting a High-level Expert Group Meeting on Pakistan Floods. Consequently, the High-level ESCAP Expert Group Meeting on Reducing Flood Risk Reduction was held in Islamabad-Pakistan on 9-10 November, 2010 (in collaboration with NDMA, Pakistan). WMO Expert Mission reported to the meeting on the outcomes of the mission.

As a follow-up of this ESCAP Expert Group Meeting, PMD and SUPARCO are co-hosting a an ESCAP Workshop on Developing Capacity Resilience to Water-related Disasters in Pakistan through Space Application & Flood Risk Management in Islamabad-Pakistan during 1–4 March, 2011.

4. Disaster Prevention and Preparedness Component

4.1 National Disaster Management Plan

National Disaster Management Authority (NDMA) of Pakistan with assistance from JICA has prepared a National Disaster Management Plan for 2011-2021. 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

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)

4.2 Strengthening of Seismic Monitoring Network in Pakistan

PMD with support by the China Earthquake Network Center (CENC)/ China Earthquake Administration (CEA) has been implementing a project for Strengthening of Seismic Monitoring Network in Pakistan. Under this project site survey for installation of ten (10) broad band seismic stations has been completed and installation of the new seismic equipment is in progress. After installation, the new seismic stations will be integrated with the existing seismic network of PMD and total number of broad band seismic stations of PMD will become twenty (20). The strengthening of seismic monitoring network in Pakistan will help PMD in better monitoring of earthquakes and precise earthquake hazard assessment.

5. Training / Education:

5.1 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 (BIP-MT) were conducted in 2008, 2009 and 2010 at PMD's Institute of Meteorology & Geophysics (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 for their participation in these courses.

In 2010, such a course was conducted successfully at IMG, Karachi from 20th March to 23rd July. In this course, eleven (11) Met. Personnel from NMHSs of neighbouring countries, Bangladesh (2), Bhutan (3), Myanmar (1), Nepal (2), & Sri Lanka (3) participated. Under this project, the fourth (and final) such course has also been scheduled in 2011. For this course, around six Met. Personnel from NMHSs of the neighbouring countries (Bangladesh, Bhutan, Myanmar, Nepal and Sri Lanka) are expected to participate. For the continuity of these training courses in the coming years, WMO is requested for necessary support.

5.2 Capacity Building/Training Abroad of PMD official

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, eight (08) officers have joined back to PMD. Two of these officers joined in 2010 after seeking higher studies from United Kingdom, Canada, Norway, China and Thailand. Two (02) of these officers have done their PhD in Meteorology, while

six (06) officers have completed their MS in Meteorology and Earth Sciences. During 2010, two (02) scientists have also completed their JICA sponsored postgraduate studies in seismology and tsunamis from Japan.

At present, twelve (12) officers of PMD have been doing their MS/PhD in China since October, 2009. Ten (10) of these officers are doing their MS (Meteorology) at Nanjing University of Science and Information Technology (NUIST), China. China Meteorological Administration (CMA) and NUIST have been very kind to provide partial financial support towards this MS (Meteorology) programme in respect of PMD officers. The remaining cost has been born by the Government of Pakistan. These officers are expected to join PMD in July, 2011 after completion of their MS (Meteorology) at NUIST. While, two (02) of the officers have been doing their PhD (Meteorology) with scholarship by the Chinese Academy of Sciences covering around 70% of their expenditures. The remaining cost of their studies has been born by the Government of Pakistan.

In addition, during 2010 PMD scientists have availed around 30 fellowships for attending short-term trainings/ training workshops abroad. These fellowships have been offered mainly by WMO, China Earthquake Administration, UN ESCAP, UNESCO-IOC, China Meteorological Administration, JICA, and KOICA etc.

5.3 Training of Met. Personnel of PMD at IMG, Karachi

During 2010-2011, various regular and special courses on meteorology were also conducted at 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 (BIP–MT), Basic Forecasting Course (BIP–M) and several others.

5.4 Training of PMD officials at COMSATS Institute of Information Technology, Islamabad

Around eight (08) officers of PMD have completed their MS (Meteorology) from Department of Meteorology, COMSATS Institute of Information Technology (CIIT), Islamabad during 2010-2011. PMD has also been providing teaching faculty support to CIIT.

6. Research:

6.1 Wind Mapping of Northern Areas of Pakistan (Phase-II):

PMD with financial support by the Ministry of Science and Technology has been carrying out wind potential survey of various areas of the country since 2001. In Phase-II of this project, PMD carried out wind survey of Northern areas

of Pakistan for determining the assessment of wind power potential of these areas. For the purpose of this project, the Northern areas of Pakistan included districts of Swat, Dir, Chitral, Gilgit, Skardu, Haripur, Shangla, Buneer, Nowshara, Peshawar, Mohmad Agency, Khyber Agency and Azad Jammu and Kashmir (AJK). The results of this study would ultimately provide a platform for the establishment of Wind Mills / Farms for power generation. The project was initiated in 2005-2006 and was completed in 2010-2011.

Wind data from 42 stations have been collected and analyzed. The reports of all 42 stations have been drafted on the basis of collected data. The comprehensive final draft report of this project is under preparation. The analysis of data suggests that Shaheed Gali (in AJK), Sost (in Gilgit-Baltistan region), Swat and Mardan in (Khyber Pakhtunkhwa province) have the potential for establishing small to medium scale wind power projects.

In Phase-III of this project, similar study would be carried out for northern and western parts of Balochistan province subject to availability of funds.

It is pertinent to mention that in Phase-I of the project, PMD has already completed the wind power potential of the coastal areas of Pakistan (Sindh-Makran coast). On the basis of the wind data analysis, a wind corridor in Gharo has been identified in Sindh, which covers an area of about 9,700 Square Kilometers and it has the exploitable Electric Power Generation Potential of 11000 Mega Watt.

A number of Research work / small projects related to forecasting Techniques, Climate Change, Climate modeling, Downscaling for Seasonal and Monthly Prediction, Verification of High resolution Regional Model (HRM), were also carried out by the scientists of PMD and they presented their research work at various conferences/ symposia / workshops at national and international levels during 2009-2010.

7. Publications:

PMD started publication of its research journal “Pakistan Journal of Meteorology” in 2004. During 2010-2011, PMD published two issues (No. 12 & 13) of “Pakistan Journal of Meteorology”. These issues contain research papers contributed by the scientists of PMD and international scholars.

In addition, 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 or proceedings of the international conferences/ seminars.

COUNTRY REPORT – SRI LANKA

1. Report on the Impact of Tropical Cyclones *(agenda item 3.2)*

Effect of Tropical cyclones: There was no tropical cyclone directly affecting Sri Lanka. However, a feeder band of tropical cyclone Laila (deep depression stage) which developed in the Bay of Bengal resulted in heavy rain in the southwestern parts during 16th and 17th May with heaviest daily falls of 313.6mm at Nittambuwa in Gampaha district on 16th and 283.8mm on 17th at Galle, affecting more than 300,000 in Colombo, Gampaha, Kalutara and Galle districts.

Tropical cyclone "JAL" moved near northeast coast of Sri Lanka enhancing the windy conditions over the northern and Eastern provinces during 05-06th November and sea areas around the island were rough with showery weather affecting fishermen with one was reported to lost.

General Weather: At the beginning of the year, there were a few incidence of strong down draft during northeast monsoon. The inter-monsoon which is characterized by usual convective showers commenced in the last week of March. Largely due to appearance of ITCZ convective activity was stronger than average and caused above average rainfall and number of lightning damages reporting 21 lives lost during inter-monsoon and pre southwest monsoon.

The southwest monsoon got established on 09th June (about two weeks delay) confining the rainfall predominantly to the southwestern parts and lasted till 25th October. The monsoon winds were quite strong with only two break features (appeared during 19-20th August and 19th to 30th September). Number of property damages reported by the strong winds during the southwest monsoon including in the second break.

During the second inter-monsoon prevailed from 26th October to 20th December, low level disturbances formed near the island on ITCZ enhanced the rainfall. A meso scale atmospheric disturbance in the western sea, associated with ITCZ caused very heavy rainfalls in the western province on 10th November night. The rainfall recorded at Colombo was 440.2mm on 10th and it is the second highest ever recorded rainfall at Colombo where longer than 125 years of rainfall history exists**.**

12 lives have been reported to be lost due to strong lightning strikes from latter part of September and in October and November. .

Rain was fairly widespread during the 03-04th of December due to a disturbance formed in the vicinity of the island causing localized floods in Western and Northern parts.

2. Meteorological Component *(agenda item 5.1)*

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 and JMA with regard to potential tsunami situation.

Synoptic Observations

Data reception from 22 operational stations with the two stations commenced in 2009 namely, Polonnaruwa and Anuradhapura (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.

Upper Air Observations

Radar wind observations in Colombo (43466) were carried out throughout except for a very few occasions. Sonde observations were done three times a week as the shortage of equipment. Out of three, two sonde observations were done using the old equipment and one were performed using the new GPS sounding. Pilot balloon observations were done at 0000, 0600 and 1200 GMT at Hambantota (497), Puttalam(424). The obscured surrounding of the ancient city Anuradhapura (421) was found to be not suitable for pilot observations hence; the pilot observations were not performed at the beginning of the year and shifted to Polonnaruwa, more towards the east with effect from May, with new annual transfers effective.

Meteorological Satellites

The reception of HRPT imageries are still not possible as the system is irreparable and funds are being sorted for a new one. Revived the FENYUNGCast system and operational.

Digital Meteorological Data Dissemination system (DMDD) donated by the Government of India through India Meteorological Department was in operation. However, it became unserviceable towards the end of the year. Joint efforts with IMD are being made to correct.

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 is poor.

Improvement of facilities/Technical Advancement

15 telemeter rain gauges were installed during the year at rain induced disaster prone areas to facilitate early warning about disasters and, along with this there are 19 locations with this facility.

Completion of access road, site preparation and commencement of foundation work done for installation of Doppler radar at Gongala Peak. Factory training for hardware and software has been completed.

With the improvement of security situation, Jaffna Meteorological office has been identified for reconstruction at a new location and a block of land has been acquired.

Storm surge model, as per WMO/ESCAP training received, is operational as a routine at the NMC.

3. Hydrological Component *(agenda item 5.2)*

In Sri Lanka, the Department of Irrigation is the responsible agency for issuing warnings/advisories in floods. The hydrology division of the Department of Irrigation maintains 33 River Gauging stations which records hourly river water levels and equipped with manual rain gauges which records 3 hourly rainfalls. In addition, another 40 river gauges have been installed at tributaries and record day time water levels which are read on

contract basis. 19 Raingauge stations are also maintained by the department of irrigations and daily rainfall are measured by contract basis and the reports are collected monthly.

Special attention is paid to re-establish the river gauge stations and a few rainfall stations in the north and east. Computer generated hydrology data are provided for the development projects in these areas where data has been practically not available due to the unsettled situation prevailed in last 30 years.

There is ongoing project funded by World Bank (DSWRPP component in HMIS) to upgrade the existing hydromet stations and to establish new stations with automatic sensors with on time communication capacity to transfer the data to the Head office, Colombo. Under this project 50 gauging stations are to be newly installed of which 40 are equipped with discharge, river level and precipitation sensors.

4. Disaster Prevention and Preparedness (DPP) Component *(agenda item 5.3)*

One Ministry was set up only for Disaster Management with effect from 30th April 2010.

The Disaster Management Centre (DMC) which is the leading state agency for Disaster management has the responsibility of implementing and coordinating national and sub national level programms for reducing the risk of disasters with the participation of all relevant stake holders.

DMC has implemented projects to mitigate the effect of floods in Ampara, Batticaloa, Polonnaruwa and Puttalam districts and landslides in Nuwaraeliya, Badulla, Matale and Kandy districts. In addition, flash floods frequently occurring in urban areas has been studied and found that inadequate maintenance of canals, unauthorized reclamation, inadequate capacity of culverts and bridges. Disaster management Centre has allocated Rs 100 Mn for the flood and landslide mitigation projects.

The dry and intermediate zones which are frequently affected by drought has been attended with rehabilitating small tank cascade systems, irrigation canals, providing drinking water schemes etc..

Hazard maps of various disasters are also under processed. Designing Disaster resistance school building structures have been prepared and submitted to the Ministry of Education and the same for Hospitals and housing sector are being developed by Technical Advisory Committee appointed by DMC.

Development of Disaster preparedness and response plans have been completed for 16 districts and workshops are being held at divisional and grama niladhari level preparation activities.

Emergency Operation Centre with coordination of Technical Agencies for warning and advisory preparation and other stake holders, forces, police, UNICEF, UNCHR, WFP,UNESCAP, UNOCHA and Red Cross etc. immediately responded to take early actions for warning dissemination, relief, search and rescue etc, at the time of disasters.

Three Tsunami evacuation drills were conducted during the year for coastal areas. 52 Early warning towers along the coast were commissioned and another 25 are projected to build. The communication links in different modes are being established.

National Safety Day was organized in Jaffna district, in collaboration with District Secretariat and the Northern Provincial Council on 26th December. The objectives of the National Safety day are to commemorate all those who have lost their lives due to disasters and to create a culture of Safety and disaster awareness among general public. The National

Disaster Management Coordination Committee (NDMCC) stakeholders have given their fullest support by sponsoring floats, prizes for school children, prizes for journalists, etc. The live telecast of the entire proceedings was carried out by Independent Television Network.

NDMCC was formed to provide a platform for the Disaster Management Stakeholders from governmental, non governmental, academic, private and media sector to meet on a regular basis and to coordinate matters related to disaster risk reduction as per the Hyogo Framework for Action (HFA). It is chaired by the Secretary to the Ministry of Disaster Management and helps to avoid duplicating of efforts and optimize utilization of resources. This platform has been supported by UNDP under United Nations International Strategy for Disaster Reduction (UNISDR)

DMC has also continued the work of publication of quarterly news letter with the assistance of UNDP. The editorial board comprises of representatives from National Building Research Organization (NBRO), Metrological Department., Ministry of Disaster Management, UNDP, Sri Lanka Red Cross and DMC. The first three quarterly Newsletters were printed in English, Sinhala, and Tamil languages.

DMC with SLMD conducted three tsunami drills to assess the performances and to find gaps of tsunami warning communication system and public preparation.

The relief measures are taken predominantly by National Disaster Relief Services Centre(NDRSC) which was under the Ministry of Relief Services came under the purview of Ministry of Disaster Management it self for more efficient relief services (with effect from 30th April 2010). NDRSC has allocated over Rs 262million of which more than 86% was for flood relief (increased by about 20 % compared with previous years). 6.3% of the total allocation being the second for drought relief. Allocation to recover the damages due to strong winds and land slides have been 4.5% and 1.2% respectively while all the other natural, man made and wild elephant attacks etc. have been accounted for about 3%.

Six roving seminars were conducted for the farmers in three districts where agricultural activities are prominent to educate them in climate and weather on agriculture. The programme was funded by WMO.

Members of Department participated in programmes in climate, weather, disaster management and climate change to make aware the public in various disciplines (administrators, flight operators, teachers, armed forces, University and school children and teachers.

5. Training component *(agenda item 5.4)*

a. Upon receipt of the offers from WMO, members of Scientific and Technical Staff of SLMD participated in the following training activities in the year 2010

1. Training in Tropical Cyclone Forecasting, 2-16th February - India, From 2/2/2010 to 16/02/2010
2. International workshop on" Towards the Successful Implementation of the WMO Information System in Asia, Japan, 08th to 12th march
3. IOC/WMO Data Buoy Capacity Building Workshop, South Africa, 19th to 23rd April
4. 7th International workshop on Tropical Cyclone, Reunion of France, 14th to 20th November
5. 4th international Port Meteorological Officers Workshop, USA, From 06th to 13th December

b. One Meteorologist is receiving the Post graduate training in Meteorology in University of Philippines under WMO sponsorship

c. Six roving seminars on Weather, Climate and Agriculture were conducted in three districts for farmers and agricultural officers with the funding facilities provided by WMO.

d. Members of Department participated in programmes to make aware the public in various disciplines, (administrators, flight operators, teachers, armed forces, University and school children and teachers.

6. Research Component *(agenda item 5.5)*

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

1. Analysis of extreme rainfall events
2. Analysis of rainfall change with the onset of SWM and NE monsoon
3. Impact of Indian ocean dipole to the weather in Sri Lanka
4. Checking the accuracy of the Astrological weather predictions
5. Studying the MJO effect
6. Studying for Seasonal Forecasting
    a. Using the forecasts provided by the regional websites
    b. Using the ITACS model
7. Developing a Visual Basic program and a Database for Training/Seminar participants information
8. Seasonal rainfall forecasting using CPT
9. Decreasing trend of tropical cyclones in Bay of Bengal and Arabian Sea

Country Report of Thailand

I Overview of tropical cyclones which have affected/impacted Member's area in 2010

1. Meteorological Assessment (highlighting forecasting issues/impacts)

During 1st November 2009 to 31st October 2010, there was only one tropical cyclone "GIRI (04B)" entering the area between latitude 0°-25° N and longitude 90° – 120° E. It was originating from an area of active low pressure cell over the Bay of Bengal on 21st October 2010 developed into a tropical depression at 0600 UTC and strengthened into the tropical cyclone at 1200 UTC on the same day. Over the following day, the tropical cyclone underwent explosive intensification, reaching its peak intensity with winds about 150 km./hr. It tracked northeastward and made landfall in northwest Myanmar shortly after peaking. Within hours of moving onshore, the tropical cyclone had substantially weakened. On 23rd October 2010, GIRI had degenerated into a land depression and respectively weakened to low pressure cell at 1800 UTC. Nevertheless GIRI was not affected Thailand.

1.1 Rainfall distribution in the Typhoon Season

In August and September 2010, rainfall pattern and distribution over upper Thailand were enhanced by the combination of the intense monsoon trough lying over northern, central and northeastern Thailand and the indirect influence of the tropical cyclones in the South China Sea. The intensification of the monsoon trough in August as a result of the tropical storm Mindulle (1005) produced heavy to very heavy rain, with flash floods in many provinces of the North, Northeast, and Central of Thailand. In September, the interaction of monsoon trough and the tropical storm LIONROCK (1007) in the South China Sea during the first week of the month strongly enhanced the rainfall situation in the Northeast of Thailand. Consequently, the upper and central parts of the country were under a series of heavy to very heavy rain during the last period of September, severe floods occurred in many provinces, with the most severe floods in Nakhon Ratchasima province where loss of lives and tremendous damage in properties were reported.

1.2 Direct impacts of Tropical cyclones

In 2010, there were two tropical cyclones over the Pacific Ocean and the Andaman Sea that posed severe effects to Thailand as seen in figure 1 below.

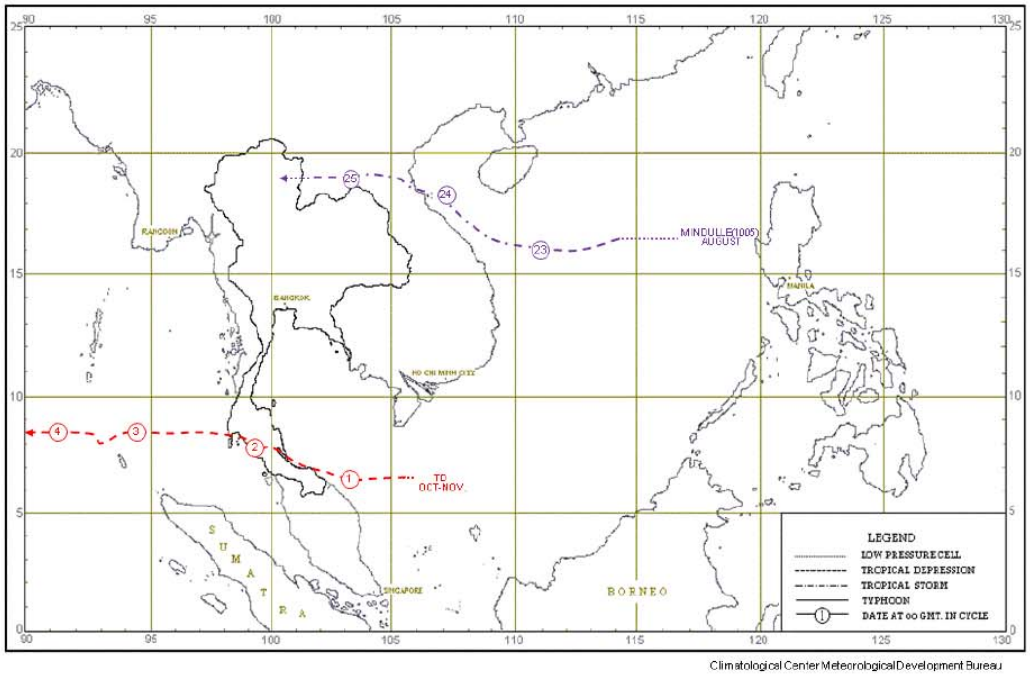
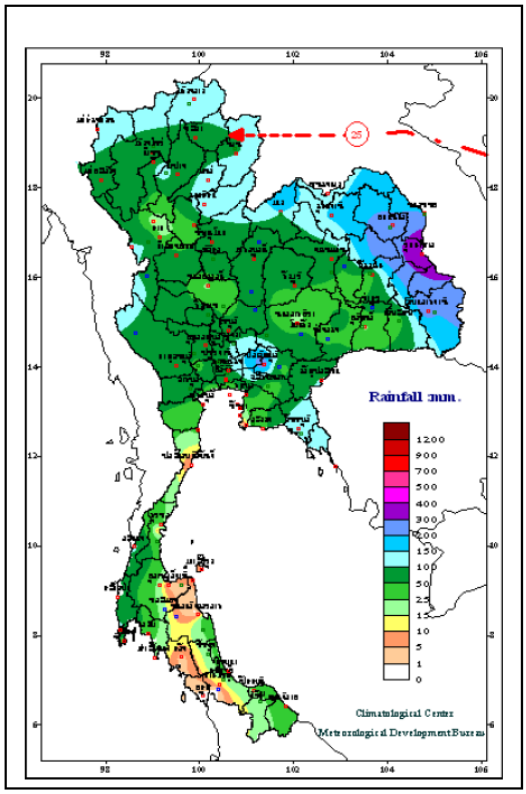


Figure 1: Tracks of Tropical Storm MINDULLE (1005) and a Tropical Depression, 2010

1.2.1 Tropical Storm "MINDULLE" (1005)

A tropical depression developed over the middle part of the South China Sea (16.5 °N, 114.5 °E) at 0600 UTC on 22nd August 2010. This depression had moved westwards on the first day before its movement changed into the west-northwest direction on the following day. In addition, it intensified into a tropical storm named ***Mindulle*** at 0000 UTC of the same day. Afterward, it turned into a severe tropical storm and reached its peak intensity with the maximum winds of 50 knots near its centre. ***Mindulle*** moved northwestwards and made landfall over northern Vietnam that evening. It subsequently dissipated over Laos close to upper northern Thailand on 25th August 2010. It intensified the monsoon trough, lying across upper Thailand and produced torrential rain with several floods in upper Thailand, especially in the Northern and the Northeastern Regions. Flash floods occurred in many provinces: Kalasin (on 21st August), Chiang Rai; Lampang; Lamphun; Chaiyaphum; and Prachin Buri (on 22nd August), Nakhon Sawan and Chanthaburi (on 23rd August), Sukhothai and Sakon Nakhon (on 24th August), Phayao and Uttaradit (on 25th August), Nan (on 26th August), and Mae Hong Son; Phrae; Phetchabun; Phichit; Ubon Ratchathani; Saraburi; and Phra Nakhon Si Ayutthaya (on 28th August). The highest daily rainfall was found to be 220.0 mm in Muang Sam Sip District, Ubon Ratchathani Province on 28th August.



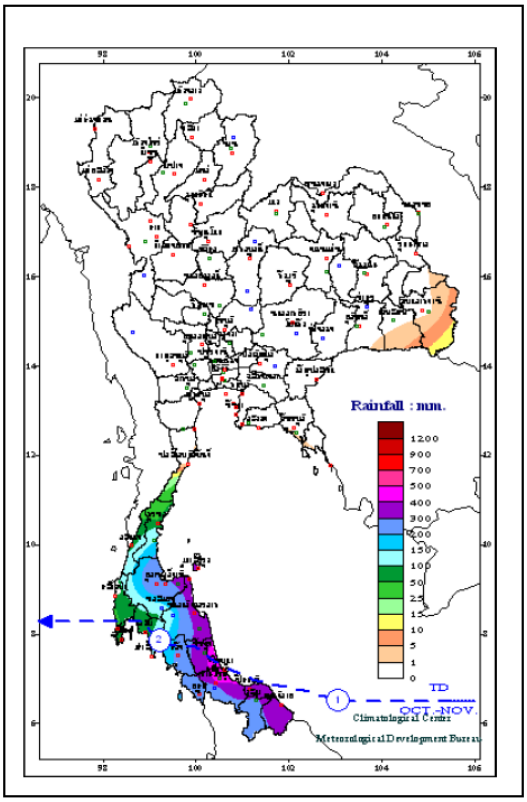


Fig.2 Fig.3

Figure 2 : Accumulated amount of rainfalls since 22nd August until 28th August 2010
Figure 3 : Accumulated amount of rainfalls since 31st October until 2nd November 2010

1.2.2 Tropical Depression

A low pressure cell in the lower part of the South China Sea intensified into a tropical depression at 0600 UTC on 31st October 2010 with its center on latitude 6.5 °N and longitude 105.5 °E. It moved in the west-northwest direction toward the lower part of the Gulf of Thailand and made landfall at Sathing Phra District, Songkhla Province in the Southern Region of Thailand at 1630 UTC on 1st November 2010. Then, it moved past Phatthalung, Trang, Krabi, and Phang-nga Provinces before entering the Andaman Sea in the evening of 2nd November 2010. It continued moving further in the Andaman Sea in the west-northwest direction before intensifying into the tropical cyclone ***JAL*** (05B) on 5th November 2010.

Being the very intense tropical depression, it had caused both strong winds and very heavy rainfalls over southern Thailand since 31st October until 2nd November 2010. As the result, serious floods were reported in 12 provinces: Songkhla, Satun, Trang, Narathiwat, Yala, Pattani, Phatthalung, Surat Thani, Nakhon Si Thammarat, Krabi,

Chumphon, and Ranong. 1,932,405 people in 609,511 families were affected by these floods and 78 people were reported dead from these disasters, with the most serious floods in Hat Yai, Songkhla Province. Fishing boats, trees, power lines, houses and other constructions along the path of the depression were also destroyed

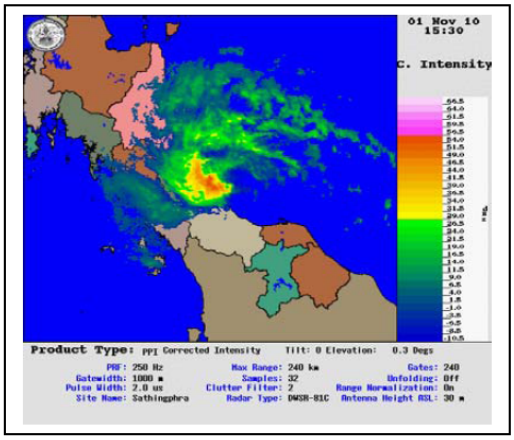
Figure 4 : A Flash Flood in Hat Yai District, Songkhla Province and damages as a result of strong winds due to tropical depression on 31st October - 2nd November 2010

1.3 Monitoring and Forecasting Aspects

To warn people of the southern part living in the tropical depression affected areas promptly and accurately, TMD closely monitored the development of any tropical disturbance formed in the lower portion of the Gulf of Thailand. Satellite data, weather charts, radar observation, and numerical prediction products had been analyzed consistently. Subsequently, a tropical depression was strongly expected to form and to hit the lower part of southern Thailand. The first depression alert to inform the high possibility of tropical depression occurrence had been announced three to four days in advances before the tropical disturbance intensified to the tropical depression.

On the 31st October 2010, almost 24 hours before the tropical depression hitting Songkhla, TMD held the press conference, which attended by all TVs and other mass media of the country, to express the most concerns and issued the first warning of the potential impacts of the impending tropical depression to the public particularly the people living in the coastal and flood-prone areas of the South. During 31st December to 2 November 2010, the tropical depression movement, its associated heavy rain, strong winds, and the possibility of storm surges had been closely monitored using radar observation in conjunction with the automatic rain gauge data. The disaster warnings had been issued

consistently to the community to be prepared for safety and evacuation. However, since the tropical was very intense, and the high intensity of rainfalls was uniformly distributed over the whole area of the city, thus Hat Yai and the surrounding areas were not be able to escape from the big floods.



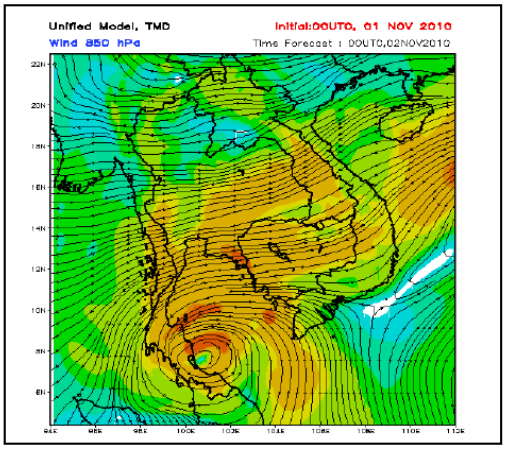


Figure 5. closely monitoring by Radar, and NWP forecast by Thailand Model

2. Hydrological Assessment (highlighting water-related issues/impact)

2.1 Flood from Min Don Lake (Mindulle) occurred 22-28 Aug 2010.

The impact was not so much. The upper area of Thailand in the north and northeast had dense and heavy rain in many areas. There was warning for the risk areas by the foot of the hill slope near the channels in the northern part, the warning of flash floods and also the embankment overflows for the east side of the northeastern part.

2.2 Flood situation in Lam Takhong Catchment in Nakorn Ratchasima, 10-24 Oct 2010.

The lower northeastern part of Thailand was under the low pressure groove during 1-19 October 2010. There was continuously rain especially, in the Khao Yai National Park and covered very large surrounding areas. The accumulated areal rainfall was about 450 mm., about 40 % of the annual amount. The maximum 3-day rainfall (14-16 October 2010) in the upstream of Lam Takhong Dam was 180.3 mm., while in the downstream was 211.6 mm. The reservoir volume rose very quickly and downstream was flooded at very wild scale.

The dam operation tried to keep flood volume in the reservoir until 17 Oct.2010. Flood began to overflow the service spillway at +277.30 m. MSL. Totally, the flood volume of about 160 mcm. was kept in the reservoir. Anyway, some part of flood still accumulated in the reservoir. On 20 Oct.2010 the volume reached the emergency spillway at +278.30 m.MSL and it started to overflow also. After that for about 22 hours, the reservoir volume reached the maximum level at +278.60 m.MSL of about 378 m.cm.

The area of Nakhon Ratchasima city was seriously flooded since there were many sideflows joining downstream of Lam Takhong dam. Some tributaries had also full reservoirs with spillway overflows. The drainage to the Mun river was quite slowly since the water level in Mun river was higher than in Lam Takhong.

The Regional Irrigation Office VIII had delivered the warnings of about 15 issues in total since July 2010 thru the local organizations, public medias and the local governmental meetings. For mitigation works, 21 pumps, 11 pumping impellers, and 24 trucks were managed to help drainage of flood and evacuation of people and properties.

2.3 Flood situation in Lam Phra Ploeng catchment, 21 Sep – 24 Oct 2010.

Monsoon during Sep – Oct 2010 caused dense and heavy rain in Nakorn Ratchasima and lower northeastern part of Thailand. Areal rainfall upstream of Lam Phra Ploeng dam during 1-19 Oct 2010 was 400 mm., about 40 % of the annual amount. The reservoir volume rised quickly and downstream was flooded for very wide area.

Rainfall during 2-4 Oct 2010 caused the reservoir volume reaching the retention at +263.00 m.MSL. Anyway, the dam operation still kept all flood volume until the highest level at +264.19 m.MSL. The downstream area was flooded for less than 2 days.

The continuously 3-day rainfall on 14-16 Oct 2010 caused maximum volume in Lam Phra Ploeng dam again. The new record was at +267.68 m.MSL, about 4.68 m. above the spillway level on 17 Oct 2010.

The warnings were delivered 8 issues in total since Sep until 15-16 Oct 2010 to inform the situation to the downstream area for evacuation of properties. On 17 Oct 2010, flood depth in Pak Thong Chai urban area was about 1 m. Many natural channels

were overflowed. The spillway overflow was maximum at 420 cms.

2.4 Flood from Depression occurred 31 Oct – 3 Nov 2010 in Hat Yai city.

2.4.1 Before flood

Songkhla Irrigation Project had managed 3 medium – scale reservoirs in the catchment to drain out, reserving the space for flood volume. The remaining in the reservoirs were about 53% , 44% , and 25% from the retention capacity of each. Totally 48% of the retention was left in the 3 reservoirs together. The flood volume of this event was cut off about 43.52 mcm. keeping in these 3 reservoirs.

2.4.2 During flood

Heavy rain on 31 Oct 2010, maximum was 301.3 mm. Royal Irrigation Department (RID) together with Songkhla province and Hat Yai municipality announced maximum flood warning by red flags at 5 PM on 1 Nov 2010. At about 10 PM of that day, Khlong Utaphao started overflowing and flooding Hat Yai city. The maximum flood peak occurred at 11 AM on the next day, 2 Nov 2010.

- Head of flood on 1 Nov 2010, water traffic was managed by 2 regulators, for the main channel (Klong Utapao) and for the drainage canal (R.1). Flood flow from 3 directions were investigated ; from the south – flow from Sadao district, from the east – flow from Klong Wa, Kor Hong, and from the west – flow from Klong Tum, Klong Wat. The 2 regulators were controlled to pass flood flow into Songkhla Lake as quickly as possible.
- Middle of flood on 2 Nov 2010, flood flow was much more than the capacity of the drainage canal. The 2 regulators were fully opened.
- Tail of flood on 3 Nov 2010, flood was drained thru the drainage canal R.1 and another natural drainage canal without further impact to the surrounding area.

To increase the drainage capacity, 2 pumping impellers were installed in Hat Yai city, 6 impellers in drainage canal R.4 connected to R.3, and about 36 pumps in the low-lying flood into the main drainage canal.

2.4.3 After flood

Flooding in Hat Yai city was back to normal on 3 Nov 2010 Some portion of flood water in the surrounding area of about 1-2 m. depth was drained by 2 Hydroflows and 10 mobile pumps into the drainage canals R.1 and R.3 until reaching the normal situation.

3. Socio-Economic Assessment (highlighting socio-economic and DPP issues/impacts)

In 2010 the impacts of tropical storms together with the influence of the active monsoon trough lying over Thailand has brought losses and damages to the country, particularly in the sector of agriculture, fishery, tourism, and to overall activities of the people. During the year 2010, Thailand was affected by the influence of 2 main tropical storms, namely Tropical Storm Mindulle (22-28 August 2010) and Tropical Depression (31 October – 2 November). Besides the influences from Typhoon related disaster, this year Thailand was also suffered from the flooding crisis from the vigorous monsoon clouds poured heavy rainfall over Thailand which occurred in over 51 provinces of Thailand and regarded as the worst flooding in decades. More than 8.9 million people and 2.6 households had been affected by flooding since the flood hit on October 10, 2010. The death toll has reached 258 in 29 provinces and the economic loss was estimated to be more than USD 1.5 Billion.

The Tropical Storm "***MINDULLE***" caused heavy rainfall and flood in the north and northeastern parts of Thailand until September 15, 2010. The total affected areas covered more 39 provinces and affected over 3 million populations. 712 people were evacuated and there were 2 deaths due to the flood. The estimated damages were over USD 185 million with damages to 87,000 hectare of agricultural areas, more than 57,000 livestock, 5,881 roads, 186 bridges, 44 schools, and 80 mines.

In October 2010 the low pressure area, moving over Southern, Central, Eastern part coupled with South East Monsoon has caused damage to 19 provinces, 94 districts, 716 sub-district, 5,474 villages, 545,447 households and 1,694,199 persons. Those provinces include 1 province in Northern part (Nakornsawan); 9 in Northeastern part (Nakornratchasima, Chaiyaphum, Srisakes, Surin, Khonkaen,

Kalasin, Mahasarakham, Roi Et and Ubonratchathani; 9 Central Provinces (Chainart, Singburi, Angthong, Suphanburi, Pra Nakhon Si Ayutthaya, Lopburi, Saraburi, Nonburi and Pathumthani). It is estimated that 6,316,156 rai of farmland (2,497,210 acres) are destroyed and 110 casualties. In addition, on October 31, 2010 the Tropical Depression moved into the Gulf of Thailand over the Southern part of Thailand, causes heavy rainfall and flooding which affected in 12 provinces, 133 districts, 874 sub-districts, 6,197 villages, 609,511 households and 1,932,405 persons. There were 78 casualties in 12 provinces, 1,499 injuries, over 799 houses were totally destroyed, 67,146 houses were partially destroyed, more than 128,000 hectare of agricultural areas and 466,142 livestock were destroyed, and 345 schools were totally damaged. The estimated losses were USD 104 million.

During the typhoon, Department of Disaster Prevention and Mitigation (DDPM), Ministry of Interior is working with 14 Southern provinces ensuring the disaster early warning system is ready for the upcoming monsoon season. Short Message Service (SMS) is assigned to be the mean of warning information exchange between province and the official in charge at site; and Multi-Media Message Service (MMS), communication radio, and internet network is assigned for disaster communication during disaster stage for updated situation and timely response. Department of Disaster Prevention and Mitigation (DDPM) dispatched 72,500 Volunteers which composed of 65,102 civil defense volunteers; 133 Emergency Response Team Officers (ERT) and 7,265 One Tambon One search and Rescue Team officers (OTOS) to support flood victim assistance throughout the country since floods occurred in Thailand in order to relieve and alleviate their difficulties

4. Regional Cooperation Assessment (highlighting regional cooperation successes and challenges)

4.1 Cooperation with China

In 2010 Thai Meteorological Department(TMD strengthened technical cooperation with the Center of Water Resource & Environment of Sun Yat-sen University and the Bureau of Hydrology of Pearl River Commission of the Ministry of water Resource of China by setting up a flood forecasting project in upper Thailand expected to be implemented in the near future (2011/2012).

Initially, for the first step of the project and further cooperation, the training course on flood forecasting which included the site survey for soil moisture/ texture data collecting in the flood forecasted project area was hold/ carried out for one week in September 2010. With this connection the Xinanjiang Model will be applied for flood forecasting in the project area.

4.2 Enhancement of data exchange among the TC Member countries

To support the enhancement of data exchange among the TC Member countries, the three-day weather forecasts of sixteen cities, including Bangkok, Mae Hong Son, Chiang Rai, Chiang Mai, Tak, Phetchabun, Sukho Thai, Khon kaen, Nakhorn Ratchasima, Kanchanaburi, Pattaya, Hau Hin, Ko Samui, Songkhla, and Phuket are produced and incorporated into the GTS and at the website http://www.worldweather.org

II. Summary of activities

a. Meteorological Activities

1. Enhancement of Radar network:

To strengthen severe weather observations and monitoring networks, and nowcasting of the country, the following three C-band Doppler Radars which started the installations in the South of Thailand in 2010 have been completely implemented and are now in operations:

(1). C-band Doppler Radar in Songkhla province,
(2). C-band Doppler Radar in Samui. Surat Thani province,
(3). C-band Doppler Radar in Surin province.

Totally, there are 25 weather radars in the TMD's precipitation monitoring network.

2. Enhancement of the Meteorological Satellite Data Receiving Station

To enhance the capability in receiving meteorological information derived from the different platforms of meteorological satellites, such as MTSAT, FY-2, TIROS (NOAA-16, NOAA-18, NOAA-19), FY-1, FY-3, MODIS, METOP, the TMD's implementation of the satellite signal receiving station, which began its installation in 2009, is now being in the last phase of the

installation process, and it is expected to be successfully completed and will be in the operation in the early 2011. TMD is strongly confident the improvement of the satellite data receiving station will have the great role in severe weather monitoring, including typhoon and typhoon-related disasters to reduce the loss of life and damage associated with typhoon and other severe weathers.

The enhanced capability of TMD in receiving the remotely-sensed data from the GEO-stationary and Polar orbits are as shown below:

Table 1.

Satellite Platforms	Current status	Remarks
GEO-stationary	MTSAT, FY2	All Implementations completed
Polar orbit	NOAA, TIROS, MODIS, METOP, FY3, METEOSAT	

3. Improvement of storm surge forecasting

To be the effective warning of storm surges that might be occur in the coastal areas in the Gulf of Thailand and the Andaman Sea during the typhoon season, the IIT Storm Surge Model was adopted and applied using the 1 km. resolution bathymetry data interpolated from the GTOPO1. The maximum storm surge height map along the coastal areas of the Gulf of Thailand for each tropical storm category/ strength has been produced. However, TMD will also be appreciated to accept and introduce the RSMC-Tokyo Storm Surge Model into the TMD storm surge forecasting of the country.

4. The Meteorological Telecommunication Data Storing and Recording Project

To improve the receiving-disseminating of meteorological data on the network of the Global Telecommunication System (GTS) in order to fully support the information exchange in the form of the Table Driven Code Form (TDCF) as specified by the WMO, the TMD's Meteorological Telecommunication Data Storing and Recording Project has been under implementation. Its installation was started in 2009, and is expected to complete by the end of 2011. The completion of this project will also lead to the increase in

potential of TMD to be the RTH Bangkok WIS portal in the South East Asia region.

5. *Enhancement of the Meteorological Telecommunication Network Control System*

The purpose of the project is to develop and enhance the telecommunication network for severe weather and weather-related disaster warning of the country, and to develop the whole country observation data collecting system

6. *The Aeronautical Data Dissemination Project*

To improve the aviation meteorological data reporting system, the improvement will disseminate the present meteorological data, forecast data, and the warning of severe weather data to pilots by using Short Wave Radio System. The project will take one year to complete, thus it will be in the TMD's operation by the end of 2011.

7. *Development of Weather Chart Display System*

To produce and display weather map of the Table Driven Code Form (TDCF) data, the Weather Chart Display System (WDS) has been developed. The WDS runs on the Messir Vision system to facilitate and assist forecasters to be able to visualize and analyze weather patterns produced by the system on an hourly basis.

b. Hydrological Activities

Royal Irrigation Department (RID) and Water Resource Department (DWR) of Thailand are responsible for water management. DWR's main functions relates to water policy, planning and strategy. RID is responsible for water source development, water management, including flood and drought relief, especially in floodplains, downstream watershed and agricultural areas, whereas DWR takes care of natural rivers and steep-slope upstream watershed. The Water Watch and Monitoring System for Warning Centre (WMSC) was set up to monitor flood situations on a 24 hourly basis by RID to decrease the loss of lives and property. There is also collaboration with other related organizations to plan flood prevention. Local flood protection systems were set up in important economic areas where severe floods may occur. In addition, early warning systems using various technologies were

established. This includes a telemetry and flood forecasting system for water management.

The RID to date has installed and operated about 208 telemetric stations in 13 of 25 river basins in Thailand. In addition, 555 manual river gauges and 2,294 manual rain gages were installed and operated all over country. As part of the local flood warning system, DWR has developed and installed early warning systems in 458 villages of the total 2,370 villages in Thailand and included with automatic flood-warning sirens are being operated.

Flood Forecasting and Warning System for protecting in 25 basins are being developed. For this system, In this 2010 the new telemetric stations and infrastructure networks will be installed 7 telemetry systems and in 2011 the new telemetry will be installed 7 networks together with a flood modeling system that include both hydrometeorology and hydrodynamic such as MIKE11, MIKEGIS ,INFOWORK and AIT Rivernetwork.

To mitigate and reduce the risk of floods, the flood warning system is carefully managed in the following process.

First, telemetry system is used as a method for flood forecasting in different river basins covering nearly the whole country. Only Royal Irrigation Department has already got the system for monitoring 12 river basins from 25 in the criteria of real-time hydrological data.

Second, the forecasting situation is then announced to public with different ways like website or radio broadcasting or networks. For network mentioned above it means regional offices which take part in communicating in the local areas with other methods or media.

Third, after flooding situation, pumping for water drainage has to be prepared in order to reduce the height of water level or inundated areas. The equipment in the Head and Regional offices are ready for flood recovery operations such as 1200 mobile pumps, 121 impeller pumps, 37 backhoes, 17 dredgers, 29 tractors 44 trucks, 295 water trucks and 6 boats.

Flood hazard mapping in Chiengmai city, Nan city and Lampang city were completed. The hazard maps are provided to concerned local government unit.

c. Disaster Prevention and Preparedness Activities

After the bureaucratic reform in 2002, the Department of Disaster Prevention and Mitigation (DDPM) has been set up under the Ministry of Interior to serve the national disaster management system so as to sustain Thailand's habitability and safety. When the current Disaster Prevention and Mitigation Act B.E.2550 was issued and forced in November 2007, the Department of Disaster Prevention and Mitigation (DDPM) has been designed as the national government organization and operating agency on national disaster prevention and mitigation activities. Moreover, DDPM can establish the Disaster Prevention and Mitigation Regional Centers and the Disaster Prevention and Mitigation Provincial Offices to carry out the efficient disaster management.

Nowadays, DDPM has set up 18 Disaster Prevention and Mitigation Regional Centers and 75 Disaster Prevention and Mitigation Provincial Offices over the country. DDPM Regional Centers and Provincial offices will be the front line unit to carry out the disaster prevention and mitigation. DDPM will cooperate with the relevant organizations both government and private sector and local agencies to perform the task. To mobilize the technology and know-how, exchange and share experience and information, DDPM has cooperated with various international organizations such as ADRC, ADPC, JICA, GTZ, UNDP UNISDR, UNOCHA, UNEP, etc.

1. Strategic Action Plan (SNAP) for Disaster Risk Reduction for Thailand

Thailand recognized that the strategic plan on disaster risk reduction is essential to minimize the incidents, consequently, DDPM cooperated with United Nations International Strategy for Disaster Reduction (UNISDR) and Asian Disaster Preparedness Centre (ADPC) to formulate Strategic Action Plan (SNAP) for Disaster Risk Reduction for Thailand and set up a working group which is composed of the representatives of the government agencies concerned, private sector and experts to draft SNAP. The draft plan is on process to submit to Cabinet for approval.

2. *Provide an effective framework for integrating early warning systems for vulnerable communities into development process.*

The early warning system in Thailand could divide into 2 levels. In the national level, there are many organizations to take responsibility for the task relevant disaster warning. Thai Meteorological Department, Royal Irrigation Department, Department of Water Resources and Disaster Forecasting and Warning of Electricity Generating Authority of Thailand (EGAT) Public Co. Ltd are the main agencies to forecast the disaster warning on their own function. Therefore, Thailand's Early Warning Information from these agencies will be transferred to the people via mass media and agencies concerned and Department of Disaster Prevention and Mitigation (DDPM) will transmit the information through mechanism of Ministry of Interior to provinces, districts and local organizations.

After Tsunami disaster triggered the 6 southern provinces of Thailand on 26 December 2004, the government reviewed disaster early warning system to develop the system more efficiency and to make more confidence in safety in the country. In 2005, the cabinet appointed the Committee on Early Warning System Development which comprise the representatives of the departments concerned, will be responsible for making the decision as to when a warning should be issued. The National Early Warning Center has been set up to carry out the early warning system.

In the local level, the rain gauge and manual disaster siren have been installed in the flood prone areas. This device is employed for observing and notifying of local flood conditions, forecasts and warnings. The rain gauge is extremely low cost and very simple to use. The villagers will be trained to measure, record and read the daily amount of rainfall. Whenever the amount of rainfall exceeds the predefined normal level, the villager in charge of surveillance signal the warning by using the manual siren device to notify the village headman to disseminate the warning through the village news broadcast center.

Thailand is not defined as the disaster prone area as other countries in the Southeast Asia. However, the influences of the depression tropical storm and typhoon are the causes of the heavy rain and flood during in May – October every year. The country does not only enface the flood but also other types of disasters such as fire, earthquake, tsunami and etc.. Therefore, the disaster prevention and mitigation are the main policy of the government to reduce the lost of people's lives and the properties.

3. *Disaster Prevention and Preparedness activities in 2010*

Recently, Disaster Management in Thailand has been focused on preparedness activities to reduce the vulnerability impacts and increase the resilience in disaster prone areas, as well as general public using Community-Based Disaster Risk Management (CBDRM) approaches. As the intermediary government agency, DDPM in cooperation with all national involved agencies has initiated various successful projects, such as CBDRM, One Tambon (Sub-district) One Search and Rescue Team (OTOS), Mr. Disaster Warning, and Civil Defense Volunteers (CDVs).

- Community-Based Disaster Risk Management (CBDRM)

Thailand has realized that it is essential to improve public safety, particularly for people who are in the risk areas. CBDRM approach is to reduce vulnerabilities and to strengthen capacity for people to cope with the disaster risk. Therefore, CBDRM has been applied to generate the awareness and also to implant the culture of safety in disaster prone areas. Cooperation with local agencies, such as Thai Red Cross, Local Authority Department and various international agencies which previously described. It has attracted the intervention of people in communities to participate in holistic disaster management. Since 2003-2009, DDPM has continuously launched CBDRM training, at present, more than 35,000 persons in 4,699 villages 75 provinces which are the risk communities have been trained on CBDRM approach.

- Mr. Disaster Warning Programme

DDPM initiated Flash Flood and Mudslide Warning Program to enhance capacity of people for risk assessment and early warning. In collaboration with Department of Provincial Administration, Department of Local Administration, TMD, National Park, Wildlife

and Plant Conservation Department, and National Disaster Warning Centre to design 'Mr. Disaster Warning' training course which aims to create disaster warning network, particularly in flash flood and mudslide prone villages. 'Mr. Disaster Warning' is the village volunteer who has been selected and trained to function as a vigilant, a forewarner and also a coordinator, with number of 10,000 people in flood prone areas were trained under this programme.

- One Tambon One Search and Rescue Programme (OTOS)

DDPM has recognized the urgent need to establish a range of search and rescue capacities at national, provincial and particularly in local level. Since 2004, DDPM has launched the 'One Tambon (sub-district) One Search and Rescue Team (OTOS) Programme' which will be resulted in the establishment, training and long-term maintenance of specially trained search and rescue team in every tambon community. As of November 2009, OTOS program is 85% completed with 6,615 SAR teams (10 members) based in each tambon or local administration offices throughout the country and more than 68,000 volunteers trained.

- Civil Defense Volunteer Programme

Civil Defense Volunteer is important resources in operation level which will be recruited from local residents who are over 18 years old and will be trained on the course for consecutively 5 days. Their functions are to holistically assist the government's operation in all types of disaster. (As of 31 October 2009, there are around 1,146,140 Civil Defense Volunteers in the country)

- Other activities

As the chair of Working Group in Disaster Prevention and Preparedness, DDPM held the meeting of The Panel on Tropical Cyclones (PTC) Working Group on Disaster Prevention and Preparedness (WG-DPP) Meeting to finalize the Annual Operating Plan (AOP) and Training on Preparation of Disaster Management Drills and Observance of DDPM's National Crisis Management Drill 2010 (C-MEX 10) from 18 to 20 August, 2010. The meeting was held at United Nations Conference Center Meeting Room F, Bangkok, Thailand and the training was held in Chantaburi Province, Thailand. The event was attended by delegates from 6 PTC member counties namely Bangladesh, Maldives, Myanmar,

India, Sri Lanka, Thailand and representatives from UNESCAP. This meeting and training was a part of PTC's Annual Operating Plan (AOP) 2010 for DPP with the participation of PTC WG-DPP members. This meeting of PTC WG-DPP is also in continuation of last year's PTC WG-DPP Workshop. The result of the meeting is provided in the Summary Report of the WG-DPP Workshop.

- DDPM Training Achievements

DDPM established Disaster Prevention and Mitigation Academy (DPMA) since October 2004 as National Training Centre for Disaster Management. DDPM cooperated with various agencies both national and international organizations in developed countries to develop curriculum and mobilize technology, including know-how for standard training. The course will be conducted to serve government officers, local administration officers, private sectors who are in charge of disaster managements, including civil defense volunteers for increasing of their capacities. DPMA has extended to 6 campuses in upcountry. The standard curriculum consists of Fire Fighting, Building Collapse (Search and Rescue), Hazmat Emergency Management, Civil Defense Volunteer and Disaster Management.

III Research, Training, and Other Achievements/Results

1. Research :

1.1 Thai Meteorological Department (TMD)
In 2010, the tropical cyclones-related and flood research topics were carried out as follows:

- The IIT Storm Surge model development for Storm surge forecast in the Gulf of Thailand and the Andaman Sea
- The amount of rainfall criteria that cause flood in upper Thailand
- The Study on Drought Indices in Thailand

1.2 Royal Irrigation Department (RID)

- Urban Flood Risk Management, the site and feasibility survey/study has been conducted by the Taskforce Team of Typhoon Committee URFM project during 12-13 December 2010 at the UFRM's Pilot City, the U-tapao Basin, Hat Yai,

Songkhla province with the collaboration of Thai Meteorological Department, Department of Disaster Prevention and Mitigation, Hat Yai Metropolitan, and the Royal Irrigation Department.

2. Training:

2.1 In 2010, TMD received WMO/ TCTF/ TCS support to attend the training courses in the TC as follows:

- Overseas Training

During 1 January 2010-30 December 2010, the staff of TMD had participated in nine overseas trainings as shown in table:

No	Course	Duration	Country	Person
1	Tsunami Early warning in the Indian Ocean	22 Jan.10 - 13 Feb.10	Indonesia	1
2	Climate applications	7-11 Jan.10	Turkey	1
3	Satellite Meteorology	22 Jun.-2 July 10	China	3
4	Multi-Hazard Early Warning	10-28 May 10	China	1
5	Weather Radar	10-14 May 10	Turkey	1
6	Information management for Maritime Activity and Disaster Prevention	8 Jun-26 N0v.10	Japan	1
7	Numerical Weather Prediction	13-24 Sep.10	China	1
8	Mesoscale Numerical Weather Prediction Phase I	27 Sep.-8 Oct.10	Republic of Korea	2
9	Flood Mitigation and Stormwater Management 2010	4-22 Oct.10	Malaysia	1

- Local Training

No	Course	Duration	Person
1	Basic of Weather Forecasting Technique	30 Aug.-3 Sep.10	40
2	Analyzing the Meteorological Satellite Data I	19-23 July 10	36
3	Analyzing the Meteorological Satellite Data II	2-6 Aug. 10	37
4	Meteorological Ozone and Radiation	23-27 Aug. 10	34
5	Numerical Weather Prediction Workshop on Data Assimilation	6-10 Sep. 10	30

2.2 Royal Irrigation Department (RID)

- RID's Hydrologist attended with the field training for Hazard Mapping for Sediment-related disaster at Zhuhai, China on September 5, 2010 and selected 2 model sites at Nam Kor-Nam Chun , Lom Sak district , Phitchabun Province and Nam Pong, Laplae district, Uttaradit province for the study areas in Thailand.
- 4 RID's Hydrologists attended the workshop on "Space Application to Reduce Water-related Disaster Risk in Asia" in Bangkok, Thailand from 7 to 9 December 2010.

3. Regional Cooperation Achievements/Results

Participation in the Regional Storm Surge Watch Scheme Suitable for the Typhoon Committee Region Project

TMD, with the kind cooperation of the Hydrographic Department Royal Thai Navy, has involved in the Regional Storm Surge Watch Scheme Suitable for the Typhoon Committee Region Project by providing the tidal data of sea level at the stations in the Gulf of Thailand expected to be in typhoon tracks. The Royal Thai Navy-created bathymetric data in the gulf of Thailand are also contributed to the RSMC -Tokyo for the storm surge watch to be modified suitably.

IV Identified Opportunities/Challenges for Future Achievements/ Results

- The KMA-supported Typhoon Committee TRCG Research fellowships on TIPs provided to TMD's staff will strengthen the potential of TMD on TIPs implementation and utilizing the ensemble typhoon forecast data of the country.
- Participating in the Pilot City Project will enhance the capability of the city regarding the flood risk management in the urban area.

Activities of PTC Secretariat during the Intersessional Period 2010-2011

- As approved by the PTC during its 37th Session (Phuket, Thailand, 15-19 February, 2010), Secretary of PTC participated in the Seventh Session of the UNESCO Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) (Banda Aceh, Indonesia 14th - 16th April, 2010) for making effective representation of PTC and for enhancing the visibility of PTC at ICG/IOTWS.
- PTC Member countries were coordinated and requested for sending their input, feedback and amendments (if any) with regards to Tropical Cyclone Operational Plan (TCP) to Mr. B.K. Bandayopadhyay (RSMC, New Delhi), the rapporteur of TCP for preparation of 2010 Edition of TCP. PTC Secretariat is thankful to PTC Members for their inputs towards TCP and Mr. Bandayopadhyay for his work as rapporteur of TCP which made 2010 Edition of TCP possible before the start of 2010 cyclone season.
- As per request made by PTC during its 37th Session (Phuket, Thailand, 15th–19th February, 2010), a meeting of PTC Working Group on Disaster Prevention and Preparedness (WG-DPP) was held at UN Building, in Bangkok, Thailand on 18th August, 2010 to finalize the Annual Operating Plan (AOP) related to DPP. The meeting was organized and supported by UNESCAP, Bangkok, Thailand and held back to back with Training on Preparation of Disaster Management Drills and Thailand's National Crisis Management Drill 2010 (C-10) organized by the Department of Disaster Prevention and Mitigation (DDPM), Thailand on 19th–20th August, 2010 in Chantaburi Province, Thailand. DPP experts and/or DPP focal persons for WG-DPP from six out of eight PTC Member countries namely; Bangladesh, Maldives, India, Myanmar, Sri Lanka and Thailand attended the meeting and training, and also observe C-MEX 10. Necessary financial support was provided to the experts by UNESCAP. PTC Secretariat is indebted to the UNESCAP and DDPM, Thailand for their continued support to PTC Members in capacity building activities related to DPP.
- PTC Secretariat published two issues of Panel News (Issue No.29 and 30) during the inter-sessional period. These issues have been distributed among the PTC Member countries, UNESCAP, WMO, representatives of other international organizations and other concerned during 38th Session of PTC (New Delhi, India, Thailand, 21-25 February, 2011).
- As per request of PTC during its 37th Session (Phuket, Thailand, 15th–19th February, 2010) WMO made arrangements with the Indian Institute of Technology (IIT), New Delhi for the attachment of two storm surge experts - one each from Maldives and Sri Lanka. The training for storm Surge Experts was scheduled from 18 to 29 October, 2010 at IIT, Delhi. PTC Secretariat extended invitation for this attachment to both countries. Necessary funding was provided to the participants by WMO from PTC Trust Fund.
- Similarly, as per request of PTC during its 37th Session (Phuket, Thailand, 15th–19th February, 2010), WMO made arrangements with the Regional Specialized Meteorological Centre (RSMC), New Delhi for provision of Training on Tropical Cyclone Forecasting to the nominees from Bangladesh, Myanmar and Oman. On invitation from PTC Secretariat, the nominations from the above mentioned countries have been received. The RSMC, New Delhi, India will host this training during the period from 28 February to 11 March,

2011. Necessary funding for the participants is to be provided by WMO from PTC Trust Fund.

- On the invitation of UNESCAP Bangkok, Secretary of PTC participated in the Preparatory Meeting of UNESCAP Expert Group Meeting on Pakistan Floods which was held in Nanjing, China on 16th September, 2010. UNESCAP experts on water security and disaster risk reduction (DRR) were also part of the WMO Expert Mission to Pakistan (8-9 November, 2010). UNESCAP in collaboration with Pakistan's National Disaster Management Authority (NDMA) organized an Expert Group Meeting on Reducing Flood Risk Reduction in Pakistan in Islamabad on 9-10 November, 2010. As a follow up of this Expert Group Meeting, Pakistan Meteorological Department and Space and Upper Atmospheric Commission (SUPARCO) are jointly hosting the UNESCAP Workshop on Developing Capacity Resilience to Water-related Disasters in Pakistan through Space Application & Flood Risk Management, in Islamabad, Pakistan from 1 to 4 March, 2011. PTC Secretariat offers its sincere thanks to UNESCAP for its continued support to PTC Member countries in DRR activities especially for the initiatives and assistance to Pakistan in wake of 2010 super floods.
- Launching of new website of PTC is under process. In this connection, necessary Registration Form along with prescribed fee and the proposed webpage design/format has been submitted to the service providers in Islamabad. The address of the website has been proposed as: www.ptc.wmoescap.org. Some of its various webpages and links are under construction. For making the website more informative and useful, the PTC Members were requested to kindly send their views and comments to PTC Secretariat. The new email address of the PTC Secretariat has been proposed to be PTC.Sectt@ptc.wmoescap.org. In this regard, PTC Secretariat would formally inform the Members during coming days.
- Information regarding financial support by WMO from the PTC Trust Fund and detailed breakup of expenses incurred by PTC Secretariat during the intersessional period (2009-2010) is attached as **Appendix IX.**

Statement of PTC Secretariat Accounts (2010 - 2011)

S. No.	*Opening Balance and Receipts*	*Amount in Pak. Rs.*
1.	Balance after 37th Session of PTC	128,590/-
2.	Amount received during the inter-sessional period (US$ 4000/= equivalent to Pak Rs.342,080/= @US$ 1 = 85.52)	342,080/-
	Total	**470,670/=**
	Expenditures	
1.	Printing of 29th and 30th Issues of the Panel News and Letterheads	95,000/-
2.	PTC Website Hosting Fee etc.	12,000/-
3.	Services for PTC Webpage design and construction etc.	20,000/-
4.	Services for compilation work of Panel News Issues	20,000/-
5.	Stationery, postages and other miscellaneous items etc.	9,000/-
6.	Honorarium to Meteorologist-PTC Secretariat @ US$100/= per month	102,000/-
7.	Purchase of Colour Toner for Colour Laser Jet printer	Nil
8.		
9.		
	Total	**258,000/=**
	Net Balance in hand	**212,670/=**

Statemem of Account of the Panel's Trust Fund

World Meteorological Organization
Organisation météorologique mondiale

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PANEL ON TROPICAL CYCLONE TRUST FUND

Interim Statement of Income and Expenditure
For the period 1 January to 31 December 2010
Amounts in US dollars

1.	Balance of fund at 1 January 2010			92,456
	1.1 Initial recognizion of assets/liabilities-adoption of IPSAS			(101)
	1.2 Adjusted balance of fund at 1 January 2010			92,355
2.	Income:			
	2.1 Contributions			
	2.1.1 India		3,920	
	2.1.2 Pakistan		2,000	
	2.1.3 Thailand		2,000	
	2.1.4 Maldives		2,000	
	2.1.5 Sri Lanka		2,000	
	2.1.6 Total contributions		11,920	
	2.2 Interest		111	
	2.3 Total revenue			12,031
3.	Total available funds during reporting period			104,386
4.	Expenditure:			
	4.1 Direct project costs:			
	4.1.1 Travel-Other representatives to attend other mtgs	6,089		
	4.1.2 Miscellaneous services	4,040		
	4.1.3 Total direct project costs		10,129	
	4.2 Indirect project costs			
	4.2.1 Support costs(13%)	1,317		
	4.2.2 Bank charges	39		
	4.2.3 Difference in exchange	(6,507)		
	4.2.4 Total indirect project costs		(5,151)	
	4.3 Total project expenditure			4,977
5.	Balance of fund at 31 December 2010			99,409

Certified correct:

Luckson Ngwira
Chief, Finance Division
7 January 2011

World Meteorological Organization
Organisation météorologique mondiale

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PANEL ON TROPICAL CYCLONE TRUST FUND

Statement of Income and Expenditure
For the period 1 January to 31 December 2009
Amounts in US dollars

1.	Balance of fund at 1 January 2009			96,540
2.	Income:			
	2.1 Contributions			
	2.1.1 Bangladesh		3,970	
	2.1.2 India		1,950	
	2.1.3 Maldives		2,000	
	2.1.4 Oman		2,000	
	2.1.5 Pakistan		1,975	
	2.1.6 Sri Lanka		2,000	
	2.1.7 Thailand		2,000	
	2.1.8 Total contributions		15,895	
	2.2 Interest		284	
	2.3 Total revenue			16,179
3.	Total available funds during reporting period			112,719
4.	Expenditure:			
	4.1 Direct project costs:			
	4.1.1 Travel-Other representatives to attend other mtgs	14,930		
	4.1.2 Miscellaneous services	4,000		
	4.1.3 Total direct project costs		18,930	
	4.2 Indirect project costs			
	4.2.1 Support costs (13%)	2,158		
	4.2.2 Bank charges	118		
	4.2.3 Difference in exchange	(944)		
	4.2.4 Total indirect project costs		1,333	
	4.3 Total project expenditure			20,263
5.	Balance of fund at 31 December 2009			92,456

Certified correct:

Luckson Ngwira
Chief, Finance Division
7 January 2011

Summary of Scientific Presentations

(to be added later)