

**JMA/WMO WORKSHOP ON EFFECTIVE TROPICAL CYCLONE WARNING
IN SOUTHEAST ASIA**

Tokyo, Japan
11-14 March 2014

Cyclone forecasting and its constrains for the Bay of Bengal

Submitted by

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Summary

Bangladesh is in the sub-tropical monsoon climate zone. Tropical cyclone, the most destructive natural phenomena. The Bay of Bangle and Arabian sea contributes about 7 percent of the global total and the ratio of the average tropical cyclones between the Bay of Bangle and Arabian sea .The tropical cyclones that form over the Bay of Bangle are the most deadly ones in the world. Meteorological forcing associated with tropical cyclone of even moderate intensity in combination of several favorable factors like high astronomical tide shallow water of the Bay of Bangle, funneling coastal configuration ,low flat terrain produces devastating storm surge over the coastal areas bordering the Bay of Bangle .Cyclone monitoring and timely warnings constitute the most important components of the short -term measures of tropical cyclone disaster prevention and preparedness .If you have proper knowledge of tropical cyclones in respect of their formation, structure, behaviors and prediction storm track techniques like climatology, synoptic , satellite techniques (Devorak), Numerical weather prediction guidance from RSMC, Rader techniques are used .We can predict the cyclone track accurately and timely then we save millions lives and property.

1. Tropical Cyclone Monitoring, Analysis and Forecasting

1.1 Tropical Cyclone Monitoring

1.1.1 Tropical Cyclogenesis Monitoring

Storm Warning Centre (SWC) of Bangladesh Meteorological Department (BMD) is responsible for the issuance of warning for the tropical cyclone and all kinds of weather warnings and weather forecasts. During cyclone season, SWC, Dhaka keeps a very watchful eye on the development of any disturbance in the Bay of Bengal for issuing timely cyclone warning to minimize the loss of life and properties. It is monitored from the formation stage till its landfall and forecast of the track is made by using Satellite imageries from different satellite, NWP products from different centers and information and products from RSMC, New Delhi. Modern technology has provided the means of early detection and constant tracking.

1.1.2 Tropical Depression (TD) Warnings

After analyzing all types of data and information, satellite images the Special weather bulletins are issued in 03(three) hourly interval and sometimes hourly message are also issued depending on the situational needs. All Warnings/Special weather bulletins disseminates to Disaster Management Department (DMD), Cyclone Preparedness Program (CPP), important Government Organizations, Bangladesh Television , Radio, mass media and other stakeholders to take prompt action. Special weather bulletins are telecast and broadcast through national and private televisions and radio. All the organizations work as per **Standing Orders of Bangladesh Government** during disasters. Due to issuance of timely and accurate forecast and warnings by Bangladesh Meteorological Department and the preparedness and mitigation measures by CPP and the Government of Bangladesh, it has now been possible to reduce the loss of lives and damage to properties significantly.

Challenges, Needs and Improvement Plans

In the Storm Warning Center conventional methods are used for analyses and subjective forecast is made. So, forecasting depends on personal skills. However, the major decision is taken by the Director of BMD and /or the Deputy Director of SWC after consultation with the operational meteorologist. In SWC NWP models (NHM on PC-cluster and WRF on a PC) is run experimentally on routine basis. Training is needed to skill the manpower on the NWP technique.

1.2 Tropical Cyclone Analysis

1.2.1 Parameters and Methods

Parameter	Time (UTC)	Methods	Other sources
position, speed, central pressure, maximum sustainable wind	Every Three hours or as required	Synoptic and upper air observations, Satellite and NWP.	RSMC New Delhi, JTWC, ECMWF, JMA, KMA

1.2.2 Challenges, Needs and Improvement Plans

Analysis system in BMD is mainly conventional. Advance NWP techniques (guidance and ensemble) are needed to be introduced in BMD. Advance Dvorak Technique (ADT) also needs to introduce in BMD.

1.3 Tropical Cyclone Forecasting

1.3.1 Parameter and Method

Parameter	Issuance Time (UTC)	Lead time (hours)	Methods
forecast TC parameters (e.g. position, central pressure, maximum sustainable wind, strong wind and areas).	Every Three hour	Not fixed	Subjective method and NWP guidance are also followed.

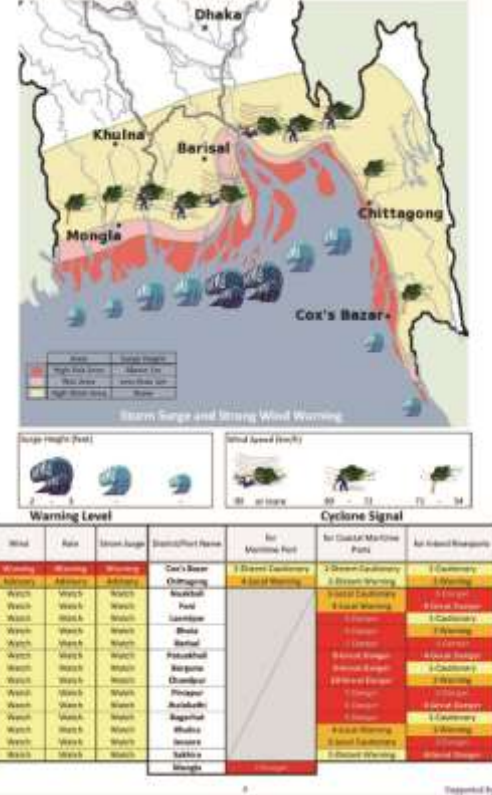
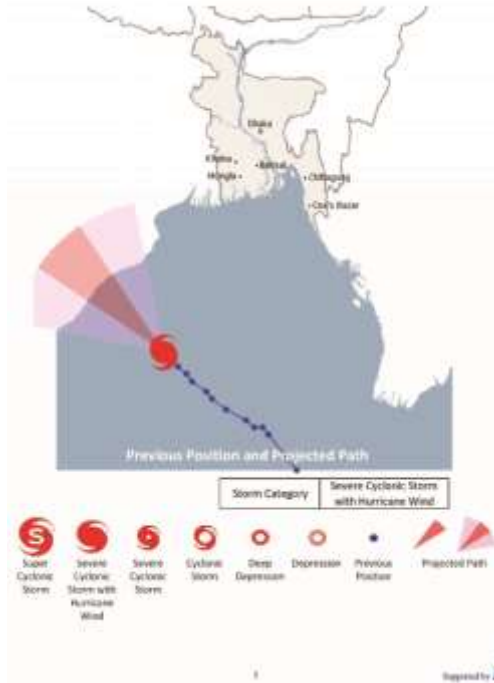
1.3.2 Challenges, Needs and Improvement Plans

TC forecasting system in BMD is mainly subjective. Advance NWP techniques (guidance and ensemble) are needed to be introduced. Advance Dvorak Technique (ADT) also need to introduce in BMD.

1.4 Tropical Cyclone Products

1.4.1 TC Products

Special Weather Bulletins including Observed and projected path of the cyclone, strong wind zone and surge height.



1.4.2 Challenges, Needs and Improvement Plans

For the preparation of Cyclone products the main challenge is the preparation of easy understandable products/graphics for end users and dissemination.

Training needed for the preparation of easy understandable products/graphics.

BMD already has a plan to improve cyclone products/graphics. To do that a GIS unit is working.

1.5 Computing Platform (including software)

To run WRF, NHM, IIT_D storm surge model and MRI storm surge and MRI wave model LINUX is being using. For Satellite imagery analysis SATAID software is using. Statistical software R and ArcInfo are using for preparation of different products and graphics.

2 Numerical Weather Prediction Status for Effective Warning

At present WRF model is running in BMD since July 2010 experimentally for 72 hours in a small domain and low resolution (27 Km). NHM model is running in BMD since July 2011 under JICA project. It is also in a small domain and low resolution (20 Km). After well tested and simulated for different cyclones with different parameter IIT-D Storm Surge Model is operationally using in BMD. MRI Storm Surge Model and MRI Wave model are also running experimentally in BMD. All models are using for day to day weather forecasting and Effective Warning purpose.

2.1 NWP in Operational Use

Model	Domain (square)	Resolution (horizontal & vertical)	Initial Time	Forecast Range	Run by (own/foreign)
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	degree)	vertical)		(hours)	centers)
WRF	16.5X16.5	27 Km, 28 levels	00 UTC	72 Hours	BMD
NHM	30X19	20 Km, 38 levels	00 UTC	72 Hours	BMD

2.2 Application Techniques of NWP Products for Operational Forecasts

At present different products from WRF and NHM are using for short range weather forecasting. Along with that ECMWF model products and model products from JMA (GSM) also using for short range weather forecasting. Validation of model output are going on.

2.3 Challenges, Needs and Improvement Plans

Advance NWP techniques (guidance and ensemble) are needed to be introduced. Advance Dvorak Technique (ADT) is also needed to introduce in BMD.

3. Storm Surge

[You are invited to describe your operational activity on storm surge information.]

1) Storm Surge Information

- a. Issuing b. not issuing

(For those who answered “b.” in 1))

2) What is the reason?

- a. No use (inland / no storm surge) b. No forecast are available
c. Other ()

(For those who answered “a.” in 1))

3) How the information is issued?

- a. Independent storm surge information b. Included in TC information
c. Other ()

4) What products (observations /forecasts) are referred to? Storm surge height and area.

5) If your Service runs a storm surge model by yourself, please describe the way in detail.

Model	Domain and resolution	Forecast Range (hours)	Frequency	Considered factors (Tide/ensemble/ inundation, etc.)
IIT-D	7X3.5 deg. 3.5 km	As required	As per required	
MRI		36 Hours	As per required	

6) In case your Service issue storm surge forecast without your own model, please briefly explain the operational procedure.

4. Effective Warnings

4.1 Emergency Response for TC Disasters

4.1.1 Legal Framework for TC Disaster Management

The Disaster Management Act creates the legislative framework under which disaster risk reduction and emergency response management is undertaken in Bangladesh, and the legal basis from which activities and actions are managed. It also creates mandatory obligations and

responsibilities on Ministries, committees and appointments.

4.1.2 Emergency Response Mechanism

An Emergency Operation Centre (EOC) at national level is an important prerequisite for effective and coordinated response to any disastrous emergency. For this a National Emergency Operation Centre (NEOC) has been setup at Disaster Management and Relief Division of Bangladesh Secretariat in Bangladesh which would operate 24x7 hours to manage information, resources and activities. It has provided with human resources, equipment and methodologies including coordination, information and telecommunication technology facilities. The Standing Order on Disaster provides that an NEOC is to provide secretarial support to the National Disaster Response Coordination Group (NDRCG). For the purpose of better communication, it is decided to use the National Disaster Response Coordination Centre (NDRCC) to be equivalent to the NEOC.

4.1.3 Organs Responsible for Warnings and Evacuation Orders

Severe Weather Phenomena	Organs responsible for Warnings	Organs responsible for Evacuation Orders
Tropical Cyclone	BMD	Department of Disaster Management(DDM)
Heavy Rain	BMD	DDM
Strong Wind	BMD	DDM
River Flood	FFWC	DDM
Storm Surge	BMD	DDM

4.2 Warnings/Advisories for Severe Weather Phenomena

4.2.1 Tropical Cyclone

Warnings/Advisories and corresponding emergency responses	Special Weather Bulletin. BMD is issuing warnings/advisories for severe weather associated with cyclone including condition of ocean state.												
Potential Disaster Risks	The strong winds, heavy rains and storm surges associated with tropical cyclones are the factors that eventually lead to loss of life and property.												
Target (warning areas)	Coastal area of Bangladesh												
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	Pressure drop, Radius of maximum wind, maximum sustained wind and astronomical tide. T-number for Cyclone intensity												
Criteria/Thresholds	Classification of tropical disturbances over the Bay of Bengal and the Arabian Sea. <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Disturbance</th> <th>Corresponding Wind Speed</th> </tr> </thead> <tbody> <tr> <td>1. Low Pressure Area</td> <td>Less than 17 knots (31 km/h)</td> </tr> <tr> <td>2. Well Marked Low</td> <td>17-21 knots (31-40 km/h)</td> </tr> <tr> <td>3. Depression</td> <td>22-27 knots (41-51 km/h)</td> </tr> <tr> <td>4. Deep Depression</td> <td>28-33 knots (52-61 km/h)</td> </tr> <tr> <td>5. Cyclonic Storm</td> <td>34-47 knots (62-88 km/h)</td> </tr> </tbody> </table>	Disturbance	Corresponding Wind Speed	1. Low Pressure Area	Less than 17 knots (31 km/h)	2. Well Marked Low	17-21 knots (31-40 km/h)	3. Depression	22-27 knots (41-51 km/h)	4. Deep Depression	28-33 knots (52-61 km/h)	5. Cyclonic Storm	34-47 knots (62-88 km/h)
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	<p>6. Severe Cyclonic Storm 48-63 knots (89-117 km/h)</p> <p>7. Very Severe Cyclonic Storm 64-119 knots (118-219 km/h)</p> <p>8. Super Cyclone 120 knots (220 km/h) or above.</p>
<p>Contents of Warning/Advisory Message</p>	<p>Position and intensity of Cyclone. Distance from the coast Past movement and expected future movement Ocean state Information about Wind, Storm surge, inundation and Heavy rainfall Advisories for fishermen</p>
<p>Sample Warning/Advisory Message</p>	<p>SPECIAL WEATHER BULLETIN: SL. NO. 22 (TWENTY TWO), DATE: 15-11-2007</p> <p>THE SEVERE CYCLONIC STORM "SIDR" (ECP 942 HPA) WITH A CORE OF HURRICANE WINDS OVER NORTH BAY OF BENGAL, MOVED NORTHWARDS AND WAS CENTRED AT 09 AM TODAY (THE 15TH NOVEMBER 2007) ABOUT 500 KMS SOUTH-SOUTHWEST OF CHITTAGONG PORT, 435 KMS SOUTHWEST OF COX'S BAZAR PORT AND 415 KMS SOUTH OF MONGLA PORT (NEAR LAT 18.6°N & LONG 89.2°E). IT IS LIKELY TO INTENSIFY FURTHER AND MOVE IN A NORTHERLY DIRECTION AND CROSS KHULNA-BARISAL COAST BY EVENING TODAY.</p> <p>MAXIMUM SUSTAINED WIND SPEED WITHIN 74 KMS OF THE STORM CENTRE IS ABOUT 200 KPH RISING TO 220 KPH IN GUSTS/ SQUALLS. SEA WILL REMAIN VERY HIGH.</p> <p>MARITIME PORT OF MONGLA HAS BEEN ADVISED TO KEEP HOISTED GREAT DANGER SINGAL NO. TEN (R) TEN. THE COASTAL DISTRICTS OF BHOLA, BARISAL, PATUAKHALI, BORGUNA, PIROZPUR, JHALOKATHI, BAGERHAT, KHULNA, SATKHIRA, JESSORE AND THEIR OFFSHORE ISLANDS AND CHARS WILL REMAIN UNDER GREAT DANGER SINGAL NO. TEN (R) TEN.</p> <p>MARITIME PORTS OF CHITTAGONG AND COX'S BAZAR HAVE BEEN ADVISED TO KEEP HOISTED GREAT DANGER SINGAL NO. NINE (R) NINE. THE COASTAL DISTRICTS OF COX'S BAZAR, CHITTAGONG, NOAKHALI, FENI, LAXMIPUR, CHANDPUR AND THEIR OFFSHORE ISLANDS AND CHARS WILL REMAIN UNDER GREAT DANGER SINGAL NO. NINE (R) NINE.</p> <p>INLAND RIVERPORTS OF THE DISTRICTS OF COX'S BAZAR, CHITTAGONG, NOAKHALI, FENI, LAXMIPUR, BHOLA, BARISAL, PATUAKHALI, BORGUNA, CHANDPUR, PIROZPUR, JHALOKATHI, BAGERHAT, KHULNA, JESSORE AND SATKHIRA HAVE BEEN ADVISED TO KEEP HOISTED RIVERINE GREAT DANGER SIGNAL NO. FOUR (R) FOUR.</p> <p>UNDER THE INFLUENCE OF THE STORM, THE COASTAL DISTRICTS OF COX'S BAZAR, CHITTAGONG, NOAKHALI, FENI, LAXMIPUR, BHOLA, BARISAL, PATUAKHALI, BORGUNA, CHANDPUR, PIROZPUR, JHALOKATHI, BAGERHAT, KHULNA, SATKHIRA, JESSORE AND THEIR OFFSHORE ISLANDS AND CHARS ARE LIKELY TO EXPERIENCE HEAVY/ VERY HEAVY RAIN ACCOMPANIED BY SQUALLY WIND SPEED UP TO 220 KPH WITH THE PASSAGE OF THE STORM.</p> <p>THE LOW-LYING AREAS OF THE COASTAL DISTRICTS OF COX'S BAZAR, CHITTAGONG, NOAKHALI, FENI, LAXMIPUR, BHOLA, BARISAL, PATUAKHALI, BORGUNA, CHANDPUR, PIROZPUR, JHALOKATHI, BAGERHAT, KHULNA, SATKHIRA, JESSORE AND THEIR OFFSHORE ISLANDS AND CHARS ARE</p>

	<p>LIKELY TO BE INUNDATED BY STORM SURGE OF HEIGHT 15-20 FEET ABOVE NORMAL ASTRONOMICAL TIDE. ALL FISHING BOATS AND TRAWLERS OVER NORTH BAY MUST REMAIN IN SHELTER TILL FURTHER NOTICE.</p>
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4.2.2 Heavy Rain

Warnings/Advisories and corresponding emergency responses	Heavy Rainfall Warning (including in Special Weather Bulletin)	
Potential Disaster Risks	Coastal flood and Land slide	
Target (warning areas)	Coastal area of Bangladesh including other vulnerable area.	
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	Intensity of the cyclone.	
Criteria/Thresholds	<p style="text-align: center;"><u>Amount of Rainfall</u></p> <p>22 - 44 mm 45 - 88 mm 89 mm or more</p>	<p style="text-align: center;"><u>Rainfall Intensity</u></p> <p>Moderately Heavy Heavy Very Heavy</p>
Contents of Warning/Advisory Message	Causes of heavy rainfall, area and time.	
Sample Warning/Advisory Message	<p>HEAVY RAINFALL WARNING MESSAGE DATE: 25-05-2009</p> <p>UNDER THE INFLUENCE OF THE CYCLONIC STORM 'AILA' HEAVY TO VERY HEAVY RAINFALL MAY OCCUR AT MANY PLACES OVER CHITTAGONG, BARISAL, KHULNA, RAJSHAHI DIVISIONS AND AT A FEW PLACES OVER DHAKA AND SYLHET DIVISIONS DURING NEXT 24 HRS COMMENCING 05 PM OF 25 MAY 2009.</p>	

4.2.3 Strong Wind

Warnings/Advisories and corresponding emergency responses	Special Weather Bulletin
Potential Disaster Risks	<p>The strong wind speed associated with a cyclonic storm. (60-90 kmph) can result into some damage to houses and tree branches likely to break off.</p> <p>Winds of a severe Cyclonic storm (90-120 kmph) can cause uprooting of trees, damage to pucca houses and disruption of communications. The wind associated with a very severe Cyclonic storm and super cyclonic storm can uproot big trees, cause wide spread damages to houses and installations</p>

	and total disruption of communications.
Target (warning areas)	Coastal area of Bangladesh including other vulnerable area.
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	Intensity of the tropical cyclone.
Criteria/Thresholds	Mentioned in the Tropical Cyclone criteria.
Contents of Warning/Advisory Message	Direction of movement, speed and affected area.
Sample Warning/Advisory Message	Special Weather Bulletin.

4.2.4 River Flood (BMD IS NOT RESPONSIBLE FOR RIVER FLOOD FORECASTING)

Warnings/Advisories and corresponding emergency responses	
Potential Disaster Risks	[Please describe potential disaster risks when the respective warnings/advisories listed above are issued.]
Target (warning areas)	[Please specify unit of warning areas (e.g. prefectural government).]
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	[Please describe meteorological variables/indices used for criteria/thresholds for warnings/advisories.]
Criteria/Thresholds	[Please describe how the above criteria/thresholds for warnings/advisories are determined.]
Contents of Warning/Advisory Message	[Please describe contents of warning/advisory message for river floods.]

Sample Warning/Advisory Message	[Please provide a sample warning/advisory message for river floods.]
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4.2.5 Storm Surge

Warnings/Advisories and corresponding emergency responses	Special Weather Bulletin
Potential Disaster Risks	Storm surge is the single major cause of devastation from tropical storms. Though, the deaths and destruction are caused directly by the winds in a tropical cyclone as mentioned above, these winds also lead to massive piling of sea water in the form of storm surge that lead to sudden inundation and flooding of coastal regions. The sand and gravel carried by the moving currents at the bottom of the surge can cause sand papering action of the foundations. The huge volume of water can cause such pressure difference that the house "floats" and once the house is lifted from the foundations, water enters the structure that eventually collapses.
Target (warning areas)	Coastal area of Bangladesh
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	Pressure drop, Radius of maximum wind, maximum sustained wind and astronomical tide
Criteria/Thresholds	Wind speed: 34-47 knots (62-88 km/h)
Contents of Warning/Advisory Message	Expected surge height above astronomical tide and affected area
Sample Warning/Advisory Message	Special Weather Bulletin.

4.3 Supporting Meteorological Information for Warning/Advisory Messages

[Please describe supporting meteorological information which provides supplementary explanation on warning/advisory messages to support emergency responses of recipients, if any.]

Name of Information	Potential Disaster Risks	Target (areas)	Issuance (update) Time	Contents
Regional Specialized Meteorological Centres(RSMC)	Depression, Deep Depression Cyclone etc	Track of cyclone and mentioned maritime ports and coastal areas	Six hourly, Three hourly, hourly	TROPICAL STORM 'MAHASEN' ADVISORY ISSUED AT 1700 UTC OF 15TH MAY 2013 BASED ON 1500 UTC CHARTS OF 15TH MAY 2013. THE CYCLONIC STORM MAHASEN OVER WEST CENTRAL BAY OF BENGAL MOVED NORTHEASTWARDS DURING PAST 6 HOURS AT A SPEED OF ABOUT 25 KMPH AND LAY CENTERED AT 1500 UTC OF 15 TH MAY 2013 NEAR LATITUDE 18.5° N AND LONGITUDE 88.5 °E OVER WEST CENTRAL AND ADJOINING EAST CENTRAL BAY OF BENGAL, ABOUT 880 KM NORTHWEST OF PORT BLAIR(4333), 440KM SOUTH-SOUTHWEST OF

				<p>KOLKATA (42807), 270 KM SOUTH-SOUTHEAST OF PARADIP(42976)AND 550 KM SOUTHWEST OF CHITTAGONG (41977). IT WOULD INTENSIFY FURTHER AND MOVE NORTHEASTWARDS AND CROSS BANGLADESH COAST NEAR CHITTAGONG AROUND 1800 UTC OF 16TH MAY 2013. MAXIMUM SUSTAINED WIND SPEED AT THE TIME OF LAND FALL WOULD BE 80-90 KMPH GUSTING TO 100 KMPH ACCORDING TO SATELLITE IMAGERIES, SATELLITE ESTIMATED INTENSITY IS T-3.0. REPEAT T-3.0. THE SYSTEM HAS SPIRAL BAND PATTERN. ASSOCIATED INTENSE TO VERY INTENSE CONVECTION AREA SEEL OVER NORTH AND ADJOINING BAY OF BENGAL NORTH OF LAT 16.5° N AND WEST OF LONG 92.5° E ADJOINING COASTAL ORRISSA AND SOUTH GANGETIC WEST BENGAL. THE LOWEST CLOUD TOP TEMPERETURE (CTT) IS ABOUT -91° C.</p>
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4.4 Institutional Coordination

4.4.1 Coordination with Disaster Management Authorities

Warning Coordination	According to SOD (Standing Order of Disaster) Special Weather Bulletins are sent to Disaster management department (DMD), Cyclone preparedness programme(CPP), Different Ministries, Different electronic & printing media, Departments related to disaster management by fax and e-mail for prompt action.
Needs from Disaster Management Authorities	Present situation taken by the Disaster Management Authorities after providing he warnings

4.4.2 Partnership and Coordination with Media

Warning Coordination	There are regular briefing during cyclone or any vulnerable situation by the head of the department or by responsible officer.
Needs from Media	Media Needs to know different terminologies and basics of meteorology to make understand mass people the general warning system & advisories. They also need the forecast translation in local languages.

4.5 Challenges (and Future Plan)

[It is always a challenging task for NMHSs to make your warnings lead to appropriate emergency responses by relevant authorities. Please describe current challenges to establish effective warning systems in your country.]

- Upgradation of BMD Forecasts
- Automated Observation System and more observatories
- Manpower Development
- Need to learn NWP Language
- High Computing Power (PC Cluster)
- Comprehensive Training on NWP
- Training on NWP development
- Interpretation of forecast products
- Forecast Translation.
- Medium Range forecast
- One month/Seasonal forecast

- Need Training on regular basis (home and abroad)
- Marine Meteorology and Hydrology