WORLD METEOROLOGICAL ORGANIZATION

WMO FACT-FINDING MISSION TO MYANMAR

Yangon and NayPyiTaw

9-13 February 2009

MISSION REPORT

CONTENTS

GENERAL SUMMARY OF THE MISSION

1. BACKGROUND

1.1 In the immediate aftermath of *Cyclone Nargis*, which hit the southern part of Myanmar on 2 and 3 May 2008, WMO carried out an emergency assessment mission composed of Mr K. Shida (Regional Office for Asia and the South-West Pacific) and Dr T. Peng (Tropical Cyclone Programme Division) from 15 to 18 May 2008 to Yangon, Myanmar. In consultation with Dr Tun Lwin, Director-General, and Dr Thein Tun, Deputy Director-General and senior staff of the Department of Meteorology and Hydrology (DMH), the WMO mission: (a) assessed damage of facilities for data acquisition and reception; (b) evaluated the warning system capacities; and (c) evaluated technical capabilities (hardware, software and trained manpower) of data processing and forecasting on tropical cyclones, storm surges and severe weather in general, and external support needed for restoring and improving such capabilities as well as the longer-term development needs.

1.2 The first WMO mission stressed that the operational meteorological infrastructure needs to be restored as a matter of urgency and the provision of meteorological information and services enhanced. Damaged hydrometeorological equipment and instruments of DMH headquarters and local stations need to be repaired or replaced and an upper-air observing system and a weather radar installed. The data processing and forecasting systems including numerical storm-surge prediction and storm-induced flood forecasting must be strengthened. A back-up electric power supply is required to ensure minimum operational services under all circumstances. Staff training is a matter of urgency both in the short and long term. Public weather services need to be enhanced for the dissemination of weather information and warnings that are clearly understandable to the general public and rural communities. Considering the importance of the international airports for the rescue and relief efforts, airport meteorological offices need to be equipped with modern observing systems and Yangon International Airport meteorological office should receive SADIS and GTS data from the headquarters.

1.3 During the visit of Dr Tun Lwin, Permanent Representative of Myanmar with WMO, to the WMO Secretariat from 19 to 22 May 2008, a meeting was organized with the Secretary-General and senior staff from relevant Departments and Offices in the WMO Secretariat on 20 May 2008, to share information on the actions taken by DMH concerning *Cyclone Nargis*; follow up the preliminary findings and recommendations of the WMO field mission team; and discuss possible next steps for enhancing the capacity of DMH, followed by individual consultations and discussions with Departments and Offices concerned.

1.4 Following the above meeting and individual discussions, the following actions were proposed for follow up:

(i) Provide DMH with emergency assistance for immediate priority requirements, through the purchase of priority equipment; and the support for the increased participation of DMH staff in WMO training opportunities, with the Emergency Assistance Fund (EAF) and VCP(F) and by requesting potential donor Members for consideration of support to the priority requirements *[priority assistance has been/is being provided]*;

(ii) Prepare and submit WMO input to the ISDR-consolidated UNOCHA Flash Appeal, for longer-term development needs for the improvement of Early Warning Systems *[action taken]*;

(iii) Evaluate further and realize external funding opportunities available for longer-term development needs, including JICA, UNDP Yangon and Bureau of Crisis Management, USAID, ESCAP and ASEAN *[action on-going]*;

(iv) Plan and carry out a second WMO mission to Myanmar in collaboration with the WMO/ESCAP Panel on Tropical Cyclone Members, to make detailed assessment of needs for priority activities; assist PR of Myanmar in working with the government authorities in

development of effective early warning systems; and to implement some key proposed assistance (*e.g.*, training and installation of the urgently required systems) *[a second WMO mission is proposed]*; and

(v) Plan a workshop to assess the timeliness and usefulness of products and information provided by DMH to national authorities and international organizations and to further review requirements for the longer-term development of DMH with the participation of national and international experts *[a workshop is proposed to be organized in conjunction with the second WMO mission]*; and a training workshop in how to communicate the warning messages to the public and how to carry out some simple forms of outreach and public education.

1.5 The WMO/ESCAP Panel on Tropical Cyclones (PTC), at its 35th session (Manama, Bahrain, 5-9 May 2008) expressed its full support to the proposed initiatives to be taken by WMO in cooperation with ESCAP and PTC Technical Support Unit (TSU) for a field mission on assessment of needs of priority activities aiming at preventing occurrence of similar disasters and also for restoration of damaged basic meteorological and hydrological networks. Some PTC Members (India, Pakistan and Thailand) indicated their possible participation in the proposed field mission.

2. ORGANIZATION OF THE MISSION

2.1 In view of the above, at the invitation of Dr Tun Lwin, Permanent Representative of Myanmar with WMO, a WMO fact-finding mission to Myanmar was carried out from 9 to 13 February 2009, in collaboration with ESCAP and PTC, with the purpose of: (a) further detailed assessment of DMH actions during and following *Nargis* and needs for priority activities for capacity development; (b) provision of guidance to PR of Myanmar in working with the government authorities in development of effective early warning systems for cyclone and storm surge forecasting and warning to minimize impacts of future cyclones; (c) implementation of some key/priority proposed assistance (*e.g.*, installation of priority equipment; demonstration of storm surge models and training); (d) familiarization of DMH staff and partners with WMO/ESCAP/PTC activities and potential opportunities for capacity development; and (e) formulation of recommendations to PR of Myanmar on the enhancement of DMH meteorological and hydrological activities, in general. The mission team was composed of representatives and experts in tropical cyclone and storm surge forecasting and warning from WMO (Dr T. Toya and Ms A. Soares); ESCAP (Dr Le Huu Ti), India (Dr M. Mohapatra and Prof. S. Dube), Pakistan (Dr Q. Chaudhry: PTC TSU Coordinator), Thailand (Dr W. Kanbua), and worked in full collaboration with Dr Tun Lwin and DMH staff. The list of delegation is given in Appendix I.

2.2 The Programme of the Mission, as given in Appendix II, was composed of: (1) DMH workshop and coordination meetings with DMH and stakeholders; (2) visit to operational facilities of DMH; (3) training DMH staff in tropical cyclone and storm surge forecasting; and (4) meetings with the Minister for Transport and senior officials of the Government of Myanmar, as well as several potential donors located in Yangon, including UNDP, JICA and Embassies. The list of persons met during the mission is given in Appendix III.

2.3 A two-day workshop was convened in DMH, from 9 to 10 February 2009, comprising three parts: (a) the first day on WMO/ESCAP activities, with special emphasis on potential opportunities for assistance; Regional framework; Role and operation of a NMS; and DMH functions and operational services; (b) the second day (a.m.) included extended presentations by the DMH staff, experts from RSMC New Delhi and the Thai Meteorological Department (TMD) on *Cyclone Nargis*, including DMH actions for monitoring/tracking and advisory/warning services; and (c) the second day (p.m.) consisted of brief presentations by partners and other stakeholders on the users' response to *Cyclone Nargis*. A summary is incorporated into Key Findings and Conclusions below and full presentations are available on a CD-ROM.

2.4 The third day, 11 February 2009, was dedicated to the consideration for development of effective early warning systems for tropical cyclone and storm surge forecasting and warning to

minimize impacts of future events, through the presentations and discussions with DMH staff and some stakeholders in Myanmar.

2.5 A one-day training workshop was convened on 12 February 2009 for DMH staff, Myanmar Engineering Society, Myanmar Maritime University (MMU), University of Mawlamyine, and Myanmar Navy. This workshop comprised: (a) Training on tropical cyclone forecasting, including installation and operation of an electronic cyclone atlas, developed by the Indian Meteorological Department (IMD), and operational aspects of cyclone monitoring and forecasting; and (b) Training on wave and storm surge forecasting, including installation and operation of the Indian Institute of Technology (IIT) storm surge model and TMD wave and storm surge models. It also included an overview of the existing models worldwide that can be accessible through the Internet. A PC was donated by Dr W. Kanbua, Marine Meteorological Centre, TMD, on which the TMD ocean wave model was installed.

2.6 The representatives of WMO, ESCAP and PTC TSU visited the Ministry of Transport, the DMH Headquarters and the National Multi-hazard Early Warning Centre in NayPiyTaw on 12 February 2009. The key outcomes of the mission were briefed to H.E. Major General Thein Swe, Minister for Transport, who expressed his appreciation for WMO assistance following *Cyclone Nargis* and confirmed his strong commitment to paying full attention and support to DMH proposals prepared through this mission.

2.7 Urgent, medium-term, and long-term priority requirements were assessed in detail for consideration of possible assistance mechanisms and implementation plan on 13 February 2009. The findings and recommendations from the fact-finding mission are given below.

3. FUNCTIONS OF THE DEPARTMENT OF METEOROLOGY AND HYDROLOGY (DMH)

Historical Background

3.1 The Department of Meteorology and Hydrology (DMH) is a state organization under the administration of the Ministry of Transport, dealing with meteorology, hydrology, agrometeorology and seismology. DMH is one of the oldest scientific institutions in Myanmar, established on 1 April 1937 as the Burma Meteorological Department (BMD). Myanmar was one of the signatory countries of the WMO Convention in 1949, and became its Member when WMO was created on 23 March 1951.

3.2 After World War II, and after the independence of the country on 4 January 1948, BMD reactivated the installation of observatories, construction of office buildings and training of personnel, and established an aviation meteorological office at the Mingaladon Airport. BMD was reorganized in October 1972, and renamed as the Department of Meteorology and Hydrology (DMH) in 1974. DMH was transferred from the Ministry of Transport and Communication to the Ministry of Communications, Posts and Telegraphs in February 1992, and again to the Ministry of Transport on 20 August 1999.

3.3 Monsoon period weather news was broadcast in news item of Voice of Myanmar in 1949 and Monsoon season flood warning was issued in 1966. The first satellite receiving system for GMS was installed in June 1973. A storm detection radar was installed at Minpyin (Kyaukpyu) in September 1979. On 19 August 1983, DMH computer section was inaugurated and started basic numerical weather prediction. DMH issued the first Agrometeorological Bulletin in June 1993. Daily Weather News and Monthly Weather News and Reviews have been telecast on the Myanmar Radio and Television (MRTV) since 1 September 1980. After establishing the TV weather presentation mini-studio, DMH has produced its own TV weather news on MRTV since 12 August 1997 and on the Myawardy (MWD) since 5 September 1997. The first programme of the daily weather news with a presenter was telecast on 2 June 2001. The DMH Website (www.dmh.gov.mm) was launched on 23 March 2005 (WMD-2005).

3.4 DMH serves as the focal point of the National Multi-hazard Early Warning Centre in Myanmar, with the responsibilities for issuance of early warnings in time for all weather-, geological- and maritime-related hazards to all public, authorities and all stakeholders, starting from 14 July 2006.

DMH Purpose, Objectives and Functions

3.5 The purpose of DMH is to render technical services on all aspects of meteorology, hydrology, agrometeorology, seismology and their related subjects, in the form of data, information, knowledge, advices, consultancy services, forecasts, warnings, joint survey and investigation, etc. Its objectives are:

(1) To promote safety, comfort, efficiency and regularity of air, land (rail and road), sea and inland water transportation;
(2) To take precautionary measures against and minimize the effects of natural disasters (flood, tropical storms, drought, adverse weather, earthquake, etc.);
(3) To bring sustainable development of natural resources (hydro-electric power, forest produce, water use, wind energy, etc.);
(4) To promote agricultural and food production;
(5) To ensure efficient operation, planning and development of activities in national defence, industry, health, social welfare and all sectors of national economy;
(6) To provide help for safety, comfort and well being of populations in all parts of the country; and
(7) To undertake international collaboration for all development activities and work of DMH.

3.6 DMH accomplishes the following functions:

(1) To exchange information with other centres on weather, water and earthquakes;
(2) To safeguard the people from losing their lives and property by issuing early warnings and bulletins for all weather-, water- and geological-related hazards;
(3) To expand the public awareness and education programmes on natural disasters, natural hazards and environmental issues;
(4) To monitor climate change, underground water resources, air and water quality of Myanmar;
(5) To assist all authorities from Transport, Health, Agriculture, Construction and Tourism by providing meteorological, hydrological and seismological information; and
(6) To assist all national projects.

DMH Organizational Structure and Staffing

3.7 The new set-up of DMH was approved by the Government of the Union of Myanmar on 21 January 1999. The staff of DMH comprises of 135 officials and 1,290 non-gazetted staff members. DMH is composed of the following nine Divisions: Administration, Budget and Account Division; Upper Myanmar Division; Lower Myanmar Division; Meteorological Division; Hydrological Division; Agrometeorological Division; Seismological Division; Aviation Meteorological Division; and Instrument and Communication Division. The organizational chart of DMH is shown in Appendix IV, Annex I.

DMH Budget

3.8 The DMH annual budget (2009-2010) is 580.0000 million Kyats (around USD 600,000). The DMH annual budget for the past 10 years since 2000-2001 is given in Appendix IV, Annex II.

DMH Forecasting and Warning Services

3.9 The number of the DMH observation stations, with types of observations, is given in Appendix V. The observational data in Myanmar is collected at the National Meteorological Centre (NMC) in Yangon by SSBs (HF transceivers) and via the Internet (e-mail). The international real-

time data and products are exchanged via the GTS. Following the tragic 2004 Indian Ocean tsunami, the GTS system (Yangon-New Delhi and Yangon-Bangkok) was upgraded from 50 bps to 64/128 kbps with the funds from UN/ISDR Flash Appeal and VCP(F). The system, composed of a Local Area Network, Internet-based Communication System, Visualization System and additional PCs and accessories, was installed in 2007-2009 in NMC Yangon by NetSys, South Africa (completed in January 2009).

3.10 DMH provides the aviation meteorological services; meteorological and hydrological services for shipping and inland water transport; meteorological services to agriculture; hydrological services; and seismological services. DMH also conducts many training courses, including BSc (Hons) Meteorology and BSc (Hons) Hydrology Academic Courses, and Natural Disaster Prevention Course.

3.11 DMH issues the following forecasts, bulletins, news and reports: (1) Daily Weather Forecast; (2) 10-day and Monthly Weather Forecast; (3) Sea Route Forecast; (4) Aviation Forecast; (5) Special Weather Forecast; (6) Water-level Forecast; (7) Lowest Water-level Forecast; (8) Water-level Bulletin; (9) General Forecast for Southwest Monsoon; (10) Pre-, Mid- and Post-monsoon Weather Forecast; (11) Analysis of Pre-, Mid- and Post-monsoon Rainfall Condition; (12) Hydrologic Summary; (13) Special Weather Condition; (14) Technical Report for Southwest Monsoon; and (15) Seismological News.

3.12 DMH issues warnings as follows: (1) Storm Warning; (2) Storm Surge Warning; (3) Strong Wind Warning; (4) Port Warning; (5) Heavy Rainfall Warning; (6) Untimely Rainfall Warning; (7) Flood Warning; (8) Significant Weather Report for Aircraft; (9) Special Weather Report for the Airport (SPECI); (10) Fog Warning; and (11) Tsunami Warning.

3.13 In accordance with the meteorological law, the above forecasts and warnings are disseminated by DMH to Government authorities; local authorities; UN Offices, NGOs and other relevant organizations; national media and the general public through telephone; fax; mobile phone; Internet (website and e-mail); VHF; port wireless; AFTN (aviation) and Radio/TV and print media.

4. KEY FINDINGS

4.1 Review of *Severe Cyclonic Storm Nargis*

Analysis of Technical Details of Nargis and its Impacts

4.1.1 According to the statistics during the period 1887-2007, April-May and October-December are two storm periods for Myanmar with possibility of land crossing. Since 2006, Myanmar has been affected seriously every year by Cyclone Marla (24-30 April 2006); Cyclonic Storm Akash (14-15 May 2007); and *Cyclone Nargis* (26 April-3 May 2008), although no storms with cyclone intensity had landed since 1994. *Cyclone Nargis* (01B08) was the first cyclone in the Northern Indian Ocean and in the Bay of Bengal in the year 2008.

4.1.2 RSMC – Tropical Cyclones New Delhi reported that a depression formed over southeast Bay of Bengal at 0300 UTC on 27 April 2008. It intensified into a cyclonic storm "*NARGIS*" at 0000 UTC on 28 April and into a very severe cyclonic storm at 0300 UTC on 29 April. The system initially moved in a northwesterly direction and then recurved northeastwards and crossed Myanmar coast near Lat. 16.0 degrees N between 1200 and 1400 UTC on 2 May 2008 (see Appendix VI, Fig. 1).

4.1.3 *Cyclone Nargis* crossed the southern Deltaic area through Hainggyi Island with near peak intensity and moved ashore in the Ayeyarwady Division starting from the evening of 2 May, and southern Yangon and Bago Divisions on that midnight. On 3 May, it crossed the Mon and Kayin States respectively and passed towards northern Thailand in the evening. *Cyclone Nargis* came

ashore across the mouths of the Irrawaddy River and followed the coastline northeast. The shallow waters allowed the counter-clockwise circulation of onshore winds around *Nargis* to pile up a large storm surge to the right of the storm's track. The observed peak surge height at Ayeyarwady Division is shown in Appendix VI, Fig. 2. Over northeastern Thailand, the cyclone weakened into a low-pressure area on the afternoon of 4 May 2008.

4.1.4 RSMC New Delhi identified the following as special features of *Cyclone Nargis*:

- The system continued to intensify even after the re-curvature;
- The system moved almost in an easterly direction from 0600 UTC on 1 May till 1500 UTC on 2 May 2008;
- The system maintained the intensity of very severe cyclonic storm for about 12 hrs after the landfall;
- After the 1991 Bangladesh cyclone (April 1991), *Cyclone Nargis* was the most devastating cyclone over the Bay of Bengal in terms of loss of life and property as about 84,000 people died (highest death toll in history in Myanmar) and 54,000 still missing due to this cyclone.

4.1.5 Immediately after *Nargis*, DMH carried out post cyclone survey missions to the affected area to assess the damage and the cyclone parameters from the extent of damage; to obtain the storm surge data; and to assess the public response to the DMH warnings. DMH missions and all key national partners, and the WMO fact-finding mission recognized that the major cause of damage and loss of lives during *Nargis* was storm surges. This confirms the storm surge experts' assessments that in general up to 90% of losses could be due to storm surges.

4.1.6 DMH assessed that the elements of hazard are of significance as:

(1) At its severe stage while crossing the southern Ayeyarwady;
(2) Moving straight eastwards along the coastline;
(3) On landfall *Nargis* was almost stationary for about four hours;
(4) The system is phenomenal in the sense that the intensity and track had never been experienced before for the Deltaic area.

4.1.7 The WMO mission further recognized that the major elements of vulnerability of the affected area were amplified due to:

(1) Very low-lying area;
(2) Most populous area of the country;
(3) Many tributaries in Deltaic areas (seven river mouths);
(4) No storm shelters and high ground;
(5) No hazard maps and risk assessment had yet been done;
(6) No past experience and extremely hard to convince local people;
(7) Risk knowledge on the disaster especially on storm surge is very low;
(8) Poor mobility, mostly waterways along small canals by boats;
(9) The non-linear interactions between the wind induced waves and the topography and high tides of the area are extremely high;
(10) The cutting off of mangrove trees.

4.1.8 Some technical features of *Cyclone Nargis* and a summary of the loss of damage are given in Appendix VII.

Monitoring/Tracking and Advisory/Warning Services provided by RSMC New Delhi and other Centres

4.1.9 RSMC New Delhi (IMD) disseminated by GTS (1) observational data; (2) satellite bulletins; and (3) RSMC bulletins, and by IMD Website (1) current weather observations from India; (2) satellite products bulletins, imageries and derived products; (3) weather charts (analysis and

forecast); and (4) RSMC bulletins. The RSMC cyclone warning and advisory were received at DMH during *Nargis*.

4.1.10 Bulletins issued by RSMC New Delhi during *Nargis* were: Tropical Weather Outlook (3 times); Tropical Cyclone Advisories (41 times every three hours); and Tropical Cyclone Advisories for aviation use (19 times every six hours). The first tropical cyclone advisory indicating landfall over Myanmar coast was issued at 0600 UTC on 1 May based on observations at 0300 UTC (about 36 hrs in advance). It was indicated in the bulletin that the system would cross Myanmar coast between Lat. 16.0 and 18.0 degrees N around night of 2 May 2008. On the morning of 2 May, it was indicated that the system would cross Myanmar coast near 16.0 degrees N around evening of the same day.

4.1.11 During *Nargis*, DMH received available information for cyclone monitoring/tracking and advisory/warning services through the GTS and the Internet on the following Websites:

Satellite images

- http://www.weather.gov.sg/wip/web/ASMC/Satellite_Imagery/Myanmar (ASMC)
- http://www.imd.gov.in/section/satmet/dynamic/insatsector-ir.htm (IMD)
- http://www.tmd.go.th/EN/ (TMD)
- http://www.monsoondata.org/wx/india.fcst.html (National Centers for Environmental Prediction: NCEP)
- http://www.jma.go.jp/en/gms/index.html? (Japan Meteorological Agency: JMA)
- http://en.allmetsat.com/images/afwa_igms_ir.php (MTSAT-India-China-Infrared)
- http://www.bom.gov.au/products/IDX1174.shtml (Australian Bureau of Meteorology)
- http://cimss.ssec.wisc.edu/tropic/real-time/indian/images/xxirmet5n.GIF (University of Wisconsin - Madison)
- http://www.pakmet.com.pk/Subpage1/S_images/satellite_image.html (Pakistan Meteorological Department: PMD)

Rainfall forecast

- http://trmm.gsfc.nasa.gov/publications_dir/dump_168hr.shtml (TRMM, NASA)
- http://www.imd.ernet.in/section/nhac/dynamic/ (IMD)

GTS data

- http://weather.noaa.gov/pub/data/raw/sm/smbm01.vbrr..txt

Cyclone analysis

- http://www.imd.gov.in/ (IMD)
- http://metocph.nmci.navy.mil/jtwc.php (Joint Typhoon Warning Center: JTWC)
- http://www.wunderground.com/tropical/?index_region=io
- http://weather.noaa.gov/pub/data/raw/wd/wdpn32.pgtw..txt
- http://weather.noaa.gov/pub/data/raw/wt/wtin20.dems..txt
- http://weather.noaa.gov/pub/data/raw/wt/wtio51.pgtw..txt
- http://weather.noaa.gov/pub/data/raw/wt/wtin01.dems..txt
- http://cimss.ssec.wisc.edu/tropic2/

Weather forecast

- http://www.imd.gov.in/ (IMD)
- http://www.monsoondata.org/wx/ (NCEP)
- http://www.wunderground.com/global/BM.html
- http://www.wunderground.com/cgi-bin/findweather/hdfForecast?query=Dawei&searchType=WEATHER
- http://www.tmd.go.th/programs/uploads/maps/2009-03-03_TopChart_07.jpg (TMD)
- http://www.tmd.go.th/programs/uploads/maps/2009-03-03_07_UpperWind850.jpg

Wave forecast

- http://www.ihad.tmd.go.th/ (TMD Integrated Hazard Awareness Display)

- http://www.ihad.tmd.go.th/f12.html

WRF/MM5 products

- http://www2.tmd.go.th/program/frames/nwp.html (TMD)
- http://www.bom.gov.au/nmoc/NWP.shtml#asia.

Among the above, DMH most utilized the MTSAT and INSAT satellite images provided by IMD and the ASEAN Specialized Meteorological Centre (ASMC) operated by the Meteorological Services Division, National Environment Agency in Singapore. The Asian Disaster Preparedness Centre (ADPC), Thailand, provided experimental forecast of Tropical Cyclone in the Bay of Bengal (*NARGIS*) (with 25-04-2008 12 UTC initial condition and valid of forecast up to 120 hrs (*i.e.,* 04-05-2008 12 UTC)).

4.2 Services provided by DMH during *Cyclone Nargis*

Cyclone Detection and Forecasting

4.2.1 Monitoring of *Nargis* by DMH was carried out at the National Meteorological Centre (NMC) in Yangon, NayPiyTaw Meteorological Centre, Aviation Meteorological Office at Mingaladon (Yangon) International Airport, Multi-hazard Early Warning Centre in NMC Yangon; and coastal observing stations. All the above five Centres served on a 24/7 basis. Accurate information was received on the cyclone track and intensity from several WMO Regional Centres, including the RSMC in New Delhi; ASMC; JMA; TMD and the China Meteorological Administration (CMA).

4.2.2 The mission found that the timely provision of data and products through the upgraded GTS (ref. paragraph 3.9) had enhanced a great deal the capacity of DMH for the *Nargis*. However, the GTS installed in DMH is Internet based and the access to the Internet in DMH is still limited. A sustainable broadband Internet connection is required at DMH.

4.2.3 DMH, with the benefit of the recent installation of some modern systems such as PCVSAT (PC-based very small aperture terminal used for receiving meteorological data and products from CMA) and MICAPS (Meteorological Information Comprehensive Analysis Process System) with the assistance of China, together with the GTS/MSS, received satellite pictures for cyclone track monitoring. However, there is a need for upgrading MICAPS for producing NWP products.

4.2.4 Forecasting tools available and used in DMH included: (a) Conventional Observation; (b) Hourly Observations; (c) Satellite Observation; (d) Synoptic Analysis; (e) Upper-Air Analysis; (f) Isallobaric Charts Analysis; and (g) Steering Current Analysis.

4.2.5 The position of the cyclone centre was also manually determined by Dr Tun Lwin at NMC Yangon by using a magnifying glass and the satellite meteorology knowledge and experience. Then the x-y coordinates of the cyclone centre measured by using a pencil and a ruler were calculated into the latitudes and longitudes by using Excel programme on a small laptop PC. The same procedures were applied to the measurements of radius of storm, movement, speed of propagation, distance from the coast, radius of maximum winds and storm coverage.

Storm Surge Monitoring and Forecasting

4.2.6 The mission recognized that DMH used an analytical method and two empirical methods (P.K. Das, 1974 and T. Lwin, 1980) to predict the storm surge height associated with the tropical cyclone *Nargis* on the river mouth. DMH staff had participated in training workshops on storm surge modelling and forecasting in order to establish a numerical storm surge prediction system in DMH. The mission noted with appreciation that IIT, JMA and TMD storm surge models are currently installed and implemented in DMH.

4.2.7 The mission further recognized that storm-induced floods in a complex delta, *e.g.*, Ayeyarwady, are influenced by many factors (topographical, hydrographical/hydrological and

physiographical conditions) and that storm surge height therefore varies from one location to another. In this context, no storm-induced flood-forecasting tool to estimate the water level in the Deltaic river area is currently available at DMH.

4.2.8 A post storm survey was conducted to evaluate the storm surge heights in different zones of the Deltaic river area, however the detailed information was not available at the time of the mission, although the evaluation is in progress. The mission noted that hazard maps are still very limited.

Warning and Dissemination

4.2.9 During *Nargis*, DMH issued (a) Daily Weather Bulletin; and (b) Special Storm News for the general public; (c) Four-stage Warnings, *i.e.,* Pre-Cyclone Watch; Cyclone Alert; Cyclone Warning; and Post Landfall Outlook for designated officials; Port Authorities; Aviation Authorities; and for the Navy, as from 29 April 2008. Special storm warnings were issued every hour from 2 May 2008 evening, with possible coastal-affected areas, and including cyclone position and forecasted direction, wind speed, storm surge height and timing.

4.2.10 The warnings were sent to: Prime Minister Office; Secretary of State Office; National Disaster Management Committee; National Disaster Risk Committee; Ministry of Defence (Central Headquarters); Ministry of Transport; Ministry of Home Affairs; Ministry of Social Welfare, Relief and Resettlement; and other relevant Ministries (34 Ministries in total); Naval Headquarters; Air Force Headquarters; Chairman Offices in Rakhine State and Ayeyarwady and Yangon Divisions; Naval Commander Office at Heingyi; Local Authorities (in Rakhine, Ayeyarwady, Yangon); NGOs, UN Offices, other relevant organizations; national media (Newspapers, TVs (4 channels), Radios (MRTV and City FM)); and four phone line services for public information.

4.2.11 The frequent power shortage disrupted the operational services of DMH and the blackout after the landfall of *Nargis* significantly affected its services. All communications were broken down in Yangon from 20:00 MST on 2 May to 17:00 MST on 3 May 2008. During that silent period, storm centres were determined by the NayPiyTaw Meteorological Centre, where satellite images were received from FengYunCAST. The Internet was unavailable for more than one day over the country. Only the communication between NMC Yangon and coastline observing stations were made by SSBs. DMH continued to provide warnings to the relevant authorities from NayPiyTaw.

4.2.12 The mission team reaffirmed that DMH, despite their capacity constraints, performed remarkably well in detection and forecasting *Cyclone Nargis*, and provided information (since its very early stage over Southwest Bay of Bengal) on the cyclone track and intensity to relevant authorities, including mass media, and issued warnings well in advance.

4.3 Response by the Different Partners and Stakeholders, Community-level Dissemination and Public Awareness

4.3.1 It was found that in general warnings issued by DMH were duly transmitted to the respective Government authorities and departments. All the authorities/organizations participating in the workshop and coordination meetings commended the timely issuance of early warnings and relevant information on *Cyclone Nargis* by DMH and stated that necessary actions (*e.g.*, rerouting flights, relocation of UN workers in the field to safer places, closing ports, etc.) were taken based on and thanks to the warnings and information provided by DMH.

4.3.2 The mission recognized that the early warnings and relevant information were duly delivered to village leaders, and the Government tried to evacuate people. DMH had also tried to communicate with the respective authorities and state/division Peace and Development Councils in a repeated manner. A good lead time was there as well for making evacuations.

4.3.3 The mission further recognized that people's lack of knowledge on the necessary actions for preparedness (many local people were aware of the warning 48 hours in advance, but they thought that staying at home and not going out was enough for storm preparedness), planning and what people would do with the warning was not quite understood at community level. Myanmar had not experienced such a cyclone (moving along the coast) for a long time. Although much of the communities had received some sort of warning at their communal levels, both local authorities and people's lack of knowledge, public awareness towards the warning, limited shelters and high ground, and poor mobility (only waterways along small canals by boats are available) made them vulnerable in a large way (ref. paragraph 4.1.7).

4.4 WMO Assistance for DMH and DMH Actions after *Cyclone Nargis*

4.4.1 The WMO support was provided to DMH for the highest priority and urgent requirements identified by the WMO emergency assessment mission (May 2008), which includes:

Equipment

- An electric generator (installed at the Multi-hazard Early Warning Centre in NayPiyTaw);
- Two PCs for storm surge modelling and forecasting;
- 20 sets of thermometers, soil thermometers and 2 PCs – by China (VCP) (on-going);
- An Automatic Weather Station (AWS) donated by Meisei Electric Co. Ltd, Japan under VCP (installed at the Multi-hazard Early Warning Centre in NayPiyTaw);
- PC and storm surge model donation by Dr W. Kanbua (Thailand Marine Meteorological Centre, TMD).

Training

- A new fellow for MSc Meteorology Course at the University of the Philippines from 04/11/08 to 31/10/10 (Ms Thet Hatr Su Hlaing);
- UKMO/WMO Aviation Seminar from 5 to 9 July 2008 in Oman;
- Fifth Regional Workshop on Storm Surge and Wave Forecasting from 1 to 5 December 2008 in Melbourne;
- Training attachment to IIT under the Tropical Cyclone Programme (November 2008).

In addition, 40 HF transceivers (SSB) were donated by Mitsubishi Electric Co. Ltd, Japan in February 2009.

4.4.2 The mission further noted that after *Cyclone Nargis* a National Multi-hazard Early Warning Centre was established in NayPyiTaw, where an AWS and an electric generator were installed with the support of Japan (VCP) and the WMO Emergency Assistance Fund, respectively. Bilateral agreements with Thailand agencies were established, and several seminars, workshops and missions were convened. Several studies were conducted by DMH and partners on tropical cyclone detection and forecasting, including *Cyclone Nargis*. Detailed information is provided in Appendix VIII.

4.4.3 The mission also noted that, following *Cyclone Nargis*, the disaster prevention and preparedness measures were carried out in Myanmar by the Ministry of Social Welfare, Relief and Resettlement (MSWRR), Ministry of Construction, Ministry of Science and Technology, the Myanmar Engineering Society and DMH under the guidance of the National Committee on Disaster Management, which is chaired by the Prime Minister. Construction work on 21 shelters and five communication roads; identification of the life saving grounds; and building of new embankments along the coastlines were underway in the Deltaic area. Ten training courses on Disaster Management were conducted by the MSWRR for the trainers.

4.4.4 As for the public education and awareness programme, the Director-General of DMH, as a national WMO focal point for public weather services and as a member of the National Committee for Public Information on Disasters, has published a book entitled "A Girl Named La Nina" and other articles on natural disasters. The book was awarded the first prize for the Knowledgeable Science Category by the Association of Writers and Literature. Moreover, DMH in collaboration

with ADPC has published an in-depth report on response system to *Nargis* (ref. Joint Rapid Situation Assessment Report, May 2008). This report is the first of its kind and has explained explicitly the state of the art of the main components of disaster management works in Myanmar.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Assessment of Priority Requirements for Further Enhancement of DMH Capacity

5.1.1 The mission and the DMH staff identified a number of issues that need to be further developed and/or capacity needs to be built, especially on storm surge forecasting. The following were assessed as very high-priority and urgent requirements:

- Reliable satellite-based broadband Internet connectivity;
- Duplicated GTS connectivity at NMC (Internet-based GTS/MSS) and NayPiyTaw (through INSAT Meteorological Data Dissemination (MDD) system);
- WAFS products collection for aviation services;
- Ensured satellite picture information at NMC;
- Ensured dissemination to Government and local authorities;
- Storm Surge Guidance from RSMC New Delhi to DMH;
- Direct contact arrangements for DMH with RSMC-New Delhi and TMD;
- MSc Education in Meteorology;
- Expert services for training on GTS issues.

5.1.2 High-priority medium- and long-term requirements would include:

- GTS link to NayPiyTaw and Yangon International Airport Aviation Meteorological Office (Mingaladon);
- Ensured dissemination to the end-users through the RANET system;
- Improvement of observations/monitoring, including a weather radar and upper-air systems;
- Special training at RSMC New Delhi for DMH cyclone forecasters;
- Expert services for training on GIS applications;
- DMH-DG visits to Bangladesh, Pakistan and Thailand (NMHSs and NDMOs, etc.) to gain experience.

5.1.3 WMO, UNESCO-IOC and ESCAP with ADPC submitted a joint proposal to the OCHA Flash Appeal on 10 June 2008, for operational early warning system for tropical cyclones, river flooding, tsunami and other coastal hazards, in which some of the requirements were properly included. Since the consideration of support for UN Flash Appeal was confined to the relief and recovery proposals from UN Organizations located in Myanmar, the joint Flash Appeal proposal should be reformulated for another scheme for establishing an effective multi-hazard early warning system for Myanmar.

Implementation of Technical Assistance Activities

5.1.4 Recommended assistance with possible mechanisms and procedures for the implementation of support by WMO, Members and potential donors for the current high-priority urgent, medium- and long-term requirements assessed by this fact-finding mission is presented in Table 1 below.

Table 1

Recommended actions for the current urgent, medium- and long-term requirements assessed by this fact-finding mission

Recommendation	*Priority*	*Time-range*	*Proposed solution*	*Funding mechanism*	*Action*
Reliable broadband Internet connectivity	Highest	Top Urgent	Satellite-based broadband Internet (in NMC Yangon and Aviation Office)	WMO Emergency Assistance Fund (EAF) (Supported)	• Local quotation from SUNTAC Technologies to be updated • DMH for justification; WMO Purchase Order (through PCC)
Duplicated GTS connectivity at NMC and NayPiyTaw	Highest	Top Urgent	INSAT-MDD (in NayPiyTaw)	WMO VCP or EAF (to be supported by IMD, India)	• IMD for technical description; DMH for request; India support • IMD for shipping and installation (with possible VCP/EAF support) • WMO to request India
GTS link to NayPiyTaw and Yangon IA Aviation Met Office (Mingaladon)	Medium	Medium-term	• Wireless LAN for 6 miles distant (Yangon IA) • Expert services for sharing GTS data in Yangon NMC	Expert services by VCP; implementation by DMH budget (+ VCP(F))	• DMH for proposals (local quotations) • DMH to request; suggestion for expert(s) (India/Thailand)
WAFS products collection for aviation services	Highest	Urgent	Internet upgrade with PC and peripherals at Yangon IA for SADIS reception	WMO AeM funds + VCP(F) (to be supported)	• Follow Internet upgrade action • DMH to consider the aviation forecaster qualification issue to meet ICAO requirements
Ensured satellite picture information at NMC	High	Urgent	• MTSAT satellite receiving system (direct receiving system) • Internet upgrade	VCP Japan, VCP(F) or private company (*e.g.,* Mitsubishi)	• VCP procedures (Request) • DMH efforts with Mitsubishi
Ensured dissemination to Gov./local authorities	High	Urgent	• Modem for dissemination of SMS for CDMA and GSM mobile systems • Other solutions to be studied	EAF (to be supported) VCP(F)	• DMH to investigate other solutions, prepare specifications (international) • WMO for expert services; procurement procedures
Ensured dissemination to the end-users	Highest	Medium-term	Develop a RANET project with DMH to establish a RANET information system for effective dissemination of information to communities in rural areas	VCP(F)	• WMO to develop proposal with DMH for VCP request • DMH – National Warning Centre: legal arrangements • DMH to ask ESCAP mission (March 2009)
Improvement of observations and monitoring	High	Longer-term	• Weather radar: radar expert services • Instruments for synoptic stations + AWSs	• VCP(F) for expert services • JICA • VCP donors and PONREPP	• WMO for expert services; • WMO and DMH for JICA assistance; • PONREPP: DMH to Gov and ESCAP

Storm surge guidance from RSMC New Delhi to DMH	Highest	Urgent	Include storm surge into TC Operational Plan at PTC-36 in Oman	PTC arrangements	PTC-36 decision; RSMC to follow up
Direct contact arrangements with RSMC New Delhi and TMD	Highest	Urgent	Consider arrangements at PTC-36 in Oman	PTC arrangements	PTC-36 decision; RSMC to follow up
MSc Education in Meteorology	High	Urgent	New Fellowship application: MSc Meteorology Course at the University of the Philippines from 2009 to 2011	WMO ETR budget (to be supported through FELCOM, May 2009)	WMO FELCOM decision; DMH for resubmission and follow up
Special training at RSMC New Delhi for DMH Cyclone forecasters	High	Medium-term	Special training opportunity to DMH (2 weeks) – Priority to WMO/TCP Cyclone forecaster training	WMO TCP budget (to be favourably considered)	• IMD for agreement; DMH for request; India for support • IMD for implementation of training
Expert Services for training on: – GTS and for sharing GTS – GIS Applications	 High High	 Urgent Medium-term	Expert Services for training on GTS and GIS	• WMO VCP(F) (to be favourably considered) • ESCAP and WMO VCP(F)	• WMO for expert services for GTS • ESCAP for GIS
DG to visit Bangladesh, Pakistan and Thailand (NMHS and NDMO, etc.) to gain experience	High	Medium-term	• Visit to PMD in mid-2009 • Visit to BMD in late 2009 • TMD in the near future (TICA arrangements)	WMO EAF (to be supported)	• DMH for request • WMO for lump-sum support • WMO to coordinate with Members

5.2 Development of Effective Early Warning Systems for Cyclone and Storm Surge Forecasting and Warning

5.2.1 After the tragic impact of the *Cyclone Nargis*, DMH and all key national partners and the current mission recognized the importance of storm surge preparedness and accurate forecasts of storm surge in the ultimate goal of building an effective multi-hazard early warning system in Myanmar and also in the Panel on Tropical Cyclones (PTC) Members. They also recognized the importance of maximizing the benefits of cooperation among the Members of PTC and with other key partners in the region, including RSMC New Delhi.

5.2.2 For this reason, and noting that the frequent power shortage and the blackout after the landfall of *Nargis* significantly disrupted the operational services of DMH, the mission recommended the following strategy to enhance capability of DMH and other related NMHSs of PTC on storm surge forecasting for an end-to-end sustainable early warning system:

(a) To coordinate activities on storm surge with those recommended earlier on cyclone EWS, including the proposed framework for enhanced cooperation with RSMC;

(b) To build on the global initiative of WMO on “Storm Surge Watch Scheme”;

(c) To continue strengthening efforts of PTC for capacity building of DMH through ongoing efforts of the Indian Institute of Technology (IIT), recent cooperation initiatives of TMD through its Marine Meteorological Centre (TMD-MMC), and any other activities organized by WMO programmes for the region; and

(d) To intensify the capacity building efforts through IIT and TMD-MMC to build up a knowledge base for more effective EWS on storm surge under severe conditions of no electricity and/or no computer.

5.2.3 As the first three groups of activities are ongoing and coordinated by the existing mechanisms, the mission, through detailed discussions with the storm surge experts from IIT, TMD-MMC and WMO, recommended to integrate the following activities into the programme of capacity building of DMH in the coming years:

(a) Sensitivity studies and analyses of storm surge models for more effective decision-making on storm surge forecasting at the mouths of Ayeyarwady Delta. It is recommended that the results of these sensitivity studies be compiled and synthesized into reports and charts as part of the knowledge base;

(b) Sensitivity studies and analyses of impacts of tidal fluctuation on storm surge prediction to enable forecasters to decompose possible contribution of tides on storm surge heights at the river mouths as boundary conditions for detailed simulation of propagation of storm surge into the Delta estuarine system. Similar to those studies proposed in (a), it is recommended that the results of these studies be compiled and synthesized into reports and charts as part of the knowledge base;

(c) Sensitivity studies and analyses of impacts of wind set-up on storm surge prediction to enable forecasters to decompose possible contribution of wind set-up on storm surge heights at the river mouths as boundary conditions for detailed simulation of propagation of storm surge into the Delta estuarine system. Similar to those studies proposed in (a), it is recommended the results of these studies be compiled and synthesized into reports and charts as part of the knowledge base;

(d) Establishment of a hydrodynamic model of the Ayeyarwady estuarine system to simulate the propagation of storm surge into the Delta to reproduce the actual situation of the *Nargis*. For this purpose, it is recommended to compile a good record of the *Nargis* storm surge in the estuarine system, with special emphasis on the key population areas;

(e) Sensitivity studies and analyses of the Ayeyarwady estuarine system model against changes at the boundary conditions, especially those at the river mouths, with special focus on key areas along the estuarine system with high population concentration. Similar to those studies proposed in (a), it is recommended that the results of these studies be compiled and synthesized into reports and charts as part of the knowledge base;

(f) Special training sessions on the use of the knowledge base developed by the activities identified above.

5.2.4 The mission recognized that above-mentioned scenarios constitute useful tools for storm surge prediction in case of no power electricity and/or no computer, and a good indicator of areas likely to be affected; therefore contributing to an effective multi-hazard early warning system in Myanmar and providing a valuable assistance to national partners involved in recovery and reconstruction activities (for details, see paragraph 5.2.9).

5.2.5 Noting that WMO has initiated a JCOMM/CHy project to: (a) develop an effective software package involving both ocean and hydrological models to enable an assessment and forecast of total coastal inundation from combined extreme events; and (b) produce guidelines on storm surge statistics, including information on archiving and analyzing historical information about storm surges/water levels and existing practices worldwide, the mission recommended that the WMO Secretariat implement this software package as a demonstration project in Myanmar.

5.2.6 Noting that in Myanmar both local authorities and people's lack of knowledge on the actions for preparedness, planning and what they would do with the warning was not quite understood at

the community level, the mission recommended that public weather services be further enhanced by developing decision-making tools. It also recommended that good practices in providing weather forecasts and warnings for the general public (*e.g.*, IMD and Australia) should be shared with Myanmar and requested the WMO Secretariat to assist on this issue.

5.2.7 The mission noted that the community that is likely to be affected by storm surges is also likely to be affected by tsunamis and other coastal hazards. The mission therefore recommended strengthening DMH's capacity on marine multi-hazard Early Warning Systems, by linking the above-mentioned initiatives with the ESCAP Tsunami Trust Fund project.

5.2.8 In view of the necessity, in order to ensure sustainable operations of effective early warning systems, of: (i) an institutional and/or legal framework for the operations at the three levels: national, sub-national and local; (ii) technical capacity of DMH to issue early warnings under any circumstances; (iii) effective dissemination of EWS to decision-makers at the three levels; and (iv) disaster preparedness of the local level, and also noting the successful experience of IMD for Standard Operating Procedures (SOP) for cyclone warning services, the mission recommended that SOP be established in Myanmar with clear mandate of operations of each relevant entities.

5.2.9 The mission noted the strategy adopted in the Post-*Nargis* Recovery and Preparedness Plan (PONREPP) to focus on "*strengthening the capacities of DRR systems and procedures, i.e., the 'software' of DRR. Building or strengthening embankments and polders, roads, flood barriers and protective walls, i.e., the hardware of DRR, is being tackled by the Government in its Reconstruction Plan. Needs in terms of storm-resistant homes and communal shelters are addressed both by the Government's reconstruction programme and by the complementary shelter programmes (as well as storm-resistant building techniques) proposed in Chapter III above. DRR considerations also emerge in the agriculture sector outcomes, and in DRR-related curricula in schools in Chapter III.*" In that context, PONREPP identified the following five expected outcomes for this sector:

(1) Communities more fully engaged in DRR measures;
(2) Communities and institutions better able to disseminate and act on early warnings, through an 'end-to-end' early warning system;
(3) Focus on locally adapted mitigation measures in vulnerable areas;
(4) Disaster mitigation better integrated into current recovery and reconstruction efforts;
(5) National and local institutions develop improved preparedness and mitigation policies, and response mechanisms.

5.2.10 Strengthening the capacities of DMH would be important to the achievement of all the five expected outcomes and instrumental especially to outcomes (4) and (5). Expected contribution of DMH could be seen from the provision of a clear understanding of key factors affecting the storm surge heights at different locations in the Delta and accurate assessment of actual water level that had killed many people during *Nargis*. This detailed understanding and capability to forecast future storm surge heights under different scenarios are essential for the design of shelters and detailed hazard maps along with escape routes for evacuation. For this reason, it is recommended to integrate the programme of strengthening DMH into PONREPP. A proposal is presented in Table 2 below.

Table 2

Outcomes	**Additional achievements (up to Dec. 2008)**	**Proposed activities up to June 2009**	**Proposed activities July-December 2009**	**Proposed activities January 2010-December 2011**
Outcome 1: Communities are engaged and empowered to manage and reduce disaster related risks (CBDRM)	1) Field data collection by the Natural Disaster Mitigation and Preparedness Research Group of the Myanmar Engineering Society (MES) 2) Initial mapping of hazard	1) Further supporting surveys are made by DMH and MES for detailed information on storm surge flooding in priority areas of 10 most severely affected communities for better CBDRM, including shelter construction and hazard mapping US $30,000	1) Detailed surveys of the lower Ayeyarwady estuarine system, including the flood areas US $70,000 2) Study detailed plan to establish a detailed hydrodynamic model of the Ayeyarwady estuarine system for accurate estimation of storm surge and flood propagation US $20,000	1) Establishment of a detailed hydrodynamic model of the Ayeyarwady estuarine system for accurate estimation of storm surge and flood propagation and training US $250,000
Outcome 2: Community and institutions have mechanism and capacity to disseminate and act on early warnings through an end-to-end early warning system		1) Preparation of a first storm surge forecasting model for all the river mouths by DMH with assistance by the Panel on Tropical Cyclones (PTC) including training US $50,000 2) Conduct a desk study on impacts of tidal fluctuation and wind-set up on storm surges at the river mouths US $10,000 3) Identify options for system to disseminate warnings including priority locations for 10 warning towers US $20,000	1) Provision of a detailed storm surge forecasting model for all the river mouths with possible impacts of tidal fluctuation and wind-set up to DMH by experts from the Panel on Tropical Cyclones (PTC) including training US $50,000 2) Establishment of monographs and conduct training to facilitate storm surge forecasting under severe working conditions without computers US $20,000 3) Procurement of the system to disseminate warnings with warning towers US $500,000	1) Conduct training of DMH staff on the use of the hydrodynamic model for storm surge and flood forecasts in the Ayeyarwady estuarine system and delta. 2) Establishment of monographs for detailed forecasting under severe working conditions without computers US $20,000 3) Construction of the priority warning system and develop SOP for warnings US $250,000
Outcome 3: Sustainable reduction of the disaster risk through locally adapted mitigation measures in the affected and vulnerable areas	1) Key stakeholders identified and sensitized on community disaster management			
Outcome 4: Disaster risk reduction (DRR) integrated in the recovery and reconstruction efforts ensuring sustainable development				
Outcome 5: National and local institutions have policy and mechanisms in place for preparedness and mitigation to effectively respond to and recover from the impact of disasters	1) *Nargis* related reconstruction and preparedness plan developed by Government 2) Action plan under development for the inclusion of DRR in public education	1) Study detailed options by international experts for upgrading DMH capacity to monitor cyclones and storm surge, including a provision of a radar system and tidal gauges. US $20,000 2) Upgrade the GTS of DMH to enhance its capacity on receiving cyclone information US $50,000 2) Design of facilities for subsequent construction. US $40,000	1) Procurement of the radar system US $1 million 2) Procurement of tidal gauges for 12 priority locations US $60,000 2) Installation of temporary gauges at the priority stations to start monitoring US $12,000	1) Installation of the radar system at DMH and conduct training 2) Installation of the tidal gauges at 12 priority stations and conduct storm surge and flood forecasting operations US $20,000
Total cost estimates		***DMH: US $220,000*** ***PONREPP: US $7.0 million***	***DMH: US $1,732,000*** ***PONREPP: US $9.5 million***	***DMH: US $540,000*** ***PONREPP: US $15.5 million***

Appendix I

List of Delegation

Name	*Country/ Organization*	*Official position*	*Address/Tel/Fax/E-mail*
TOYA, Dr Tokiyoshi	WMO Representative	Regional Director for Asia and the South-West Pacific	World Meteorological Organization (WMO) 7 bis, avenue de la Paix Case postale 2300, CH-1211 Geneva 2, Switzerland Tel: +41 22 730 8252 Fax: +41 22 730 8118 E-mail: ttoya@wmo.int
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SOARES DOS SANTOS, Ms Alice	WMO Secretariat	Scientific Officer Marine Meteorology and Ocean Affairs Division	World Meteorological Organization (WMO) 7 bis, avenue de la Paix Case postale 2300, CH-1211 Geneva 2, Switzerland Tel: +41 22 730 8449 Fax: +41 22 730 8181 E-mail: asoares@wmo.int

Appendix II

Programme of the Mission

Monday, 9 February 2009

09:00 Welcome Address — Tun Lwin (DG of DMH)
Opening Remarks — T. Toya (WMO)

DMH WORKSHOP

Background/Introduction

1. Mission Brief — T. Toya (WMO)

2. Introduction of WMO/ESCAP and international organizations activities
   (a) WMO and programme activities — T. Toya (WMO)
   (b) Introduction to ESCAP: Disaster reduction — Le-Huu Ti (ESCAP)
   (c) WMO capacity building activities — T. Toya (WMO)
   (d) JICA and its role in disaster management — H. Oi (JICA)

3. Regional framework
   (a) WMO Regional Association II (Asia) — T. Toya (WMO)
   (b) WMO/ESCAP Panel on Tropical Cyclones — Q. Chaudhry (TSU, Pakistan)
   (c) RSMC New Delhi regional services — M. Mohapatra (IMD, India)
   (d) Regional storm surge watch scheme — A. Soares (WMO)

4. Role and operation of a NMS
   (a) WMO perspective — T. Toya (WMO)
   (b) NMHS perspective: Case study of Pakistan — Q. Chaudhry (PMD, Pakistan)

5. DMH functions and operational services — T. Lwin (DMH, Myanmar)
   - Institutional framework
   - Observation, telecommunication and forecasting systems

Tuesday, 10 February 2009

DMH WORKSHOP (continued)

Review of Cyclone Nargis – Analysis of technical details of Nargis and its impact

6. *Cyclone Nargis* and its impact
   (a) Analysis of SCS "*Nargis*" in the Bay of Bengal — D.K.C.C. Shein (DMH, Myanmar)
   (b) Storm surge of *Nargis* (including flooding and damage) — T. Lwin (DMH, Myanmar)

Review of Cyclone Nargis – DMH actions for monitoring/tracking and advisory/warning services

7. RSMC New Delhi services provided during *Nargis* — M. Mohapatra (IMD, India)

8. TMD services for *Nargis* — W. Kanbua (TMD, Thailand)

9. DMH services for *Nargis*

- Observation, monitoring and prediction — D. L.L. Aung (DMH, Myanmar)
- GTS — K.L. Oo (DMH, Myanmar)
- Storm surge forecasting — D.M.K. Chaw (DMH, Myanmar)
- Dissemination of advisories/warnings (existing EWS) — T. Lwin (DMH, Myanmar)

Review of Cyclone Nargis – Dissemination of advisories/warnings, user responses and requirements for advisory/warning services

10. Procedures for early warning (dissemination to users) during and after *Nargis*

11. Existing programmes of action to enhance disaster preparedness in Myanmar

10 and 11 to be discussed with Government authorities, local authorities, mass media and International Organizations (see Appendix III) with the following presentations:

(a) Status of Myanmar Maritime University in light of Meteorology — H.H. Nwe (MMU)
(b) Construction on the Cyclone-affected Areas — T. Schwe (Min. of S&T)
(c) Disaster Management in Myanmar — K. Than (Min. of Home Affairs)
(d) DOH Services for *Nargis* to enhance Disaster Preparedness — T.H. Win (Dept of Health)
(e) *Cyclone Nargis* Warning and Rescue — T. Oo (Port Authority)
(f) Role of Dept of Marine Administration on the Dissemination of Advisory Services — H. Win (Dept of Marine Adm.)
(g) Early Warning for *Cyclone Nargis* — H. Wynn (Myanmar Five Star Line)
(h) Myanma Airway's Response to *Nargis* — N. Nyi (Myanma Airways)
(i) Overview of *Nargis* Warning Services in Myanmar — M. Htoo (Myanmar Police Force)
(j) *Cyclone Nargis* Response — N.Y. Aye (Relief and Resettlement Dept)
(k) Disaster Risk Reduction — T.Z. Htay (GAD, Dadeye Township, Ayeyarwady Division)
(l) Review on *Nargis* and Future Implementation of Effective Early Warning for Natural Disasters — N. Oo (Myanmar Navy)
(m) *Cyclone Nargis* and Myanmar Printing Media — P. Nu (Eleven Media)
(n) News and Periodicals Enterprise — S. Kyi (Min. of Information)

Wednesday, 11 February 2009

COORDINATION MEETING

Development of effective system for forecasting/warning on tropical cyclones and associated storm surge and flooding, including the best use of available data and products

12. Early Warning System (EWS) framework

(a) WMO/IOC guidelines — A. Soares (WMO)
(b) Experiences in development of regional framework for EWS — Le-Huu Ti (ESCAP)
(c) Development concept of Standard Operating Procedures (SOPs) — Le-Huu Ti (ESCAP)
(d) SOPs for cyclone warning services in India — M. Mohapatra (IMD, India)

13. Modernization of forecasting system and disaster management

(a) Natural disasters in Myanmar — T. Lwin (DMH, Myanmar)
(b) Experiences and recommendations — Q. Chaudhry (PMD, Pakistan), W. Kanbua (TMD, Thailand), M. Mohapatra (IMD, India)

- Severe Weather Forecasting Demonstration Project concept and Storm Surge Watch Scheme for Bay of Bengal — A. Soares (WMO)

14. Introduction of numerical storm surge prediction models

- IIT model — S. Dube (IIT, India)
- TMD model (including wave model) — W. Kanbua (TMD, Thailand
- Other models — A. Soares (WMO)

15. Introduction of storm-induced flood forecasting system — Le-Huu Ti (ESCAP)

16. *Visit to operational facilities of NMC Yangon*

Thursday, 12 February 2009

Training in Tropical Cyclone Forecasting and Storm Surge Modelling

17. Practical training for staff

(a) Cyclone forecasting group — M. Mohapatra
(b) Storm surge forecasting group — S. Dube, W. Kanbua and A. Soares

Note: T. Toya, Le-Huu Ti and Q. Chaudhry to visit the Ministry of Transport and DMH HQ in NayPyiTaw, as well as Aviation Meteorological Office, Yangon International Airport on 12 February 2009.

Friday, 13 February 2009

COORDINATION MEETING

Assessment of requirements

18. Urgent, medium- and long-term requirements — T. Lwin (DMH, Myanmar)

Recommendations

19. Consideration of Findings and Recommendations for Report
A. Soares (Rapporteur) and T. Toya (WMO)

Implementation of technical assistance activities

20. Consideration of assistance and assistance implementation plan — T. Toya (WMO)

Appendix III

List of Persons met

Ministry of Transport

H.E. Major General Thein Swe, Minister for Transport

Ministry of Transport, Department of Meteorology and Hydrology (DMH)

Dr San Hla Thaw, Former Director-General (Retired)

Dr Tun Lwin, Director-General (dg.dmh@mptmail.net.mm)

Dr Thein Tun, Deputy Director-General

Mr Tin Ngwe, Director (Lower Myanmar)

Mr Tin Hla, Director (Upper Myanmar)

Mr Tun Aye, Deputy Director (Telecommunications)

Ms Ye Ye Nyein, Assistant Director (Agrometeorology)

Ms Khin Cho Cho Shein, Assistant Director (Meteorology)

Mr Maung Maungg Soe, Assistant Director (NayPyiTaw: International Relations)

Ms May Khin Chaw, Assistant Director (Meteorology)

Mr Zin Aung, Assistant Director (Advisor to PR)

Mr Kyaw Lwin Oo, Staff Officer (Meteorology)

Ms Lai Lai Aung, Staff Officer (Agrometeorology)

Mr Hla Tun, Staff Officer (Meteorology)

Ms Htay Htay Than, Staff Officer (Hydrology)

Mr Than Htay Myint, Staff Officer (Hydrology)

Mr Than Zaw, Staff Officer (Computer)

Ms Thin Thin Nyein, Deputy Superintendent (PA to PR)

Mr Than Naing, Deputy Superintendent

Ms Myint Myint Aye, Deputy Superintendent

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Mr Tin Oo, Pilot

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Mr Hla Wynn, Research Officer

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Mr Nyi Nyi, Captain

Ministry of Home Affairs, General Administration Department

Mr Kyaw Than, Assistant Director

Mr Thant Zaw Htay, Deputy Township Administration Officer (Phyarpon District)

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Police Major Myint Htoo, Police Major

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Mr Kyaw Zaw, Assistant Director

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Lt (S.G.) Naing Oo, Head, Cartographic Division, Myanmar National Hydrographic Centre

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Mr Kyaw Thiha, Reporter, 7 Days News Journal

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Mr Andrew Mittelman, Early Recovery Programme Manager, UNDP

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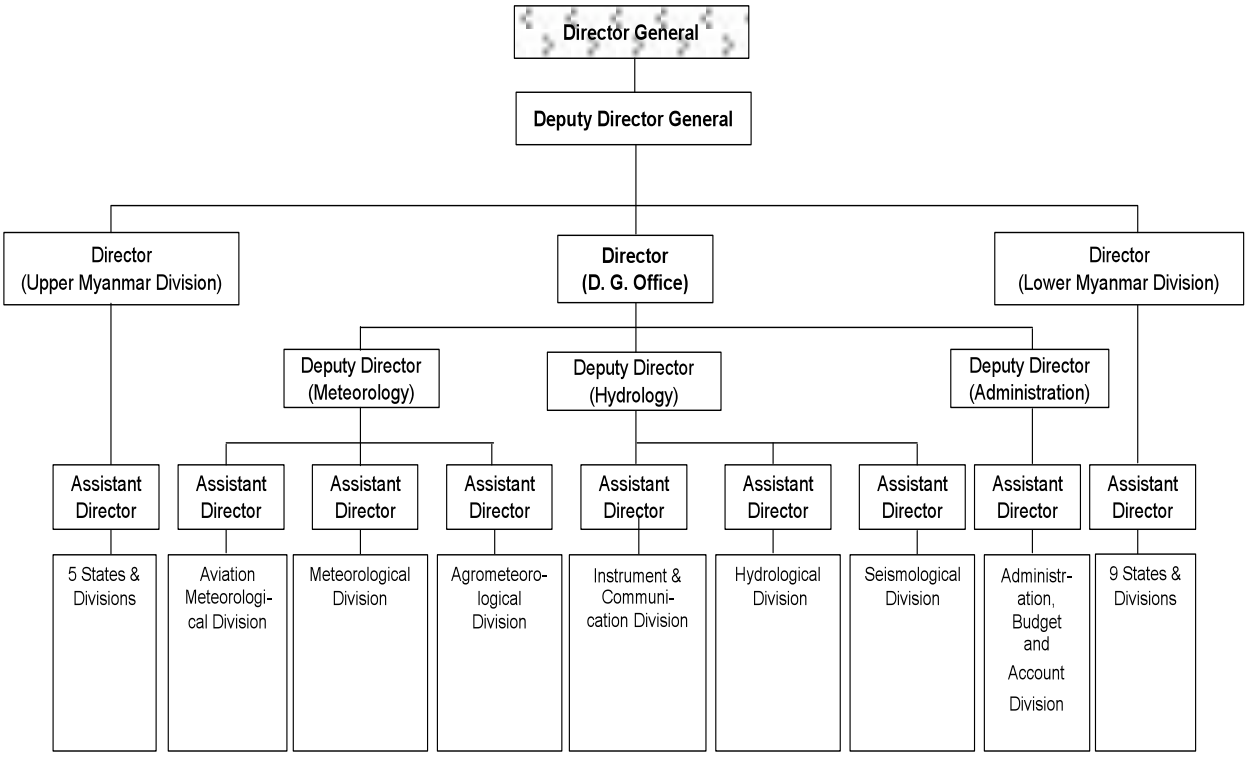
Mr Shinichiro Serizawa, Project Manager, Japan International Cooperation System, Tokyo

Appendix IV

Annex I – Organizational Chart of DMH



Annex II – Annual Budget of DMH

Year	Annual Budget (Kyats in million)
2000-2001	85.8000
2001-2002	86.9680
2002-2003	89.8000
2003-2004	120.5430
2004-2005	178.8900
2005-2006	158.0000
2006-2007	459.4370
2007-2008	498.6235
2008-2009	523.5330
2009-2010	580.0000

Appendix V

DMH Observation Stations

Full-time basic Stations

(a) Meteorological Stations	63
(b) Hydrological Stations	30
(c) Meteorological and Hydrological Stations	39
(d) Agrometeorological Stations	18
(e) Seismological Stations	11
(f) Aviation Meteorological Stations	6

Part-time Stations

(a) Rainfall Stations	81
(b) Climate Stations	53
(c) Water level Stations	23

Special Measurement Stations

(a) Upper-air Stations	5
(b) Radiosonde Station	1
(c) Storm-detection Radar Station (no function)	1
(d) Satellite Receiving Station	1

Types of observations

(a) Rainfall	108
(b) Maximum Temperature	102
(c) Minimum Temperature	102
(d) Solar Radiation	8
(e) Sunshine Hour	10
(f) Evaporation	45
(g) Humidity	102
(h) Wind Force	102
(i) Wind Direction	102
(j) Atmospheric Pressure	15
(k) Water Level	65
(l) Water Temperature	37
(m) Water Discharge	37
(n) Sediment Discharge	22
(o) Soil Temperature	18
(p) Earthquake Intensity	11

Appendix VI

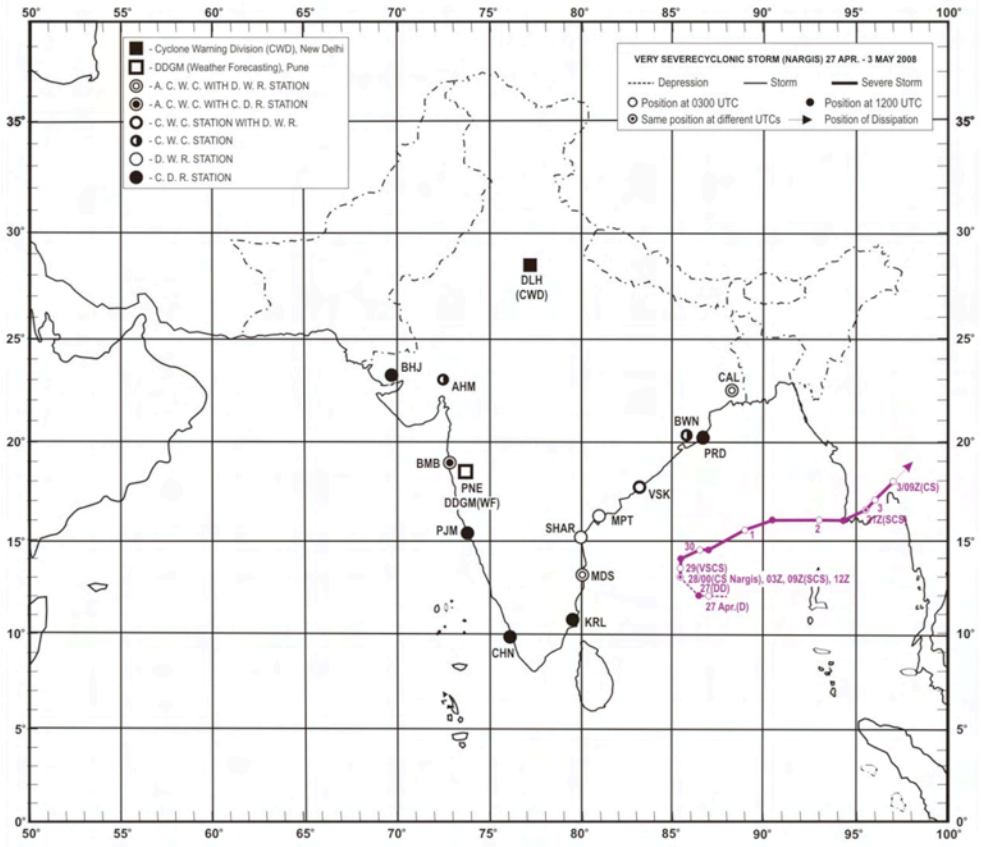


Fig. 1 – Observed Track of *Nargis* (Source: RSMC New Delhi)

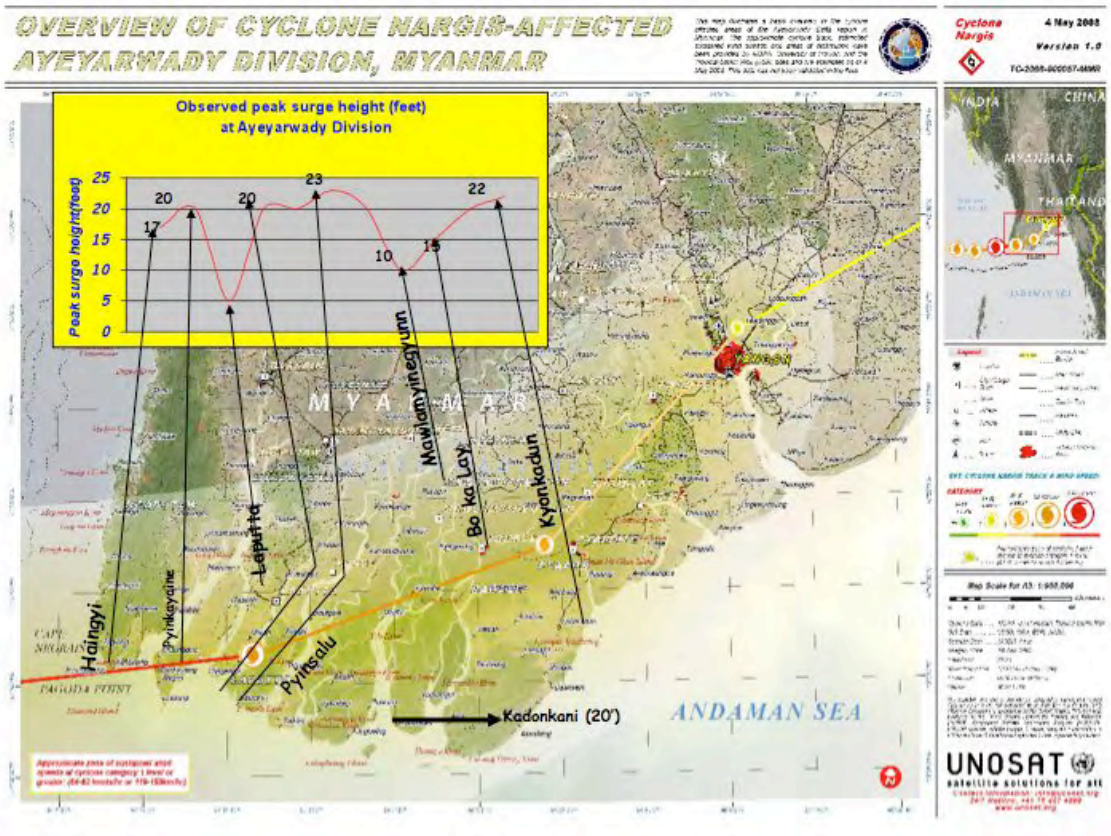


Fig. 2 - Observed Storm Surge Height at Ayeyarwady Division (Source: DMH and UNOSAT)

Appendix VII

Technical Features of *Cyclone Nargis* [Source: DMH]

Life span	26 April 2008 to 3 May 2008
Landfall area	Ayeyarwady, Yangon and Bago Divisions, and Mon and Kayin States
Category	Severe Cyclonic Storm (SCS)
Radius of storm	approximately 250 miles (400 km)
Maximum wind speed	approximately 130 mph (58 m/s)
Maximum peak surge	approximately 22 feet (6.7m)

Loss of Damage by *Cyclone Nargis* [Source: DMH]

Affected population	11 million
Houses Damaged	745,764
Deaths (human)	84,000
Missing (human)	54,000
Injured people	20,000
Death of cattle, bulls, buffaloes, household animals	155,248 above
Area covered by salty sea water	72,798 acres
National Sector Loss	3.3547 trillion kyats
Private Sector Loss	8.3800 trillion kyats

Appendix VIII

WMO Assistance and DMH Actions after *Cyclone Nargis*

Infrastructure/equipment:

- Establishment of the National Multi-hazard Early Warning Centre in NayPyiTaw
- Installation of an electric generator (WMO Emergency Assistance Fund)
- GTS upgrade (Tsunami UN/ISDR Flash Appeal)
- Regional Weather and Climate Centre Establishment
- Establishment of National Tsunami Early Warning System in Yangon

Bilateral agreements:

- DMH-Department of Alternative Energy Development and Efficiency (DEDE), Thailand
- DMH-Indian National Centre for Ocean Information Services (INCOIS)

Observing system:

- Installation of an Automatic Rain Gauge
- Installation of an Earthquake Data Centre Satellite Disc
- FengYunCAST Satellite Receiving System (by CMA)
- AWS (WMO VCP by Meisei Electric Co. Ltd, Japan)
- Seismological Data Centre (China Earthquake Administration: CEA)
- Solar Energy Measuring Instruments (DEDE)
- HF Transceivers (Mitsubishi Electric Co. Ltd, Japan)
- Broadband seismometers (CEA) – stations in Myitkyina, Namh Sam, Sittwe - Establishment of Seismological Network (in situ and remotely based)
- Tide Gauge in Diamond Island (IOC/ADPC)
- Five stations under construction for wind energy (DEDE)

Seminars and Workshops:

- Earthquake Seminar (23 August 2007)
- Monsoon Forum-2008 (5 June 2008) - Community Resilience Workshops
- JICA Expert Mission (22 August 2007)
- Experts from Malaysian Space Technology Company based in Singapore (28 May 2008)
- MICAPS installation and training – CMA mission (12-22 August 2007)
- Thailand Ministry of Information Communication and Technology mission
- Risk Communication Workshop (Four Party Groups: DMH, media, local authorities and local communities)
- Stakeholders (Private Sector)
- Visit of DG to the WMO Headquarters (20 May 2008)
- DEDE mission, Thailand
- WMO fact-finding mission (February 2009)

Studies:

- Running WRF V2.2 for Very Severe Cyclonic Storm *NARGIS* – by DMH in collaboration with the Regional Integrated Multi-hazard Early Warning System (RIMES)
- Flood extended area in Deltaic – by INCOIS-RIMES
- GIS Hazard Mapping – by DMH
- Joint Rapid Assessment Report – by DMH and ADPC
- Tsunami Modelling Training Course and Workshop – by DMH and UNESCO/IOC
- Diagnostic Study on the Changing of Ocean Atmospheric Pattern over the South East Asia Region during (1960-2008) – by DMH-RIMES

Appendix IX

ABBREVIATIONS

AeM	*Aeronautical Meteorology*
AFTN	*Aeronautical Fixed Telecommunication Network*
ADPC	*Asian Disaster Preparedness Centre*
ASEAN	*Association of South-East Asian Nations*
ASMC	*ASEAN Specialized Meteorological Centre*
AWS	*Automatic Weather Station*
BMD	*Bangladesh Meteorological Department*
BMD	*Burma Meteorological Department*
CBDRM	*Community-based Disaster Risk Management*
CEA	*China Earthquake Administration*
CHy	*Commission for Hydrology (WMO)*
CMA	*China Meteorological Administration*
DEDE	*Department of Alternative Energy Development and Efficiency (Thailand)*
DG	*Director-General*
DMA	*Department of Marine Administration (Myanmar)*
DMH	*Department of Meteorology and Hydrology (Myanmar)*
DRR	*Disaster Risk Reduction*
EAF	*Emergency Assistance Fund (WMO)*
ESCAP	*Economic and Social Commission for Asia and the Pacific*
ETR	*Education and Training (WMO)*
EWS	*Early Warning System*
FAO	*Food and Agriculture Organization*
FELCOM	*Fellowship Committee (WMO)*
GIS	*Geographical Information System*
GMS	*Geostationary Meteorological Satellite (Japan)*
GTS	*Global Telecommunication System*
ICAO	*International Civil Aviation Organization*
IIT	*Indian Institute of Technology*
IMD	*India Meteorological Department*
INCOIS	*Indian National Centre for Ocean Information Services*
INSAT	*Indian national satellite*
IOC	*Intergovernmental Oceanographic Commission*
IPRD	*Information and Public Relation Department (Myanmar)*
ISDR	*International Strategy for Disaster Reduction (UN)*
IWT	*Inland Water Transport (Myanmar)*
JCOMM	*Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology*
JICA	*Japan International Cooperation Agency*
JMA	*Japan Meteorological Agency*
JTWC	*Joint Typhoon Warning Center*
MA	*Myanma Airways (Myanmar)*
MDD	*Meteorological Data Dissemination*
MES	*Myanmar Engineering Society*
MFSL	*Myanmar Five Star Line*
MICAPS	*Meteorological Information Comprehensive Analysis Process System (China)*
MMC	*Marine Meteorological Centre (Thailand)*
MMU	*Myanmar Maritime University*
MPA	*Myanmar Port Authority*
MRTV	*Myanmar Radio and Television*
MSS	*Message Switching System*
MST	*Myanmar Standard Time*
MSWRR	*Ministry of Social Welfare, Relief and Resettlement (Myanmar)*
MTSAT	*Multifunctional transport satellite (Japan)*
MWD	*Myawardy (Myanmar)*
NASA	*National Aeronautical and Space Administration*
NCEP	*National Centers for Environmental Prediction*
NDMO	*National Disaster Management Office*
NGO	*Non-Governmental Organization*
NMC	*National Meteorological Centre*
NMHS	*National Meteorological and Hydrological Service*
NPE	*News and Periodicals Enterprise (Myanmar)*
NWP	*Numerical Weather Prediction*
OCHA	*Office for the Coordination of Humanitarian Affairs (UN)*
PCC	*Procurement and Contracts Committee (WMO)*
PCVSAT	*PC-based very small aperture terminal*
PMD	*Pakistan Meteorological Department*
PONREPP	*Post-Nargis Recovery and Preparedness Plan*
PR	*Permanent Representative (of Member with WMO)*
PTC	*Panel on Tropical Cyclones (WMO/ESCAP)*
RANET	*Radio and Internet (for the communication of hydrometeorological and climate information)*
RIMES	*Regional Integrated Multi-hazard Early Warning System*
RSMC	*Regional Specialized Meteorological Centre (WMO)*
SADIS	*Satellite distribution system (for information relating to air navigation) (ICAO)*
SCS	*Severe Cyclonic Storm*
SIGMET	*Significant Meteorological Information (meteorological warning message) for Aircraft*
SOP	*Standard Operating Procedure*
SPECI	*Aviation selected special weather report*
SSB	*Single Side Band (transceivers)*
TC	*Tropical Cyclone*
TCP	*Tropical Cyclone Programme (WMO)*
TICA	*Thailand International Development Cooperation Agency*
TMD	*Thailand Meteorological Department*
TSU	*Technical Support Unit (PTC)*
UKMO	*The Met Office (United Kingdom Meteorological Office)*
UN	*United Nations*
UNDP	*United Nations Development Programme*
UNESCO	*United Nations Educational, Scientific and Cultural Organization*
UNICEF	*United Nations Children's Fund*
USAID	*United States Agency for International Development*
UTC	*Universal Time Coordinated*
VCP	*Voluntary Cooperation Programme (WMO)*
VCP(F)	*Voluntary Cooperation Programme Fund*
VHF	*Very High Frequency*
WAFS	*World Area Forecast System (WMO/ICAO)*
WMD	*World Meteorological Day (23 March)*
WMO	*World Meteorological Organization*

PHOTOS

Participants in DMH Workshop (mission team members, DMH staff and stakeholders)

Yangon NMC, 9 February 2009

Training Workshop on Tropical Cyclone Forecasting and Wave and Storm Surge Forecasting

Yangon NMC, 12 February 2009