Component-2

Change Review of Warning System for Climatic Disasters

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ABBREVIATIONS AND ACRONYMS

BMD	Bangladesh Meteorological Department
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
DoE	Department of Environment
EWS	Early Warning Systems
FFWC	Flood Forecasting and Warning Centre
IWFM	Institute of Water and Flood Management
NASA	National Aeronautics and Space Administration
NGO	Non Government Organization
WMO	World Meteorological Organization

CHAPTER ONE
INTRODUCTION

1.1 Background

Climatic disasters are one of the main causes of human sufferings, loss of life and properties, disruption of economic and social activities, etc. Post disaster conditions may become havoc for a long duration, if properly not handled. As per United Nations International Strategy for Disaster Reduction (UNISDR): “A disaster is a serious disruption of the functioning of a society or community that causes widespread human, material or environmental loss which exceeds the capacity of the affected society to cope without external intervention” (Cap-Net, 2009).

Bangladesh’s unique geographic location, positioned in the downstream of great GBM basin, with the Indian Ocean to the south, the Himalayas to the North and almost flat (80%) topography, has made it one of the disaster prone countries of the world. It is highly vulnerable to cyclones and storm surges as vast funnelling Bay of Bengal significantly enhances these disasters. Thunderstorms, tornados and hailstorms are happened frequently in years which are aided by warm air moisture from Bay of Bengal and the crisscrossing river systems and by the cold and heavy air from the north and east of the country (Peterson and Metha, 1981; Habib 2009). As it is located at the confluence of great GBM basin, huge amount of river water during the rainy season has drained through the country cause floods almost every year. More over disasters like drought, heat waves or cold waves, erosion and earthquakes are also occurs (Karim, 1995).

Majority of rural inhabitants of Bangladesh lives functionally under the poverty line. Thus it is not affordable to implement capital intensive preventive measures to avoid or minimize hazard loss (Haque, 1993). Changes in human hazard preparedness could be effective tools for minimizing hazard impacts. As a result, early warning system can be a key element of disaster reduction.

Early hazard warning systems have generally very effective for developed country as people have information of disaster in earlier time. In Bangladesh, government has a strong commitment towards the reduction of the human, economic and environmental costs of disasters by enhancing overall disaster management capacity. In respect to flood and tidal surges Flood Forecasting and Warning Centre (FFWC) of BWDB provides an early warning before 24, 48 and 72 hours lead time (BWDB, 2010). And for the Cyclone warning, Bangladesh Meteorological Department (BMD) prepares early warning only for maritime or sea ports and inland river ports (Habib, 2009). Before the development of these warning systems, people of the village have their own indigenous early warning of disaster from the nature (Howell, 2003). But their effectiveness is negligible.

Figure 1.1: Cyclone Aila at 2009
(Courtesy: firstperson.oxfamamerica.org)

Figure 1.2: Flood in Bangladesh
(Courtesy: climatevictims.blogspot.com)

Figure 1.3: River Erosion in Bangladesh
(Courtesy: www.dailyprimenews.com)

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(Courtesy: samad-banglalink.blogspot.com)

Photographs: Natural Disasters in Bangladesh

1.2 Rationale of the Study:

Bangladesh is facing an increasing trend of climatic disasters over the years (Pramanik, 1995). The increase of the mean temperature is about 0.74 ^{o}C per century and the sea level rise is about 59 cm by the end of 21st century due to climate change (IPCC, 2007). Recent studies (Fung et al. 2006, ITN-BUET, 2009, IWM, 2009) also suggested that geographical location of Bangladesh has aggravated this rising trend. People's sufferings are also increasing. Warning system is among some preventive measures to lessen the negative impact of climatic disasters. Warnings is a directive that alerts people about an imminent extreme event and guide the steps necessary to be taken to reduce losses (Alexander, 1993).But the present warning system of Bangladesh has been designed for primarily for navigation purposes. This old warning system should be revised. Accurate and real time forecasting can reduce human causalities and damage of properties caused by these disasters. Weather forecasting can play vital role in cyclonic and storm surge forecasting, flood forecasting, drought predictions, heat wave and cold waves forecasting.

1.3 Objectives

This study focuses on the review of present weather forecasting and dissemination systems of Bangladesh. The objectives of this study are –

1. To review the warning system,
2. Identify the limitations and
3. Find a correlation of climatic disasters with global and local impact of climate change considering the effect of ENSO.

1.4 Outline of the Methodology

Disaster monitoring and warning data are collected from Bangladesh Meteorological Department (BMD). Both distribution free methods and re-sampling methods are used for data analysis as per requirement. Apart from BMD, present warning and dissemination data have been collected from the Flood Forecasting and warning Center (FFWC) of Bangladesh Water Development Board (BWDB). Information collected from these mandated national centers will be reviewed to determine the needs, gaps and opportunities exists for providing real time accurate warnings. Discussions with local people are conducted by using Participatory Rural Appraisal (PRA) tools to get their views about the possible warning system. The efficiency of warning system will be assessed on the basis of present trend and future prediction of climate change and local people's perception.

1.5 Scope of the Study:

The most common natural disasters are classified into two categories. Hydro-meteorological disasters (floods, droughts, cyclones, storm surges, river erosion etc.) and geophysical disasters (Earthquakes; volcanic eruptions, etc.) (WDR, 2003)

This study deals with disasters; originate from climatic disruptions, the hydro-meteorological disasters. It will also evaluate the warning system of Bangladesh.

CHAPTER TWO
LITERATURE REVIEW

2.1 Climatic Disasters and Warning Systems:

The numbers and severity of disasters with hydro-meteorological origins are increasing. A comparison of statistical record (CRED, 2005) between two consecutive decades 1985-1994 and 1995-2005 show that the number of affected people, economic damages and total deaths in later decade (1995-2005) increased by 1.5, 1.8 and 2.0 times respectively from the previous decade (1985-1994). Although the Tsunami in 2004 affect the death figure but in general the trend in death rates was downward since 1950s (Basher, 2006). Early Warning System plays an important role to reduce the death rates.

Warning System is a non structural measure to mitigate the impact of climatic disasters. As per Waidyanatha (2010), "an early warning system is a chain of informationcommunication systems comprising sensor, detection, decision, and broker subsystems, in the given order, working in conjunction, forecasting and signalling disturbances adversely affecting the stability of the physical world; and giving sufficient time for the response system to prepare resources and response actions to minimise the impact on the stability of the physical world".

2.2 History of Warning System:

Although warning system is an important preventive measures from climatic disasters, but it took a very long time to forecast it officially. For example, United States Army Signal Corps's John Park Finley used statistics from a network of tornado observers and a study of previous tornadoes that had occurred throughout the country to compile a list of rules for tornado prediction. The Signal Corps in 1884 allowed Finley to issue trial tornado forecasts, but the fear of public panic led the chief signal officer to ban the use of the word ‘‘tornado". Although, Finley and his supporters had verified the effectiveness of tornado forecasting, but due to the internal conflicts, the experiment had to be ended in 1886. The Agriculture Department, which assumed jurisdiction for the civilian-controlled Weather Bureau in 1890, continued the ban on the use of the word tornado in forecasts until 1938. In spite of the loss of thousands of lives to tornadoes during this period, the Weather Bureau not only failed to encourage research on the subject but also failed to institute any type of forecasting or warning system. Residents in tornado-prone areas learned to rely on signs in nature and their own senses to warn of approaching severe weather. A systematic approach to tornado forecasting and warnings was as nonexistent in 1940 as it had been in 1870 (Bradford, 1998).

In recent years, early warning system has drawn significant attention by the international community. The first world conference on Natural Disaster Reduction, held in Yokohoma Japan on 23-27 May, 1994 developed a ten year's framework for Natural Disaster

Reduction. The Yokohoma Strategies acknowledged the fact that disaster prevention, mitigation and preparedness are better than disaster response (UN, 1994). Ten years after this conference, United Nations International Strategy for Disaster Reduction (UN-ISDR) organized the Second World Conference on Disaster Reduction in Kobe,Hyogo, Japan from 18 to 22 January 2005. This conference identifies the specific gaps and challenges of Yokohoma Strategy in the following five main areas:
(a) Governance: organizational, legal and policy frameworks;
(b) Risk identification, assessment, monitoring and early warning;
(c) Knowledge management and education;
(d) Reducing underlying risk factors;
(e) Preparedness for effective response and recovery.

Based upon these key areas, a relevant framework for action for the decade 2005–2015 was developed. The "Hyogo Framework for Action 2005–2015" (HFA): Building the Resilience of Nations and Communities to Disasters is negotiated and adopted by 168 countries. It is a shifting of the paradigm for disaster risk reduction from post disaster response to a more comprehensive approach, also including prevention and preparedness measures (UN, 2005; Golnaraghi, 2012)

The second high-priority area of the HFA stresses the need for, "identifying, assessing and monitoring disaster risks and enhancing early warning." The HFA further stresses that EWS must be an integral component of any nation's disaster risk management strategy, enabling governments at national to local levels and the communities to take appropriate measures toward building resilience in anticipation of disasters. Many good practices around the world have demonstrated that EWS should be developed with a multi-hazard, multi-sectoral and multi-level (national to local) approach. Effective EWS are comprised of four operational components, to ensure that,

- Hazards are detected, monitored, forecasted, and hazard warnings are developed;
- Risks are analysed and this information is incorporated in the warning messages;
- Warnings are issued (by a designated authoritative source) and disseminated in a timely fashion to authorities and public at-risk;
- Community-based emergency plans are activated in response to warnings, to reduce potential impacts on lives and livelihoods.

These four components need to be coordinated across many agencies at national to local levels for the system to work. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is a national responsibility; thus, roles and responsibilities of various public and private sector stakeholders for implementation of the EWS should be clarified and reflected in the national to local regulatory frameworks, planning, budgetary, coordination, and operational mechanisms. In 2006, the Global Survey of Early Warning Systems and the outcomes of the Third International Early Warning Conference (EWC-III) concluded that though progress has been made, many gaps remained to be addressed to ensure that EWS are implemented in all countries, particularly those with least resources. The 2006 Global Early Warning Survey Report cited challenges on legislative, financial, organizational, technical, operational, training and capacity building fronts. Throughout these international events and assessments, it has become clear that governments and various agencies could benefit from experiences of other governments, with good practices in EWS that had been demonstrated to reduce loss of lives and livelihoods. It also has been voiced in many international and regional forums that there is a need for systematic documentation of such good practices, lessons learned, and synthesizing the factors that have contributed to their successes. To this end, the 15th World Meteorological Congress in 2007 requested that such an initiative be undertaken by the WMO in partnership with its Member States and UN (Golnaraghi, 2012).

Recent three decades history of natural disasters (e.g., tropical storms, floods, droughts, cyclones, storm surges, etc.) pointed to the fact that over 80% of these disasters were meteorologically driven. In addition, two thirds of the disastrous damages resulting from these events were in reaction to adverse hydrological impacts (Ingram, 1997). So, Reliable forecasts form the basis of any warning system (Jayawardena et al, 1997). It should also be people oriented to empower communities to prepare for and confront the power of natural hazards (León et al., 2006). Nowadays, forecasting hydrological events is an important topic of concern for hydrologists (Jayawardena, 1997). Therefore the necessity and enhancement of hydrologic services, which assess when and where water will be needs to be properly focused (Ingram, 1997).

2.3 Required Improvement:

Every year natural hazards cause significant loss of life and set back economic and social development by years, if not decades. As expressed in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, which WMO co-sponsors, there is increasing evidence of greater vulnerability to the risks associated with hydro-meteorological hazards, due to climate variability and change. On a global scale, as revealed by statistics for the past five decades, the economic losses attributable to hydro-meteorological hazards have increased significantly over the last decade; however, the reported loss of life has decreased dramatically during the same period as a consequence of the development of early warning systems (EWS) in a number of high-risk countries (Golnaraghi, 2012) .

Lack of common measures in evaluating, comparing and contrasting Early Warning Systems (EWSs) is a persistent problem. As such, there is a growing need for an abstract technical definition of EWSs and a framework to classify them, which would help developers set standards. The standards can be the basis for effective EWS deployments. Practitioners and researchers have been using EWSs for detecting and communicating events for risk aversion. Some EWSs focus on the detection and decision aspects, and others focus on the warning and response aspects, without a precise foundation to follow in the design, deployment and evaluation of an end-to-end 'integrated functional EWS' (Waidyanatha, 2010).

The recent 2013 Moore tornado which struck Moore, Oklahoma, USA on May 20, 2013; killing more than 23 people and injuring 377 others, is an example which directs the necessity for further improvement of warning system. It was an EF5 category tornado and first warning message was issued at 2:40 p.m. CDT. At 2:56 p.m. CDT, the tornado touched down roughly 4.4 miles (7.1 km) west of Newcastle in Grady County as an EF0. Tracking northeast through McClain County, the tornado rapidly intensified, attaining EF4 intensity within ten minutes and 4 miles (6.4 km) of touching down. By 3:01 p.m. CDT, a second more strongly worded warning was issued for the area. A tornado emergency was declared for southern Oklahoma City and Moore as storm spotters confirmed a large and violent tornado approaching the area (Wikipedia, 2013). Residents of these locations only had about 36 minutes to prepare themselves for this violent tornado that flattened the Oklahoma. This is evidence from a technological advanced country and gives the message that more development is necessary for increasing the lead time, issuing warning messages.

Disaster risk reduction has always been at the core of the mission and among the highest priorities of the World Meteorological Organization (WMO) and the National Meteorological and Hydrological Services (NMHSs) of its 189 Members. Moreover, in referring to the Hyogo Framework for Action, in 2011, the sixteen World Meteorological Congress highlighted the importance of Multi-Hazard Early Warning Systems (MHEWS) as a proven tool for saving lives while also stressing the value of appropriate documentation and the sharing of good practices and lessons learned (Golnaraghi, 2012).

CHAPTER 3
PHYSICAL PROCESSES OF MAJOR CLIMATIC DISASTERS AND ITS IMPACT

The worst disasters in the world tend to occur in a region between Tropics of Cancer and Tropics of Capricorn (Carter, 1991). As Tropics of Cancer passes through Bangladesh (23°26′N 88°47′E), so naturally, due to its unique geographic settings, it becomes a place vulnerable to several disasters. Bangladesh faces a number of different types of natural disasters. Most prominent of them are floods, cyclones and associated storm surges, thunderstorms / tornadoes / hailstorms, drought, heat waves / cold waves, landslides etc.

3.1 Flood:

3.1.1 Physical Processes:

A flood is an unusual high-water period in which water overflows its natural or artificial banks onto normally dry land. It is a regular and natural occurrence to which communities must adapt as part of the usual living conditions that can affect them at any time. (Cap-Net, 2009).Flood are more or less recurring phenomena in Bangladesh and often have been within tolerable limits. But occasionally they become devastating. Each year in Bangladesh about 26,000 sq km, 18% of the country is flooded. During severe floods, the affected area may exceed 55% of the total area of the country. In an average year, 844,000 million cubic metre of water flows into the country during the humid period (May to October) through the three main rivers the Ganges, the Brahmaputra-Jamuna and the Meghna. This volume is 95% of the total annual inflow. By comparison only about 187,000 million cu m of stream flow is generated by rainfall inside the country during the same period (Banglapedia, 2006).

Floods in Bangladesh can be divided into three categories: (a) monsoon flood - seasonal, increases slowly and decreases slowly, inundates vast areas and causes huge losses to life and property; (b) flash flood - water increases and decreases suddenly, generally happens in the valleys of the hilly areas; and (c) tidal flood - short duration, height is generally 3m to 6m, blocks inland flood drainage. The combined annual flood wave from the Ganges, Brahmaputra and Meghna rivers passes through a single outlet, the lower Meghna tide levels in the bay of Bengal, reducing the slope and discharge capacity of the Lower Meghna. The effects of these high river water levels extend over most of the country and are the main determinant of the drainage condition and capacity. The discharge from minor rivers is reduced and surface drainage by gravity is limited to land above the prevailing flood level. Flooding caused by this drainage congestion exists nearly everywhere except in the highland and hilly areas in the northern and eastern parts of the country (Banglapedia, 2006)

3.1.2 Impact of Flood:

Flood is not always curse for the people of Bangladesh.They have some positive impacts such as:

- Nutrients — Flood enrich the floodplain with nutrients and fertile its soil;
- Recharge — floods replenishes ground water systems by recharging the underground aquifers;
- Replenishes — reservoirs are filled which enhances the national water security; and
- Washes away — accumulated waste from water channels and improve the channel water flow.

Despite the potential positive impacts, floods can also bring significant negative impacts:

- Drowning is the leading cause of death in the case of flash floods and coastal floods;
- Fatal injuries can occur during the evacuation or cleanup activities. Injuries consist of small cuts or puncture wounds from glass debris or nails. Electric shocks can also occur;
- In the short-term, the impact of floods on the transmission of communicable diseases is limited, although there is definitely an increased risk for water-borne and vector-borne diseases;
- Flooding can damage lifeline systems, such as the water and sanitation infrastructure, and can interrupt water supply and sanitation services;
- Water sources might become contaminated during flooding. Latrines and shallow wells could be flooded, representing a major health hazard; and
- Toxic chemicals could contaminate water sources during flooding, but this has not been adequately documented to date.

Floods can cause great damage to land and water-related infrastructure and it can have disastrous short and long-term consequences for people and economies. With regard to extremes at the upper end such as the 1988 and 1998 flooding events, climatic variability (including events such as the El Nino Southern Oscillation) as well as long term climatic change could certainly be contributing factors (Banglapedia, 2006).

3.2 Drought

3.2.1 Physical Processes:

Drought occurs when there is a situation of abnormally dry weather in a region where precipitation is usually expected. It occurs when evaporation and transpiration exceed the amount of precipitation for a reasonable period. This absence of precipitation causes a serious imbalance in the hydrological system which, for example, leads to water-supply reservoirs and wells drying up leading to water shortages. The severity of a drought is measured by duration, the degree of moisture deficiency and the size of the affected area. Droughts can last from a few weeks (partial drought) to as long as a number of years.Drought causes the earth to parch and a considerable hydrologic (water) imbalance resulting water shortages, wells to dry, depletion of groundwater and soil moisture, stream flow reduction, crops to wither leading to crop failure and scarcity in fodder for livestock. Drought is a major natural hazard faced by communities directly dependent on rainfall for drinking water, crop production, and rearing of animals. Since ancient times droughts have far-reaching effects on mankind. Large land areas often suffer damages from dust storms and fire. Drought could be the reason for migration of early human communities. It has long been considered to be a natural hazard responsible for ups and downs of many civilizations of the world. The worst drought of the last century in the sub-continent occurred in 12 states of India in 1999-2000. (CapNet, 2009, Banglapedia, 2006)

In Bangladesh drought is defined as the period when moisture content of soil is less than the required amount for satisfactory crop-growth during the normal crop-growing season. Droughts are common in the northwestern districts of Bangladesh. Some of these droughts usher in famine. One definite manifestation of the onset of the drought is the 'top burning' of the bamboo and betel nut trees, that is, they loose green foliage and the fresh leaves turn brown because of lack of moisture in soil and air. The condition often culminates to their death, if there is no rain or irrigated water for a substantially long time. However, drought can also occur in areas that usually enjoy adequate rainfall and moisture levels. Due to drought severity, crop loss ranges between 20 and 60 percent or even may be more for transplanted aman and other rice varieties. Depending on the intensity of drought, the estimated yield reduction of different crops varies from 10% to 70%. The yield loss may considerably be reduced through judicious and limited irrigation at the critical stages of crop growth (Banglapedia, 2006).

Drought has become a recurrent natural phenomenon of northwestern Bangladesh (ie barind tract) in recent decades. Barind Tract covers most parts of the greater Dinajpur, Rangpur, Pabna, Rajshahi, Bogra, Joypurhat and Naogaon districts of Rajshahi division. Rainfall is comparatively less in Barind Tract than the other parts of the country. The average rainfall is about 1,971 mm, which mainly occurs during the monsoon. Rainfall varies aerially as wells as yearly. For instance, rainfall recorded in 1981 was about 1,738 mm, but in 1992 it was 798 mm. The distribution of rainfall is rather variable from one place to another. Thus this region has already been known as drought prone area of the country (Banglapedia, 2006).

The average highest temperature of the Barind region ranges from 35°C to 25°C for the hottest season and 12°C to 15°C for the coolest season. Generally this particular region of the country is rather hot and considered as a semi-arid region. In summer, some hottest days experience the temperature of about 45°C or even more in the Rajshahi area, particularly at Lalpur. Again in the winter the temperature even falls at 5°C in some places of Dinajpur and Rangpur districts. So this older alluvium region experiences the two extremities that clearly contrast with the climatic condition of the rest of the country (Banglapedia, 2006).

3.2.2 Drought Impacts

Drought is known to have a slow onset making it more predictable than floods. It is difficult to tell when a drought starts and when it ends. It is therefore considered to be a slow-creeping hazard with devastating impacts. Drought mostly affects Bangladesh in pre-monsoon and post-monsoon periods. From 1949 to 1979 drought conditions had never affected the entire country. The percentage of drought affected areas were 31.63% in 1951, 46.54% in 1957, 37.47% in 1958, 22.39% in 1961, 18.42% in 1966, 42.48% in 1972 and 42.04% in 1979. During 1981 and 1982 droughts affected the production of the monsoon crops only. During the last 50 years, Bangladesh suffered about 20 drought conditions. The drought condition in northwestern Bangladesh in recent decades had led to a shortfall of rice production of 3.5 million tons in the 1990s. If other losses, such as, to other crops (all rabi crops, sugarcane, tobacco, wheat etc) as well as to perennial agricultural resources, such as, bamboo, betel nut, fruits like litchi, mango, jackfruit, banana etc are considered, the loss will be substantially much higher (CapNet, 2009, Banglapedia, 2006).

3.3 Tropical Cyclones, Hurricanes and Strom Surges

3.3.1 Physical Processes

Cyclone is an atmospheric system characterized by the rapid inward circulation of air masses about a low-pressure center, usually accompanied by stormy, often destructive weather. Cyclones circulate counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. Tropical Cyclone Genesis is the technical term for the process of storm formation that leads ultimately to what are called hurricanes, typhoons, or tropical cyclones in various parts of the world. In Bangladesh, it is known as tropical cyclone. The tropics can be regarded as the region lying between 30° N latitude and 30° S latitude. All the tropical cyclones of the world born form all tropical seas of the earth except the south Atlantic and southeast Pacific. The characteristic that separates tropical cyclones from other cyclonic systems is that at any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings; a phenomenon called "warm core" storm systems (Banglapedia, 2006).

Himalayas on the north and the funnel shaped coast touching the Bay of Bengal on the south made the geography of Bangladesh into a part of the humid tropical environment. This brings not only blessing monsoon precipitation but also devastating tropical cyclones. All tropical cyclone forms from the Bay of Bengal move towards the land side. Ideal condition for formation of tropical cyclones is in the deep seas and hence their study has been very difficult. It is only with advent of the Space age that weather satellites have provided valuable information about them. Direct studies of cyclone with aircraft reconnaissance are also being carried out by advanced countries. However, only a beginning has been made in Bangladesh towards the understanding of Cyclones.

The formation of tropical cyclones (TCs) has long been a major area of research. In mesoscale climatatology, different theories like the convective instability of the second kind (CISK; Charney and Eliassen 1964) surface heat exchange by wind (WISHE; Emanuel 1986) are the result of these researches. However, the determining system still not clear and is the focus of ongoing research. But from large scale, the basic environmental conditions favorable for formation of tropical cyclone have been known for years (Gray 1968, 1998). To formation of tropical cyclones following conditions are required.

- High underlying sea surface temperatures (at least 26.5 °C in the upper most ocean layer)

- a strong decrease of air temperature with altitude
- low wind shear (low level winds with directional changes known as wind shear) in the upper troposphere or low wind changes due to height
- strong convection and condensation
- minimum Coriolis Force or some distance from the equator
- A weak organized disturbance to grow from
- Moisture throughout all layers of the atmosphere
- high relative humidity in the middle troposphere

The diameter of a cyclone may range from 300 km to 600 km. A cyclone is accompanied by winds with speeds in excess of 118 km/hr, which flow toward the centre of a very strong low pressure. Pressure at the centre of the low may be 50-60 hPa (Hexa Pascal) less than in its outskirts. Strong winds bring in enormous amounts of moisture and latent heat toward the centre of the low, which supply the necessary energy to the cyclone. The spiraling winds converge toward the centre of the low pressure where they rise at a tremendous speed. The most striking feature of a cyclone is its 'eye'. The eye can be seen clearly in satellite pictures in the case of a well-developed cyclone. The eye is small and almost circular; it coincides with the area of lowest pressure and has a diameter ranging from 8 km to 50 km. The eye is warmer than the rest of the storm area. The more violent the storm, the warmer the eye. The winds are very light in the eye, usually not more than 25 to 30 km/hr and rain is practically absent. In contrast, the strongest winds and the heaviest rain occur just outside this central eye.

Wind speed gradually diminishes as one moves away from the region of strongest wind. The main cyclone is often accompanied by a long tail having more than one band. The whole thing has a spiral structure, and looks like a comma. The tail may extend up to a few hundred kilometers. The tail usually crosses the land well before the main core of the cyclone and as a result the sky becomes overcast with clouds and rain often sets in before the onset of a cyclone. Such symptoms can serve as a warning for the possible approach of a cyclone. The right-hand side of a travelling cyclone has more destructive power than its left-hand side. The duration of a cyclone, from the beginning to the end, may range from 7 to 10 days and it may produce 25 cm to 50 cm of rainfall. The life cycle of a cyclone ends soon after the cyclone reaches land ('landfall'), because it is cut off from its moisture source.

The most destructive element of a cyclone is its accompanying surge. There is little that can withstand a great mass of onrushing water often as high as 6m. In Bangladesh, cyclones occur in April-May and also in September-December. On an average, five severe cyclonic storms hit Bangladesh every year and the accompanying surge can reach as far as 200 km inland. Surge-heights increase with the increase of wind speed. Astronomical tides in combination with cyclonic surges lead to higher water levels and hence severe flooding.

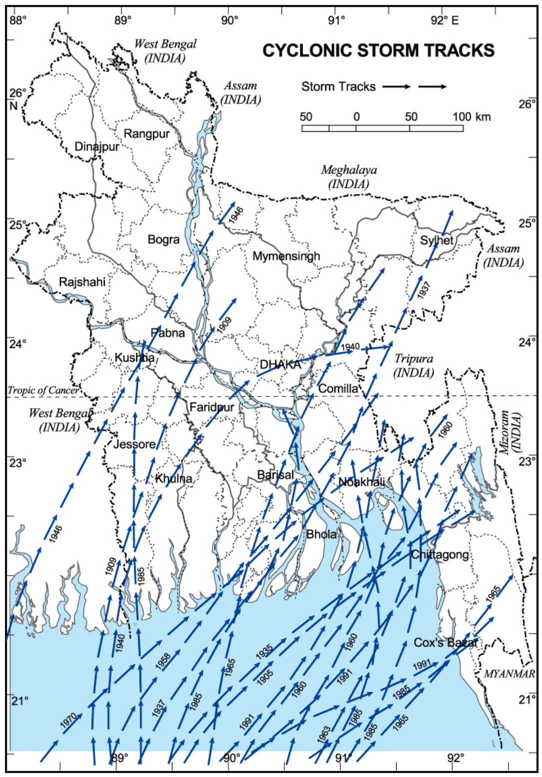

Figure 3.1: Cyclone Storm Tracks (Source: Banglapedia, 2006)

3.3.2: Impacts of Cyclone:

Because of the funnel shaped coast of the Bay of Bengal, Bangladesh very often becomes the landing ground of cyclones formed in the Bay of Bengal. The Bay cyclones also move towards the eastern coast of India, towards Myanmar and occasionally into Sri Lanka. But they cause the maximum damage when they come into Bangladesh, west bengal and Orissa of India. This is because of the low flat terrain, high density of population and poorly built houses. Most of the damage occurs in the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands of Bhola, Hatiya, Sandwip, Manpura, Kutubdia, Maheshkhali, Nijhum Dwip, Urir Char and other newly formed islands.

From 1981 to 1985, 174 severe cyclones (with wind speeds of more than 54 km/hr) formed in the Bay of Bengal. The month-wise occurrence is as follows: 1 in January, 1 in February, 1 in March, 9 in April, 32 in May, 6 in June, 8 in July, 4 in August, 14 in September, 31 in October, 47 in November and 20 in December. It is apparent from the above figures that severe cyclones occur mostly during pre-monsoon (April-May) and post-monsoon (September-December) periods and they are the ones which cause the most destruction.

Storm surges accompanying cyclones hitting Bangladesh have been noted to be 3m to 9m high. The 1970 cyclone (12-13 November) with a cyclonic surge of 6m to 10m and a wind speed of 222 km/h occurred during high tide causing an appalling natural disaster that claimed 0.5 million human lives. The cyclone of 29 April 1991 hit Chittagong, Cox's Bazar, Barisal, Noakhali, Patuakhali, Barguna and Khulna along with a tidal bore (6.1m to 7.6m), killing 140,000 people.

In cyclone forecasting, it is often assumed that a cyclone follows the direction of the upper atmospheric current. SPARRSO (Space Research and Remote Sensing Organisation) in collaboration with Dhaka University has undertaken an investigation of the problem and it has been found that there seems to be a steering current for every cyclone, but the level differs from cyclone to cyclone and there does not seem to be any relationship with the intensity of the cyclone. Moreover, the upper atmospheric current is as variable as the tract of the cyclone. SPARRSO has installed the model TYAN for predicting the track of a cyclone based on the climatology of the Bay of Bengal cyclones for the last one hundred years. The model has shown promising results in forecasting a cyclone's movement twenty-four hours ahead of landfall.

3.4 River Bank Erosion

3.4.1: Physical Processes:

River bank erosion occurs primarily through a combination of three mechanisms: mass failure, fluvial entrainment, and subaerial weakening and weathering. Subaerial processes are often viewed as 'preparatory' processes, weakening the bank face prior to fluvial erosion. Within a river basin downstream process 'domains' occur, with subaerial processes dominating the upper reaches, fluvial erosion the middle, and mass failure the lower reaches of a river.

Riverbank Erosion is an endemic and recurrent natural hazard in Bangladesh. When rivers enter the mature stage (as in the case with the three mighty rivers, Ganges, Brahmaputra and Meghna) they become sluggish and meander or braid. These oscillations cause massive riverbank erosion. Some rivers cause erosion in large scale and high frequency due to their unstable character. These rivers assume a braided pattern consisting of several channels separated by small islands in their courses. During the last 200 years or so, the channels have been swinging between the main valley walls. During the monsoon, extensive overbank spills, bank erosion and bankline shifts are typical. The gradual migration or shifting of channels of the major rivers in Bangladesh amount to anywhere between 60m to 1,600m annually. In a typical year, about 2,400 km of the bank line experiences major erosion. The unpredictable shifting behaviour of the rivers and their encroachments not only affect the rural floodplain population but also urban growth centres and infrastructures (Banglapedia, 2006).

No systemic pattern has yet been observed of the erosion hazards because of the involvement of a large number of variables in the process. The intensity of bank erosion varies widely from river to river as it depends on such characteristics as bank material, water level variations, nearbank flow velocities, planform of the river and the supply of water and sediment into the river. For example, loosely packed, recently deposited bank materials, consisting of silt and fine sand, are highly susceptible to erosion. Rapid recession of floods accelerates the rates of bank erosion in such materials.

3.4.2: Impacts of River Bank Erosion:

Every year, millions of people are affected by erosion that destroys standing crops, farmland and homestead land. It is estimated that about 5% of the total floodplain of Bangladesh is directly affected by erosion. Some researchers have reported that bank erosion is taking place in about 94 out of 489 upazilas of the country. A few other researchers have identified 56 upazilas with incidence of erosion. At present, bank erosion and flood hazards in nearly 100 upazilas have become almost a regular feature. Of these, 35 are severely affected. For example, A newspaper report stated that over 25,000 families were rendered homeless in June 1993 by riverbank erosion in 16 districts (Banglapedia, 2006).

Socio-economic impact riverbank erosion has disastrous socio-economic effects. The majority of the affected people perceive riverbank erosion as a natural phenomenon but in many cases the people believe erosion to be the 'will of God'. However, these days, riverbank erosion is seen as one of the major causes for national poverty. The degree of economic loss and vulnerability of population due to bank erosion has dramatically increased in recent years. The impact of land loss involves primarily the loss of homestead land, housing structures, crops, cattle, trees and household utensils. Loss of homesteads forces people to move to new places without any option and puts them in disastrous situations. About one million people are directly affected each year by bank erosion in the country. The total monetary loss is estimated to be approximately $500 million a year. An estimated 300,000 displaced persons usually take shelter on roads, embankments and government-requisitioned lands. Bank erosion affects people, irrespective of farm sizes. Riverbank erosion causes setback for village agriculture. Along with homestead settlements, it erodes farmland, infrastructure and the communication system. It affects the crop income of vulnerable groups. The big farmers are the worst affected, followed by medium farmers, and marginal groups. The affected people lose their assets and are forced to draw on savings and often fall into further debt. Researchers found that the land lost is much more than the land that rises out of riverbed through accretion. This erosion-accretion phenomenon is a characteristic feature of the courses of the rivers in Bangladesh and gives rise to a lot of tension in local politics.

Displacement is the immediate impact of riverbank erosion. The displaced usually move to nearby areas but migration to distant places is not uncommon. In erosion-prone areas, most families have witnessed a displacement in their lifetime. This involuntary movement can go up to 10 times or even more. A survey conducted in two Dhaka slums has revealed that they consist of migrants who mostly originated from the districts of Faridpur (34%), Barisal (25.6%), Comilla (24.3%) and Dhaka (14.3%). A closer examination of this distribution further revealed that most of the migrants came from an area consisting of only a few upazilas mostly located around the Ganges-Padma and the Meghna and their combined estuaries. The displacement caused by erosion, mostly involve displacement of whole families. On an average, a household experienced riverbank erosion 2.33 times in the life of its members. Some of them experienced displacement 4-5 times or more. Most of the environment-induced refugees turn mainly into labourers or rickshaw pullers. A large proportion of the victims remain unemployed due to lack of work oppurtunities. Moreover, women head many of these families. The female-headed households displaced by riverbank erosion and residing on embankments are the most deprived group. Fortunately, nowadays, social workers are focusing on these problems and also suggesting strategies of survival to these people (Banglapedia, 2006).

3.5 Landslides

3.5.1 Physical Processes:

Landslides are another water related disaster. It includes a wide range of ground movement activities such as rock falls, deep failure of slopes and shallow debris flows, which can occur in offshore, coastal and onshore environments. The action of gravity can be seen as the primary driving force for landslides to occur, other contributing factors can influence the original slope stability. Characteristically, pre-conditional factors build up specific sub-surface conditions that make the area or slope prone to failure, while the actual landslide frequently require a trigger before being released.

Commonly identified causes of landslides are:

- Groundwater pressure acting to destabilize the slope;
- Loss or absence of vertical vegetative structure, soil nutrients, and soil structure;
- Erosion of the toe of a slope by rivers or ocean waves;
- Weakening of a slope through saturation by heavy rains;
- Earthquakes adding loads to barely-stable slopes;
- Earth vibrations from machinery, traffic or blasting;
- Earth work which alters the shape of a slope, or which imposes new loads on an existing slope;
- In shallow soils, the removal of deep-rooted vegetation that binds colluviums to bedrock; and
- Activities such as construction, agricultural, or forestry which change the amount of water which infiltrates into the soil.
  (Text adapted from http://en.wikipedia.org/wiki/List_of_geological_phenomena)

3.5.2 Impacts of Landslides:

Landslides are a major cause of erosion, causing the strongest degradation known, often exceeding 10,000 tons per sq km in a year. They are common in the hilly areas of southeastern Bangladesh. These areas have a long history of instability. Although written records of landslide incidents are very rare, they have been a hazard to people ever since they have been living there. In fact, every year especially in the rainy season landslides take place in both natural and man-induced slopes. Although, Bangladesh is a densely populated country, the hilly region presents a sharp contrast with the overall demographic pattern. This is partly due to the landslide hazard potential which discourages many people to live there as well as to build infrastructures; however, inaccessibility, dense forest cover and the hilly topography are also discouraging factors (Banglapedia, 2006).

One of the main problems related to landslides is blocking of roads. This problem is very common in Bandarban and Rangamati districts. The major roads connecting Bandarban town with the rest of the country are affected by landslides almost every year isolating the town and contiguous areas. Landslides due to the construction of buildings and other infrastructures have been mostly restricted to the urban and semi-urban centres of hill districts town. Many buildings and infrastructures especially those located on steep high slopes usually fail due to landslides causing the loss of property and lives. The effect of jhum cultivation and other forms of cultivation on steep slopes also played a significant role in the occurrence of landslide in the past years (Banglapedia, 2006)..

3.6 Earthquake and Tsunami

3.6.1 Physical Processes:

An earthquake (also known as a quake, tremor or temblor) is the result of a sudden release of energy in the Earth's crust that creates seismic waves. The seismicity, seismism or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. Earthquakes are measured using observations from seismometers. The moment magnitude is the most common scale on which earthquakes larger than approximately 5 are reported for the entire globe. The more numerous earthquakes smaller than magnitude 5 reported by national seismological observatories are measured mostly on the local magnitude scale, also referred to as the Richter scale. These two scales are numerically similar over their range of validity. Magnitude 3 or lower earthquakes are mostly almost imperceptible and magnitude 7 and over potentially causes serious damage over large areas, depending on their depth. The largest earthquakes in historic times have been of magnitude slightly over 9, although there is no limit to the possible magnitude. The most recent large earthquake of magnitude 9.0 or larger was a 9.0 magnitude earthquake in Japan in 2011 (as of March 2011), and it was the largest Japanese earthquake since records began. Intensity of shaking is measured on the modified Mercalli scale. The shallower an earthquake, the more damage to structures it causes, all else being equal.

At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacement of the ground. When the epicenter of a large earthquake is located offshore, the seabed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides, and occasionally volcanic activity.

In its most general sense, the word earthquake is used to describe any seismic event — whether natural or caused by humans — that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. An earthquake's point of initial rupture is called its focus or hypocenter. The epicenter is the point at ground level directly above the hypocenter.

A tsunami a series of water waves caused by the displacement of a large volume of a body of water, typically an ocean or a large lake. Earthquakes, volcanic eruptions and other underwater explosions (including detonations of underwater nuclear devices), landslides, glacier calvings, meteorite impacts and other disturbances above or below water all have the potential to generate a tsunami. Tsunami waves do not resemble normal sea waves, because their wavelength is far longer. Rather than appearing as a breaking wave, a tsunami may instead initially resemble a rapidly rising tide, and for this reason they are often referred to as tidal waves. Tsunamis generally consist of a series of waves with periods ranging from minutes to hours, arriving in a so-called "wave train". Wave heights of tens of meters can be generated by large events. Although the impact of tsunamis is limited to coastal areas, their destructive power can be enormous and they can affect entire ocean basins; the 2004 Indian Ocean tsunami was among the deadliest natural disasters in human history with over 230,000 people killed in 14 countries bordering the Indian Ocean.

The Greek historian Thucydides suggested in 426 B.C. that tsunamis were related to submarine earthquakes, but the understanding of a tsunami's nature remained slim until the 20th century and much remains unknown. Major areas of current research include trying to determine why some large earthquakes do not generate tsunamis while other smaller ones do; trying to accurately forecast the passage of tsunamis across the oceans; and also to forecast how tsunami waves would interact with specific shorelines.

CHAPTER 4
IMPACT OF CLIMATE CHANGE ON CLIMATIC DISASTERS

4.1 What is Climate Change?

Climate Change has become a crosscutting issue at present world. It's a slow ongoing process due to the negative impact of technological advancement and affects the entire population of the world in different degrees. The geographical setting of Bangladesh has made it one of the most vulnerable countries susceptible to climate change disasters. As per Cap-Net's Manual on Hydro-Climatic Disasters in Water Resources Management (2009), climate change can be defined as "a long-term shift in the climate of a specific location, region or planet. The swing is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation". An important thing is to be noted that a change in the variability of climate is also considered as climate change, even though the average weather conditions remain the same. Climate variability is the results of deviations from the long-term meteorological averages of different parameters (precipitation, temperature, humidity, etc.) over a certain period of time like a specific month, season or year. Climate variations can take place without affecting the overall average. For example, a place may have a wetter than normal year followed by a drier than normal year but the average stays nearly the same (Cap-Net, 2009).

4.2 Climatic Parameters affected by Climate Change

The drivers of climate (rainfall, temperature, humidity, etc.) are greatly influenced by climate change. The pattern of rainfall will change due to global warming although the exact amount of this change is not yet evaluated. This change will affect fresh water supplies that have already been stressed by the rising population and increased per capita consumption. This change will also cause the extreme events to be more erratic, which will pause higher degree of difficulty in estimating extreme rainfall events since there will no longer be a homogeneous series of values which can be extrapolated statistically (Linarce, 1992). Rainfall belts in many areas have been shifting resulting in more frequent and more severe extreme climate and weather events. These changes are associated with population pressures on land and environmental degradation through deforestation in general (Cap-Net, 2009).

It has also been observed that the mean global temperature of the earth has increased by on the average 0.5ºC during the last about 100 years triggering a prolonged debate on climate change over the last 20 years.. The temperature rise in the lower atmosphere is because of increased green house gas concentrations that block the outgoing long wave radiation. The costs are manifested in a change in climatic patterns and the appearance of extreme events in greater frequency and severity (Cap-Net, 2009).

The rate of evaporation from the land surface is driven essentially by meteorological controls, mediated by the characteristics of vegetation and soils, and constrained by the amount of water available. The most common types of evaporation from the land surface include: evaporation from open water; soil; shallow groundwater; water stored on vegetation; and transpiration through plants. Climate change has the potential to affect all of these factors — in a combined way although this is not yet clearly understood — with different components of evaporation affected differently. The primary meteorological controls on evaporation from a well-watered surface (often known as potential evaporation) are the amount of energy available (characterized by net radiation), the moisture content of the air (humidity—a function of water vapour content and air temperature), and the rate of movement of air across the surface (a function of wind speed). Increasing temperature generally results in an increase in potential evaporation, largely because the water-holding capacity of air is increased. Changes in other meteorological controls may overstress or offset the rise in temperature, and it is possible that increased water vapour content and lower net radiation could lead to lower evaporative demands. The relative importance of different meteorological controls, however, varies geographically. In dry regions, for example, potential evaporation is driven by energy and is not constrained by atmospheric moisture contents, so changes in humidity are relatively unimportant. In humid regions, however, atmospheric moisture content is a major limitation to evaporation, so changes in humidity have a very big effect on the rate of evaporation (Cap-Net, 2009).

Soil moisture is another important component affected by climate change. The amount of water stored in the soil is fundamentally important to agriculture and is an influence on the rate of actual evaporation, groundwater recharge, and the generation of runoff. The local effects of climate change on soil moisture, however, will vary not only with the degree of climate change but also with soil characteristics. The water-holding capacity of soil will affect possible changes in soil moisture deficits; the lower the capacity, the greater the sensitivity to climate changes. Climate change also may affect soil characteristics, perhaps through changes in water logging or cracking, which in turn may affect soil moisture storage properties. Infiltration capacity and water-holding capacity of many soils are influenced by the frequency and intensity of freezing (Cap-Net, 2009).

4.3 ENSO's effect on Climatic Parameters

El Nino/Southern Oscillation (ENSO) is an important phenomenon, associated with some climatic disasters like flood, drought, etc. This phenomenon is a result of interactions between large-scale oceanic and atmospheric circulation processes in the equatorial Pacific Ocean (Kawamura et al., 2005). It was discovered by Sir Gilbert Walker in the early 20th Century after he tried to identify the reasons behind failure of Indian monsoon, which led to drought and famine in India in 1899. ENSO events are very useful for prediction purposes, especially to forecast drought and flood (Chowdhury, 2003;Choudhury, 1994)

An El Nino event, which usually exists 12-18 months and occurs irregularly at 2 to 7 years intervals, represents the period of shortage of rainfalls and drought condition. Its opposite event is La Nina, when surplus amount of rainfall occurs and which sometimes lead to flooding condition. These two reverse situations is compared with sea-saw phenomenon and termed as Southern Oscillation (SO), an exchange of tropical sea level pressure between eastern and western hemispheres (Kawamura et al., 2005; Chowdhury, 2003).

The Southern Oscillation Index, or SOI, gives an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean. For this study, SOI data (1876-2012) have been downloaded from Australian Bureau of Meteorology (www.bom.gov.au). The method used by the Australian Bureau of Meteorology is the Troup SOI which is the standardized anomaly of the Mean Sea Level Pressure difference between Tahiti and Darwin. It is calculated as follows:

$$SOI = 10 * \frac{Pdiff - Pdiffav}{SD(Pdiff)}$$

Where,

Pdiff = (average Tahiti MSLP for the month) - (average Darwin MSLP for the month),
Pdiffav = long term average of Pdiff for the month in question, and
SD(Pdiff) = long term standard deviation of Pdiff for the month in question.

The multiplication by 10 is a convention. Using this convention, the SOI ranges from about –35 to about +35, and the value of the SOI can be quoted as a whole number (www.bom.gov.au).

Analysis of SOI data:

SOI data from 1960 to 2012 are used to reveal its relationships with three climatic variables, e.g., rainfall, temperature and mean sea level pressure.The investigation has been carried out using daily records of precipitation, temperature, sea level pressure observed at 29 ground based stations of Bangladesh Meteorological Department (BMD) distributed over the country during the time period 1961-2010.Figure 4.1 represents the Southern Oscillation Index (SOI) for the years 1960-2012.

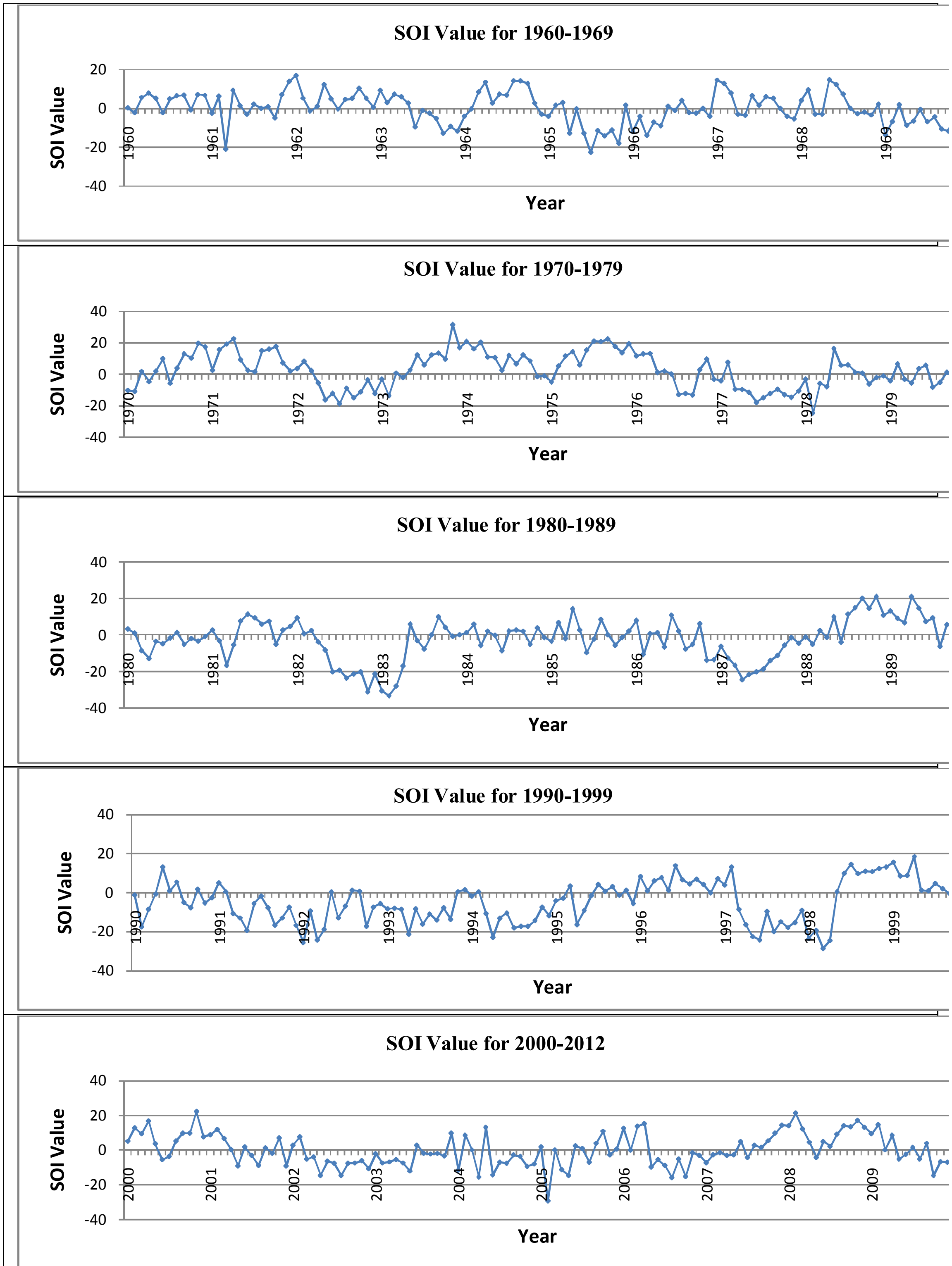

Figure 4.1: Diagram showing SOI for 1960-2012 period

SOI values below -8 represents El Nino events. During this time, central and eastern tropical Pacific Ocean get warmer, and the strength of Pacific Trade Winds decreases. As a result, monsoon rainfall reduced over Indian subcontinent and tends to be drier than normal period. On the other hand, SOI values above +8 indicate La Nina events which are accompanied with stronger Pacific trade winds and warmer sea temperatures to the north of Australia. Consequently much more rainfall occurs over Indian subcontinent and prevail wetter conditions.

Figure 4.2 presents the trend and pattern of recent twelve years SOI data and their five years moving average to smooth out short-term fluctuations and highlight longer-term trends or cycles.

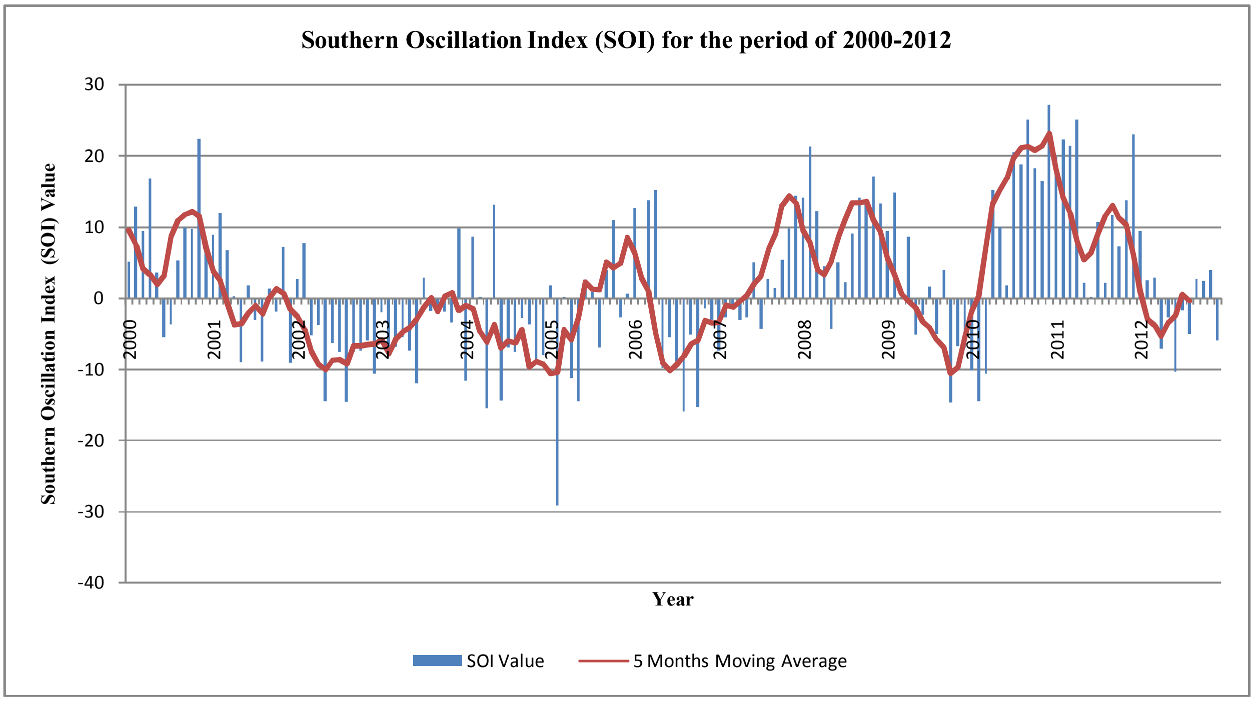

Figure 4.2: Trend and pattern of SOI from 2000 to 2012

The following table gives a list of El Nino and La Nina years –

Table 4.1: List of El Nino and La Nina years.

ENSO TYPE	Season		ENSO TYPE	Season		ENSO TYPE	Season	
	1989	1990	SE	1997	1998	WL	2005	2006
	1990	1991	ML	1998	1999	WE	2006	2007
SE	1991	1992	SL	1999	2000	ML	2007	2008
	1992	1993	WL	2000	2001		2008	2009
	1993	1994		2001	2002	ME	2009	2010
ME	1994	1995	ME	2002	2003	SL	2010	2011
WL	1995	1996		2003	2004	WL	2011	2012
	1996	1997	WE	2004	2005		2012	2013

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño
WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

(Source: http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml)

Relationship with Climatic Variables:

Monsoon (June, July, August and September) season contributes much in the total amount of rainfall in Bangladesh. Last 50 years BMD data shows that annual average rainfall in Bangladesh is 2443.161713. Out of which 70.92 % rainfall (1732.743 mm) occurs at monsoon. ENSO weakens Monsoon circulation system. Figure 4.3 shows monsoon rainfall and SOI pattern for last 50 years and figure 4.4 represents deviations of monsoon rainfall with the fluctuation of SOI values.

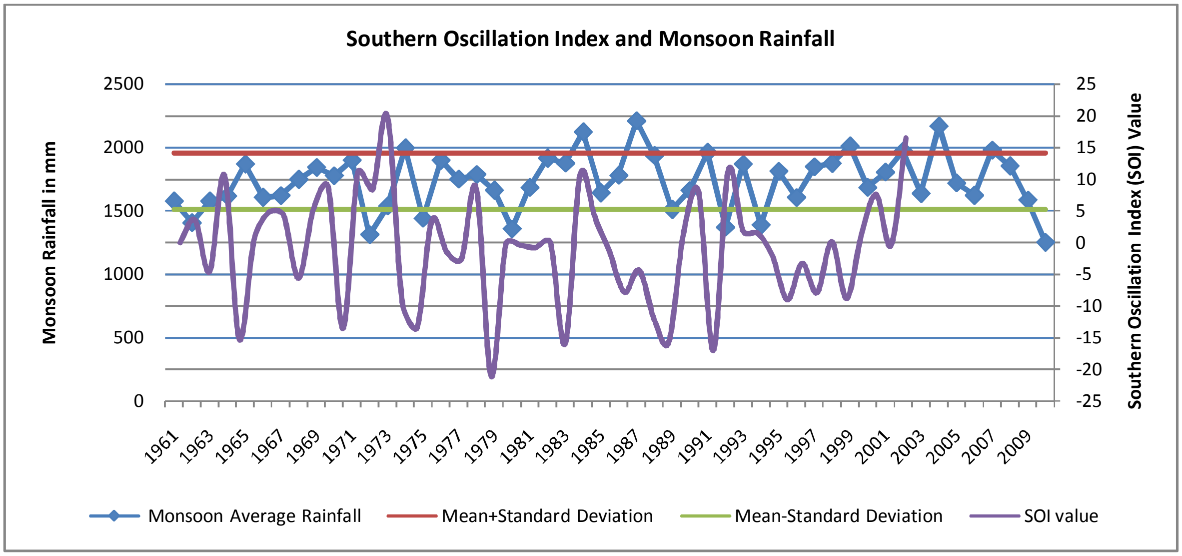

Figure 4.3: Variation of Summer Monsoon rainfall with Southern Oscillation Index.

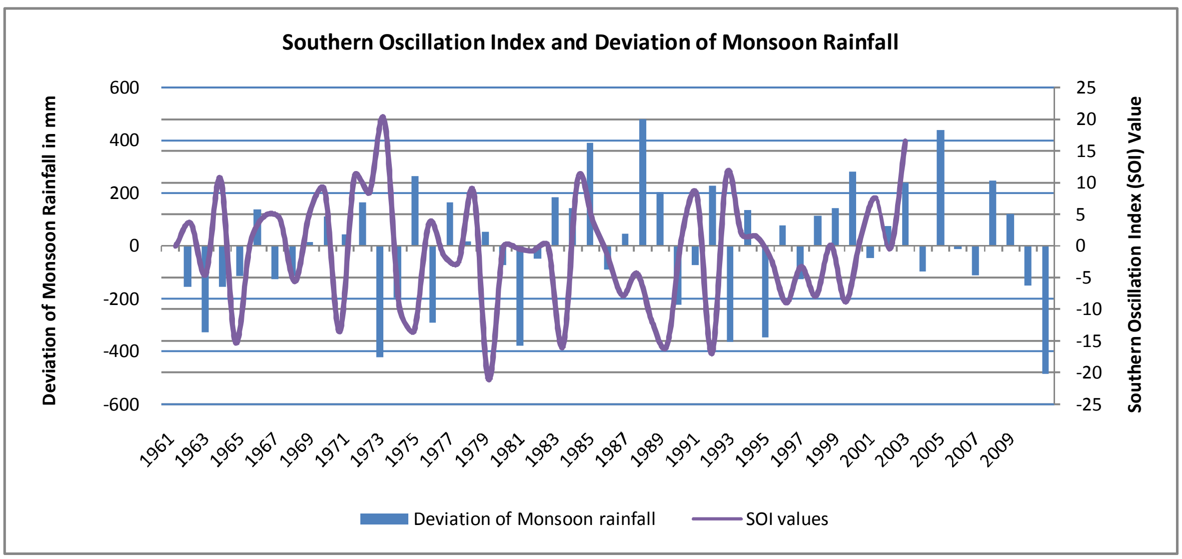

Figure 4.4: Deviation of monsoon rainfall along with SOI values

According to above tables and figures strong and moderate El Nino years in recent 50 years data are 1965, 1972, 1982, 1986, 1987, 1991, 1994, 1997, 2002. In most cases, monsoon rainfall reduced significantly in these periods. La Nina years are 1964, 1970, 1973, 1975, 1988, 1998, 1999, 2007, 2010 and 2011 which are mostly associated with less rainfall. There are some exceptions, like in 1987, an El Nino year, monsoon rainfall was noticeably high. So neither all the El Nino years nor all the La Nina years are accompanied with less or more rainfalls respectively.

Temperature and sea level pressure, other two climatic variables remain almost same in both El Nino and La Nina periods. So these two parameters do not change with the fluctuation of SOI value. Figure 4.5 and figure 4.6 depict the relationship of temperature and sea level pressure with SOi values.

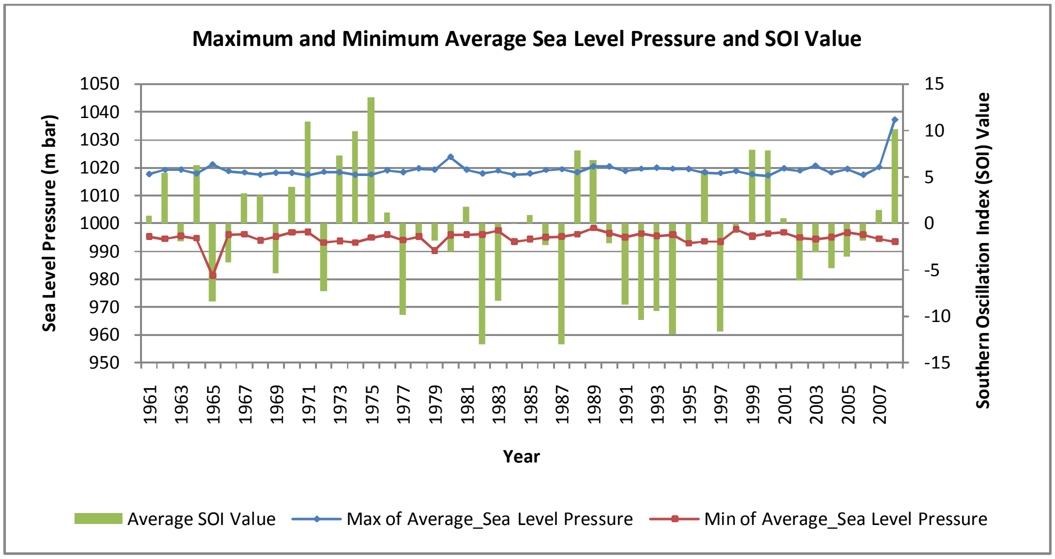

Figure 4.5: Relationship between sea level pressure and SOI values

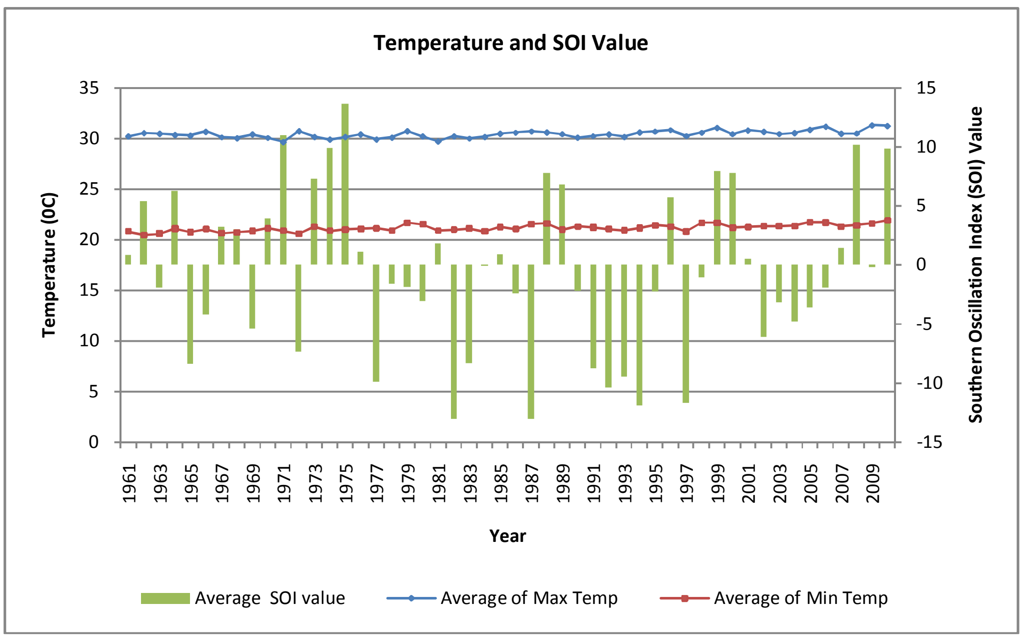

Figure 4.6 Relationship between sea level pressure and SOI values

4.5 Climate Change Impact on Climatic Disasters

Since the early stages of concern over the possible consequences of global warming, it has been widely recognized that changes in the cycling of water between land, sea, and air could have very significant impacts across many sectors of the economy, society, and the environment. The characteristics of many terrestrial ecosystems, for example, are heavily influenced by water availability and, in the case of in-stream ecosystems and wetlands, by the quantity and quality of water in rivers and aquifers. Water is fundamental to human life and many activities — most obviously agriculture but also industry, power generation, transportation, and waste management — and the availability of clean water often is a constraint on economic development. Consequently, there have been a great many studies into the potential effects of climate change on hydrology (focusing on cycling of water) and water resources (focusing on human and environmental use of water). The sensitivity of a water resource system to climate change is a function of several physical features and, importantly, societal characteristics. Physical features that are associated with maximum sensitivity include (Cap-Net, 2009):

- A current hydrological and climatic regime that is marginal for agriculture and livestock;
- Highly seasonal hydrology as a result of either seasonal precipitation or dependence on snowmelt;
- High rates of sedimentation of reservoir storage;
- Topography and land-use patterns that promote soil erosion and flash flooding conditions; and
- Lack of variety in climatic conditions across the territory of the national state, leading to inability to relocate activities in response to climate change.

Natural hazards are severe and extreme weather and climate events occur naturally in all parts of the world, although some regions are more vulnerable to certain hazards than others. Natural hazards become natural disasters when people's lives and livelihoods are destroyed. Human and material losses caused by natural disasters are a major obstacle to sustainable development. Issuing accurate forecasts and warnings in a form that is readily understood and educating people on how to prepare against such hazards, before they become disasters, lives and property can be protected. Observations have shown that:

- One of the critical issues regarding climate change is with respect to the extreme events such as floods, droughts, heat waves, cold spells, strong winds and hurricanes; and
- A number of studies suggested that there are significant changes in the frequency and intensity of extreme events with only small changes in climate (i.e. relatively higher frequencies and more intense extreme climate events)

[Text from http://www.meteo.slt.lk/Researches.htm and
http://whc.unesco.org/documents/publi_climatechange.pdf)]

These changes could have extensive and/or unpredictable environmental, social and economic consequences (Cap Net, 2009):

- The global sea level could rise due to several factors including melting ice and glaciers;
- Rising sea levels could damage coastal regions through flooding and erosion;
- The climate of various regions could change too quickly for many plant and animal species to adjust;
- Harsh weather conditions, such as heat waves and droughts, could also happen more often and more severely;
- Climate change could also affect health and well-being; and
- Many mega cities could experience a considerable rise in the number of very hot days. This will increase air pollution problems putting children, the elderly and people suffering from respiratory diseases at risk. Another problem could be an increase in mold and pollens due to warmer temperatures leading to respiratory problems such as asthma.

CHAPTER 5
WARNING SYSTEM OF BANGLADESH:

Early hazard warning systems have generally very effective for developed country as people have information of disaster in earlier time. In Bangladesh, government has a strong commitment towards the reduction of the human, economic and environmental costs of disasters by enhancing overall disaster management capacity. In respect to flood and tidal surges Flood Forecasting and Warning Centre (FFWC) of BWDB provides an early warning before 24, 48 and 72 hours lead time (BWDB 2010). And for the Cyclone warning, Bangladesh Meteorological Department (BMD) prepares early warning only for maritime or sea ports and inland river ports (Habib 2009). Before the development of these warning systems, people of the village have their own indigenous early warning of disaster from the nature (Howell 2003). But their effectiveness is negligible.

5.1 Indigenous Early Warning System

Cyclones and tidal surges are extremely vulnerable on the chars and in some rural coastal district of the country as flat, with limited forestation and less than one meter above sea level. There are few cyclone shelters and paths to them are unsafe during the time of disasters. In these areas most people do not fully understand the signal system. Though it is 'unscientific', they sometime relays on some indicators of animal behavior or natural phenomenon by the approval of their older generation.

A view of early warning indicators of cyclones is provided as follow (Howell, 2003):

Table 5.1: early warning indicators of cyclones

Weather patterns	Sky turns gloomy and overcast Black rolls of cloud Weather unusually hot and humid/hot spells after rain Strong wind blows from the south/south-east East wind blow: at full moon
Sea/river patterns	Big wave/dark rolls of water 'Goroom goroom' noise in the river Smokey or cloudy shapes in the sea Pond and river water becomes hot*
Animal behaviour	Cattle become restless and stop eating grass *** Cattle/dogs wail continuously/at night *** Ants climb trees with eggs on their backs Bees move around in clusters *Kurpals* (type of gull) fly high and cry Birds fly without destination Increased number of flies and mosquitoes Insects attack cattle ** Fish jump in the rivers and ponds Crows/cockerels call/fly at night Frogs call constantly Foxes bark during the day Crabs come into the house and courtyard ****
Other	Bending trees Water hyacinth in the canal Leaves of the *mandar* and cotton tree turn upside down New leaves of trees fall to the ground Muddy smell on the wind

* Up to one day before
** 1-2 Days before
*** 3-7 Days before
**** 10-12 Days before

In another study, it is found that about 34% of the household in coastal area can predict impending cyclone by indigenous mean. Examples of such prediction methods are listed as follow:

1. Observations of the abnormal south-easterly wind circulation along with a dark and cloudy sky (31%).
2. The tendency of ants to climb walls carrying grain and moving purposefully towards higher ground or the roofs of houses (23%).
3. Sea birds coming inland in groups (20%)
4. Abnormal increase of water temperature in the sea and rivers (15%)
5. Flies attaching themselves to cattle for protection against the surge water and wind (8%)

Majority of the respondents mentioned that they have learned these methods through experience (64%) or from elderly people and neighbors. Nonetheless, more than one quarter of the respondents can make predictions and perceive these indigenous predictions as effective (Paul, et.al., 2010).

5.2 Present Warning System:

5.2.1 Introduction:

Present warning system of Bangladesh has been designed for primarily for navigation purposes. The warning system in our country mainly developed through cyclone, storm surges. Although flood is very common natural disaster in our country but with respect to number of deaths, cyclone holds more priority position.

The cyclone preparedness program was began in 1965 after a request made by Bangladesh Red Crescent Society (Then the National Red Cross Society) to the International Federation of Red Cross and Red Crescent Societies (IFRC) to support the establishment of a warning system for the people in the coastal belt. A pilot scheme for cyclone preparedness along with warning equipments (e.g., transistor radios, sirens, training of local militia (ansars) etc.) was implemented by the International federation and Swedish Red Cross in 1966.

Although immediately after the independence, the focus was limited in relief and rehabilitation activities, but after the devastating effect of 1988 flood and 1991 cyclone, the entire disaster management program had renewed. Since then the disaster management had gone through a process of significant reforms. In 1993, Government of Bangladesh (GoB) formed Disaster Management Councils and Committees from national to down level to gather and disseminate information in root level. At the same year GoB established Disaster Management Bureau (DMB) as a technical arm of Ministry of Food and Disaster Management to coordinate all the activities, perform expert support functions to district and Upazilla level authorities, and the concerned line ministries under the overall authority of high level inter ministerial disaster management coordination committee. The Comprehensive Disaster Management Program (CDMP) was established in November 2003 and has been designed as a long term program of the ministry of Food and Disaster

Management with multi agency involvement. (Golnaraghi, 2012). Both international and national organizations take part actively during the dissemination of warning system.

5.2.2 International

International organizations take active parts during the events of disasters. The following organizations provide assistance through providing information, advice and cooperation to the national organizations.

- **World Meteorological Organization (WMO)** provides real-time data and information through the global telecommunications system to BMD, provides expertise and guidance materials to BMD and the Department of Hydrology.

- **World Health Organization (WHO)** provides help and advice to the Governmental and non-Governmental health sectors through its Country Office in Dhaka, Bangladesh.

- **International Red Cross and Crescent Societies** through the Bangladesh Red Crescent Society (BDRCS) administrates the CPP in cooperation with the DMB.

5.2.3 National

The following committees are working during the climatic disasters (e.g. Cyclone and storm surge) for dissemination, monitoring and conducting relief activities.

- **National Disaster Management Council (NDMC)** headed by the Hon'ble Prime Minister to formulate and review disaster management policies and issues directives addressing EWS key stakeholder and partner concerns.

- **Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC)** headed by the Hon'ble Minister in charge of the Ministry of Food and Disaster Management (MoFDM) to implements disaster management policies and decisions of NDMC.

- **National Disaster Management Advisory Committee (NDMAC)** headed by an experienced person nominated by the Hon'ble Prime Minister. **Cyclone Preparedness Program Implementation Board (CPPIB)** headed by the Secretary, Ministry of Food and Disaster Management to review the preparedness activities in the face of initial stage of an impending cyclone.

- **Disaster Management Training and Public Awareness Building Task Force (DMTATF)** headed by the Director General of Disaster Management Bureau (DMB) to co-ordinate the disaster related training and public awareness activities of the Government, NGOs and other organizations.

- **Focal Point Operation Coordination Group of Disaster Management (FPOCG)** headed by the Director General of DMB to review and co-ordinate the activities of various departments/agencies related to disaster management and also to review the Contingency Plan prepared by concerned departments.

- **NGO Coordination Committee on Disaster Management (NGOCC)** headed by the Director General of DMB to review and co-ordinate the activities of concerned NGOs in the country.

- **Committee for Speedy Dissemination of Disaster Related Warning/ Signals (CSDDWS)** headed by the Director General of DMB to examine, ensure and find out the ways and means for the speedy dissemination of warning/ signals among the people.

5.2.4 NGOs

A number of non-government organizations were found active during the cyclone SIDR for evacuate people and disseminating cyclone warnings. NGOs also provided relief to the cyclone and flood effected people. A few NGOs maintain cyclone shelters by providing support to the local volunteers and schools inside the shelters. CARE Bangladesh, BRAC and Muslim Aid were found supporting cyclone victims.

5.2.4.1 Local

In the event of a tropical cyclone, the CPP receives the cyclone warning signals from Storm Warning Centre (SWC) of BMD as soon as a depression is formed in the Bay of Bengal. The information is transmitted to the six Zonal offices over HF radio as shown in Figure 2.1. The Assistant Directors in turn pass it on to Unions through VHF radio. Where VHF radio has not yet been installed, messenger then passes on the message. The Union team Leaders contact the Unit Team Leaders immediately (Figure 2.2). The Unit Team Leaders with their volunteers spread out in the villages and disseminate the cyclone warnings, almost door-to-door, using megaphones, hand sirens and public address systems. The Team Leaders at the same time keep track of the approaching cyclone by listening to national radio broadcasts over transistor radios. Team leaders are thus alerted and start work without losing time. The volunteers keep on announcing the special weather bulletins on the characteristics of the approaching cyclone as per their action plan.

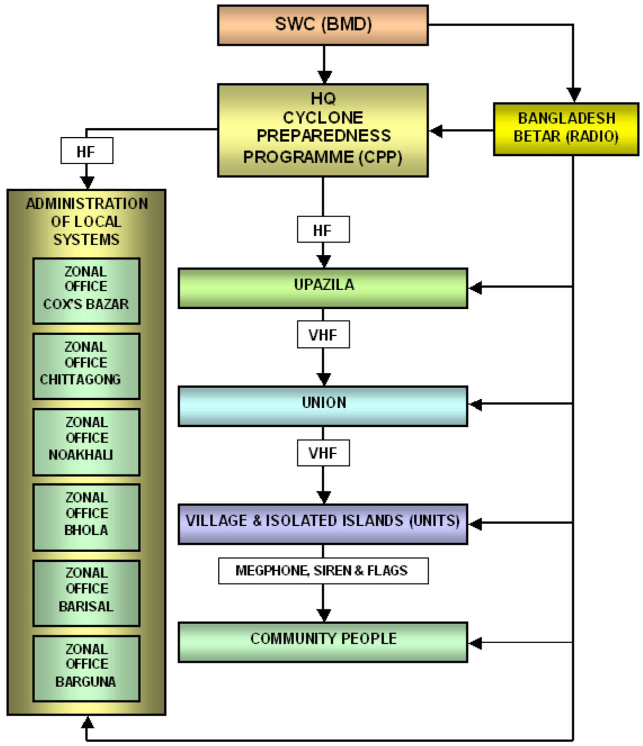

Figure 5.1 : Dissemination of warnings and signals from the Storm Warning Centre (SWC) of BMD through the Cyclone Preparedness Programme (CPP) to the community people

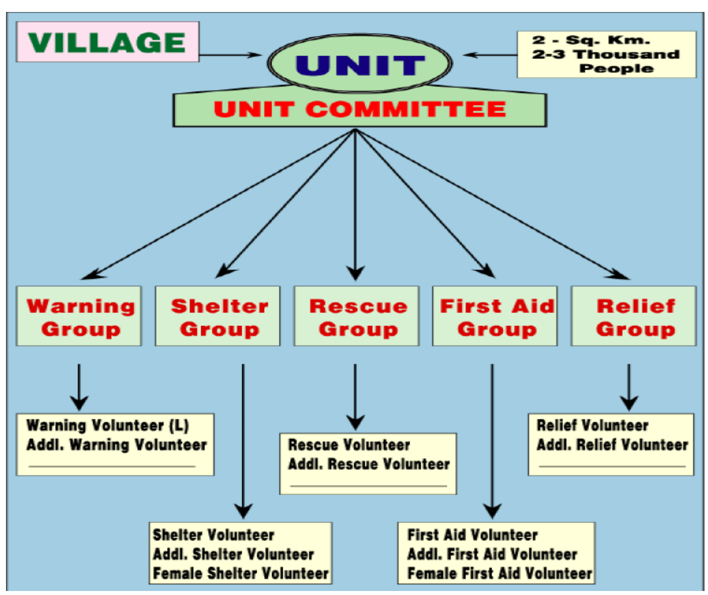

Figure 5.2: Cyclone Preparedness Programme (CPP) organization from Unit level

5.2.5 Access to information from researchers

The information of past floods and cyclone is available for researcher from BWDB and BMD database. However, the storm surge level of various coastal locations hit by the cyclone is not collected.

5.2.5.1 Dissemination strategy

There are two stages to the Bangladesh Meteorological Department issues their warnings:

Alert Stage

a) Issue as soon as possible the alert warning signals of cyclone, at least 36 hours ahead of formation of depression in the Bay of Bengal.
b) Supply information through Fax/telephone/teleprinter to Cyclone Preparedness Programme (CPP) about the formation of depression in Bay of Bengal so as to allow CPP to take appropriate actions including dissemination of information to all concerned.
c) Issue warning signals code 'Whirlwind' to all concerned officials through telephone, teleprinter, telegram etc., fax, (email)
d) Prepare and submit Special Weather Bulletin and broadcast/publicise the same through national news media such as the all stations of Radio and Television and in national newspapers for the benefit of the general people. In case of Local Cautionary Signal no. 3, arrange for adequate and full time coordination between SWC of the Meteorological Department, Bangladesh Betar, Bangladesh Television for publicity beyond normal broadcasting hours.
e) Send Special Weather Bulletins to EOC at the Ministry of Disaster Management and Relief, the Directorate of Relief and Rehabilitation, the Cyclone Preparedness Programme and Bangladesh Red Crescent Society for undertaking adequate arrangements.

Warning Stage

Publicize warning signals at each of the following specified stages using the all the available means (Radio/TV/Web/Fax/telephone/teleprinter).

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

The same warning signals are to be repeated to the Emergency Operations Centre (EOC) at the Ministry of Disaster Management and Relief, Control Room of the Disaster Management Bureau, the Directorate of Relief and Rehabilitation, the Cyclone Preparedness Programme and the Bangladesh Red Crescent Society. The following information are mentioned in the signals to be disseminated.

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

Flood warning dissemination

Information of riverine floods occurred during pre-monsoon, monsoon and post monsoon season are sent on daily basis to the following national organizations,

- - President's Office
- - Prime Minister's Office
- - Ministry of Water Resources
- - Ministry of Relief & Rehabilitation
- - Disaster Management Bureau
- - Army Headquarters
- - Public Information Department
- - Government Departments
- - News Agencies - Radio & TV
- - NGO's & International relief organizations (MSF, Red Cross)
- - Foreign embassies and consulates in Dhaka
- - Field Wireless Stations
- - And other places as directed by Disaster Management Bureau

5.2.5.2 Tools of dissemination

Flood warning dissemination

The following systems has been used to disseminate flood warnings

- Internet:
    - Flood warning has been updated daily during the monsoon season in the FFWC web site at http://www.ffwc.org
- Email:
    - Flood warning bulletin is sent daily to the relevant organizations and important stakeholders during the monsoon season.
- Fax, Telephone & Wireless:
    - Flood information has been sent daily to District Disaster Management offices
- Radio & Television
    - During severe floods, warnings has been published in the electronic and print media.

Cyclone warning dissemination

The following systems has been used to disseminate cyclone warnings-

- Internet
    - Information is available from the BMD website at http://www.bmd.gov.bd
- Email
    - Email has been sent to relevant organizations
- Fax, Telephone & Wireless
    - Warning has been provided through these media to the local DMB offices.
- Radio & Television
    - Hourly bulletin of cyclone warnings are published in the electronic media.
- Disaster Management Brue and Committees.
    - BMD provides warning to the DBM and local disaster management committees.

A number of committees as mentioned earlier have been activated and coordinated and monitor the cyclone and storm surge. Figure 2.3 shows a schematic of the cyclone warning dissemination systems of Bangladesh.

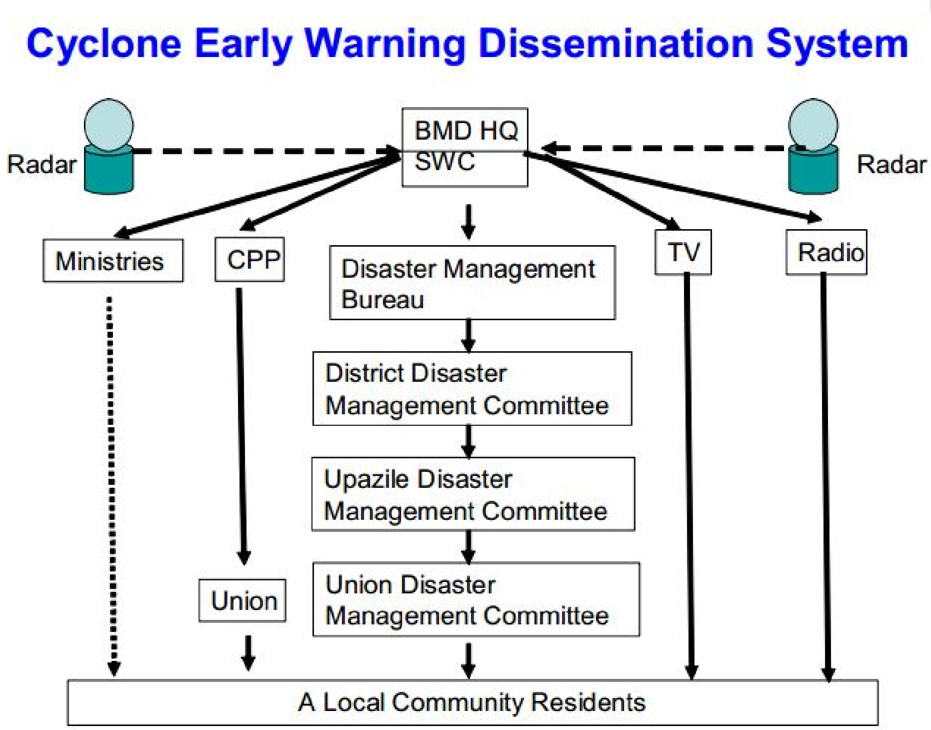

Figure 5.3: Cyclone warning dissemination systems

5.2.6 Geographical scale and coverage

Weather forecasting from BMD has been disseminated to all over Bangladesh through radio, TV, internet. Figure 2.4 shows a typical experimental 24hours rainfall forecast maps generated by the WRF model.

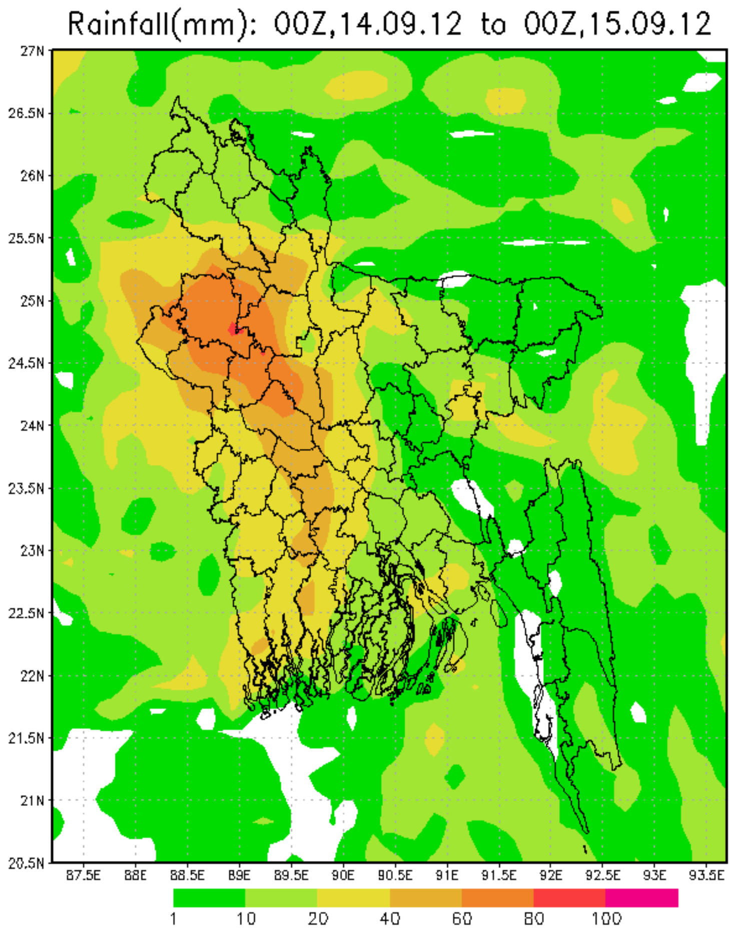

Figure 5.4: A typical experimental 24 hours rainfall forecast maps. District boundaries are also shown.

Flood forecasting and warning information has also covered the whole country. 3 day forecast has been provided for a total of 30 stations located in the major rivers of Bangladesh. Water level above danger level for next 72 hours has been provided for these stations. Flood inundation map for the whole country also prepared. Figure 2.5 shows typical flood inundation maps based on forecast of next 48hours.

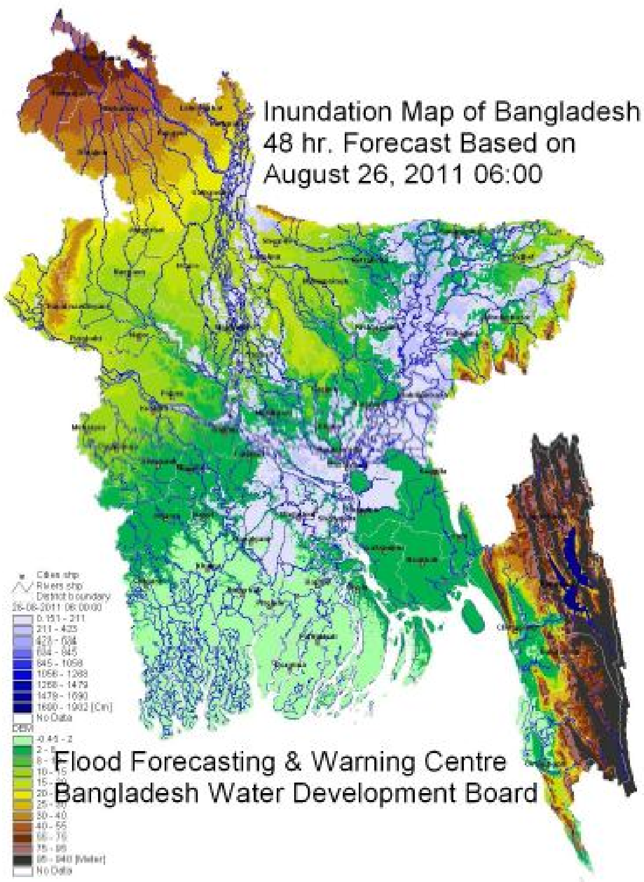

Figure 5.5: A typical 48 hours flood inundation maps of Bangladesh

5.2.7 Degree of certainty and specificity

The weather forecasting information has been disseminated and coordinated by the above mentioned systems. Performance of these dissemination systems is improving though they have suffered from inaccuracy. The number of death toll has been gradually reduced for four major cyclones hit coastal areas of Bangladesh. Rainfall forecasting has not been observed very accurate or fulfills need of the local communities. Heavy rainfall, untimely rainfall and drought predictions need to be included in the present dissemination system.

Flood forecasting has been done using the above communication media. However, it suffers from the accuracy of the rise of flood level with respect to the local community. Community based flood forecasting and warning system should be introduced to disseminate location specific flood information to the villagers. Lead time of forecasting should be increased for better flood management.

5.2.8 Signal system and typical weather forecasts of BMD

During the cyclone and storm surge, BMD issues two types of warning signals. Table 5.1 presents signals used for maritime ports with the respective thresholds. Table 5.2 represents the signals used for inland river ports with the respective thresholds. There has been no signal issued considering the conditions of devastation and damages over land. Community based warning for the cyclone and storm surge was not disseminated.

Table 5.3 provides an example of typical weather forecasts from BMD for next 12 hours for major division of Bangladesh.

Table 5.1: Signal system for maritime ports with thresholds

Sl. No.	Signals	Explanation
1	Distant Cautionary Signal Number -I	There is a region of squally weather in which a storm may be forming (well marked low or depression) with surface winds up to) 61 km/h. (33 knots))
2	Distant Warning signal number -II	A storm has formed (cyclonic storm with surface winds 62-87 km/h. (34-47 knots))
3	Local Cautionary signal number -III	The port is threatened by squally weather (cyclonic circulation with surface winds 40-50 km/h. (22-27 knots)) or squalls due Nor'westers)
4	Local Warning signal number -IV	The port is threatened by a storm, but it does not appear that the danger is as yet sufficiently great to justify extreme measures of precaution (cyclonic circulation) with surface winds 51-61 km/h (28-33 knots))
5	Danger Signal -VI	The port will experience severe weather from a cyclonic storm of moderate intensity (cyclonic storm with surface winds 62-88 km/h (34-47 knots))
6	Great Danger Signal –VIII	The port will experience severe weather from a storm of great intensity (Severe Cyclonic Storm with surface winds 89-117 km/h (48-63 knots))
7	Great Danger Signal –IX	The port will experience severe weather from a storm of very great intensity (Severe Cyclonic Storm with a core of Hurricane winds with surface winds 118 - 170 km/h (64 -119 knots)
8	Great Danger Signal –X	The port will experience severe weather from a storm of very great intensity (Severe Cyclonic Storm with a core of Hurricane winds with surface winds 171 km/h and above (120 knots and above))

Table 5.2: Signal system for inland river ports with thresholds

Sl. No.	Signals	Explanation
1	Local Cautionary signal number –III	Your area is threatened by squally winds of transient nature (Nor'wester squall of wind speed 40-50 km/h (22-27 knots)). Look out for further development
2	Local Warning signal number –IV	A storm (of depression intensity, associated sustained winds 51-61 kph (28-33 knots)) or Nor'wester squalls (of wind speed 51-61 kph (28-33 knots) is likely to strike you (vessels of length 65 feet or less are to seek shelter immediately
3	Danger Signal –VI	A storm of moderate Intensity or Nor’wester squalls, associated sustained winds 62-88 km/h (34-47 knots) may strike you. All vessels are to seek shelter immediately and keep in shelter till further notice.
4	Great Danger Signal –VIII	A violent storm or Nor’wester, associated sustained wind 89-117 km/h (48-63 knots) may strike you. All marine vessels have to keep in shelter till further notice.
5	Great Danger Signal –IX	A very severe cyclonic storm with very high intensity with sustained wind 118-170 km/h (64-119 knots) may strike you. All marine vessels are to be in shelter till further notice.
6	Great Danger Signal –X	A very severe cyclonic storm with the intensity of super cyclone with sustained wind of 171 km/h or more (120 knots or more) may strike you. All marine vessels are to be in shelter till further notice.

Table 5.3: A typical example of weather forecast from BMD which is valid for 12 hours.

Divisions	Forecast
Dhaka	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Dhaka city 29.2°C Today's minimum temperature of Dhaka city 26.6 °C
Chittagong	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Chittagong city30.0°C Today's minimum temperature of Chittagong city 26.0°C
Rajshahi	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Rajshahi city 30.8 °C Today's minimum temperature of Rajshahi city 25.5°C
Rangpur	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Rangpur city 26.5°C Today's minimum temperature of Rangpur city 24.6°C
Khulna	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Khulna city 32.0°C Today's minimum temperature of Khulna city 26.5°C

Barisal	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Barisal city 28.0°C Today's minimum temperature of Barisal city 25.4°C
Sylhet	**Sky:** Partly cloudy to cloudy. **Weather**: Light to moderate rain/T.showers accompanied by tempo. gusty wind is likely to occur at many places over the area with moderately heavy falls at places. **Temperature:** Day and night temperature may remain nearly unchanged over the area. Yesterday's maximum temperature of Barisal city 31.6°C Today's minimum temperature of Sylhet city 25.0°C

CHAPTER 6
PEOPLE'S PERCEPTION ON PRESENT WARNING SYSTEMS

Initial Findings from field: Two field visits with a total of five days were done by research team. Preliminary findings from these two field visits are given below-

First Field Visit:

A field visit of three days took place at different locations of cyclone affected areas of Khulna from 09.03.2012 to 11.03.2012 to check the effectiveness of warning system and find its weak points, lacking, etc. For this purpose, six key informant interviews, one group discussion with local people, one focus group discussion with high school teachers and one informal interview with a local resident held at different locations of Khulna. Kalipur village of Kamarkhola union, Pankhali village of Dakob Union, Dakob Sadar Upazilla, Khulna city, Jessore are the places where the PRA tools are applied to gather information from local people, local government and non government officials etc.

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A list of the PRA tools applied in this field visit has been given in table 6.1:

Table 6.1: list of the PRA tools applied in the field visit

Serial No	Location	Methodology	Type of respondents
1	Pankhali Village, Dakob Thana	Group Discussion	Family members of crab harvesters, fishermen, grocery shopkeepers
2	Kalinagar Village, Kamarkhola Union	Key Informant Interview	Uma Shankar Roy, Chairman of Kamarkhola Union
3	Kalinagar High School, Kamarkhola Union	Focus Group Discussion	High School teachers
4	Kalinagar Village	Informal Interview	Local resident
5	Dakob Sadar Upazilla	Key Informant Interview	Nazrul Islam, Monitoring and Documentation Officer, USS(Ulashi Shrijonshil Shangstha)
6	Khulna city	Key Informant Interview	Mr. Bishwanath Roy, Coordinator, PRODIPON
7	Khulna city	Key Informant Interview	Sub divisional Engineer and Sub Assistant Engineer, BWDB
8	Khulna city	Key Informant Interview	Mr. Md. Faruq Ahmed, Rupantar
9	Jessore	Key Informant Interview	Disaster Management Officer, USS (Ulashi Shrijonshil Shangstha)


Figure 6.1: A FGD with High School Teachers at Kalinagar High School, Kamarkhola Union


Figure 6.2: Key Informant Interview (KII) with an employee of Dakob Upazilla Livestock office

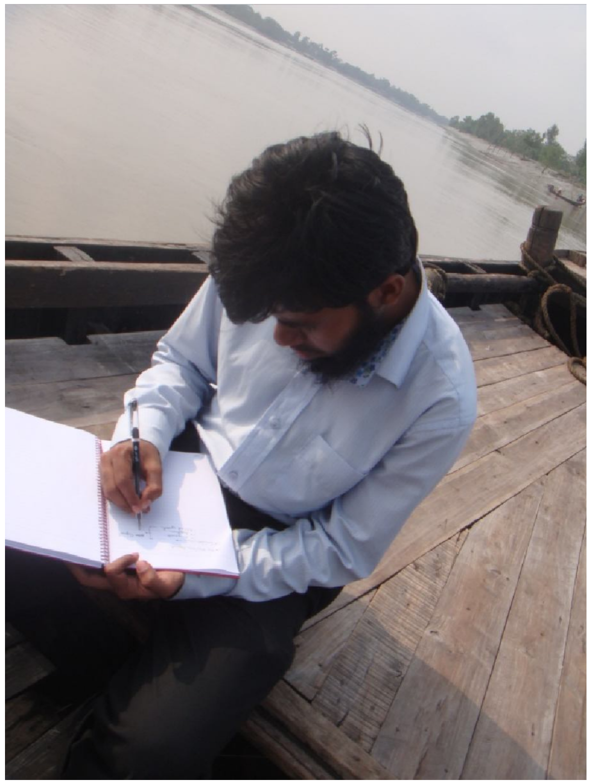


Figure 6.3: Information collection by one of the research team members

Second Field Visit:

Second field visit of two days took place at Shyamnagar, Shatkhira, the most severely affected area by cyclone Aila from 26th September to 27th September, 2012. The target of this field visit is to check the effectiveness of warning system and find its weak points; lacking, etc. in addition with the observation of a NGO's (Practical Action) work in weather broadcasting system.

Satkhira is not a cyclone prone area and before Aila, its people hardly have an experience of cyclone. Government's Cyclone Preparedness Program was not at all effective at Shatkhira. So, the cyclone Aila brought sudden inexperienced miseries, knows no bound. After Aila, this particular place becomes the centre of working place of many NGO's. An International NGO, Practical Action has established a weather forecasting board in the Atulia union office, Shyamnagar, Shatkhira. The message of this forecasting board is easily understandable by the local community and is a good example of dissemination of warning system.

Figure 6.4: Weather Forecasting Board (a project of Practical Action) at Atulia Union of Shyamnagar, Shatkhira

Discussions with local people were conducted by using PRA tools to get their views about the warning system. It was found from the recent field visits at Aila and Sidr affected areas that local people's responses were not all through similar to warning messages. Many of the local people of Shyamnagar Upazilla, one of the most affected areas by Cyclone Aila, didn't have any idea before the cyclone. Again the local people of Kamarkhola Union, Dakob Sadar Union got the warning messages of cyclone timely but they were very reluctant to response. Although a review of cyclone tracks show that the landfall of cyclones may happen on any place in 700 km long coastline of Bangladesh, but CPP are not equally effective all along the coastal area.

The following initial key findings can be made from this ongoing study-

- Flood forecasting has maximum lead time of 72 hours (3 days). However, the present flood warning system is provided only for the rivers. No information is available for the location specific land inundation due to floods.

- Long and medium durational flood forecasting information is essential for farmers and fishermen.

- Weekly agro-meteorological forecast is presently circulated from BMD. However, the information was not found adequate and not provided for specific locations.

- There exists no long term agricultural calendar considering weather information. Development of such calendar is crucial for the sustainability of agriculture sector and for food security of the country.

- BMD is able to deliver the cyclone forecasting information to the local people. However, there accuracy of information suffers greatly. At present no operational storm surge information has been provided for the coast areas of Bangladesh.

- The present cyclone warning system is for the marine and rivers only. However, adequate information and warnings on the impact of cyclone over land are missing.

- The seasonal rainfall forecasting is essential for farmers for selecting crop types, plantation and harvesting time. It can also help decision makers and planners which can ensure food security of the country. Present agro-climate forecasting is only for one week which is not sufficient.

- The flood forecasting provides water level above danger level. However, transferring this information to the local administrative level with respect to local datum is important. It is also essential to improve lead time of flood forecasting.

- As Bangladesh is located lower riparian of the Ganges-Brahmaputra-Meghna delta, cooperation with the neighboring countries (e.g. India, Nepal) for data and information sharing is essential for accurate flood forecasting. Under the present agreement with FFWC, water level information is available for the Ganges and Brahmaputra River for a few upstream locations. Basin-wise real time data sharing and exchange are essential to manage flood related disasters.

Suggestions to improve warning messages:

i. Signal/flag can be mounted on the top of tower/ tall buildings
ii. BWDB works for embankment should be quality controlled
iii. Mobile Technology: Voice Message, bangla sms could be some effective ways warning dissemination system.

Limitations / constraints and opportunities:

The present warning systems have many limitations despite the success of saving more lives during cyclone than in the past. A list of major limitation of disseminating weather forecast has been listed below.

- The present cyclone warning system is based on considering the river and marine conditions, ports and navigations. However, this system suffers from providing useful information about the devastations on the land.
- The current warning system is not found very accurate in terms of providing storm surge height. It also doesn't provide any location specific surge information.
- Flood forecasting presently provide short durational warning for the major rivers of the country. However, translating the information from the technical people to the local community is not found. It is also important to increase lead time of flood forecasting for agriculture and other sectors.
- The increase and decrease of water levels of floods with respect to the local datum is not provided.

- Seasonal forecast is essential for the farmers. BMD currently provided weekly agro-meteorological forecast for various regions of Bangladesh. However, location specific agro-meteorological weather forecasting is needed for farmers.
- Information about risks and hazards for the community is not presented with the present warning system. It often doesn't provide information about the preparedness for the weather hazards. Although a number of NGOs and volunteers are working during the cyclone, it is essential for providing such kinds of services for other weather related disasters (e.g. floods, droughts etc.).
- Under the present agreements with Indian Govt., FFWC has received daily water levels for a few gauge stations on the Ganges and Brahmaputra River. However, this information is not sufficient for designing basin-wise flood forecasting information system for Bangladesh.

CHAPTER 7
CASE STUDIES

7.1 Case Study 1- The Brahmanbaria tornado on March 22, 2013:

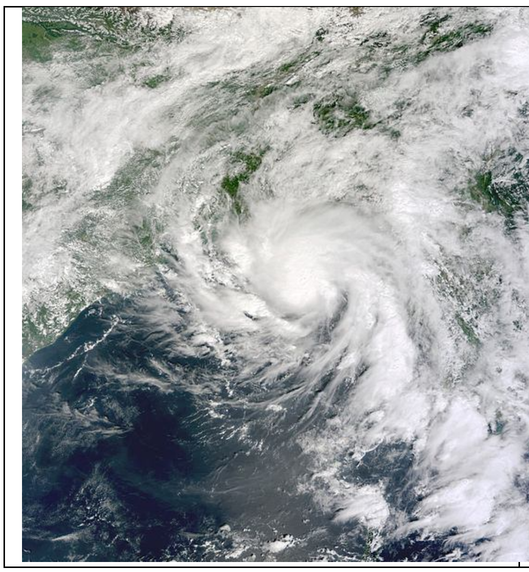
The Brahmanbaria tornado 2013 was a deadly tornado that took place in the Brahmanbaria District, of Bangladesh on March 22, 2013. The tornado struck 20 villages with along an 8 kilometres (5.0 mi), traveling at a speed of 70 kilometres per hour (43 mph) killing 31 people and injured approximately 500.The worst damage damage occurred in the Bijoynagar and Akhaura, Bangladesh Upazila of this district. Thousands of trees and utility poles were toppled and thousands of peoples were left homeless. The tornado disrupted both train and road communication, which interrupted rescue operations. Part of jail house of this district was collapsed, resulting in the death of one guard. Many crops, mostly consisting of rice, were damaged as well (The Daily Star, March, 2013)

Figure 7.1: The devastation in Chinair village of Brahmanbaria sadar upazila left by the 15-minute tornado which ripped through 20 villages of the district's three upazilas on Friday evening (Figure courtesy: The Daily Star)

Assessment of Warning System: It is very difficult to predict a tornado and its path that will hit the ground. In general BMD provides warning messages for tornado in such a way that covers a wide range of area. It identifies the locations where the environment conditions are favorable to form tornado. Forecast based on specific location with lead time is yet to achieve. The most precarious thing is that there is very little time gap between tornado formation and tornado attack. Today the average lead time for tornado is 13 minutes. Suitable hiding places (e.g, basement) are as important as good warning system.

7.2 Case Study 2: Tropical Storm on the southeast coast of Bangladesh on 11th October 2012

At least 30 people were dead, 57 left missing and 106585 were affected after a tropical storm swept through Bangladesh's coastal areas at 2200 hours of 10 October 2012. The tropical storm that lashed several sub-districts of Noakhali, Bhola, Chittagong and Cox's Bazar districts, ravaged many houses, uprooted trees and damaged standing crops which are leading to temporary human displacement and threats to food security (as per reported by Oxfam). Strong squalls on the coast had prevented fisherman returning to shore, leaving many missing in the bay, private broadcaster Radio Today reported. Police said at least 1,500 mud, tin and straw-built houses were also leveled in the storms that swept Bhola, Hatiya and Sandwip Islands and half a dozen coastal districts after Wednesday midnight. At the worst-hit island of Hatiya, at least five people were killed after they were buried under their houses or hit by fallen trees, said local police chief Moktar Hossain. More than 1,000 houses were flattened. The police chief of Bhola district, Bashir Ahmed, told *AFP* more than 500 fishermen were missing from the country's largest island and at least 500 mud and straw-built houses were leveled by the sudden storm (bdnews24.com, 2012).



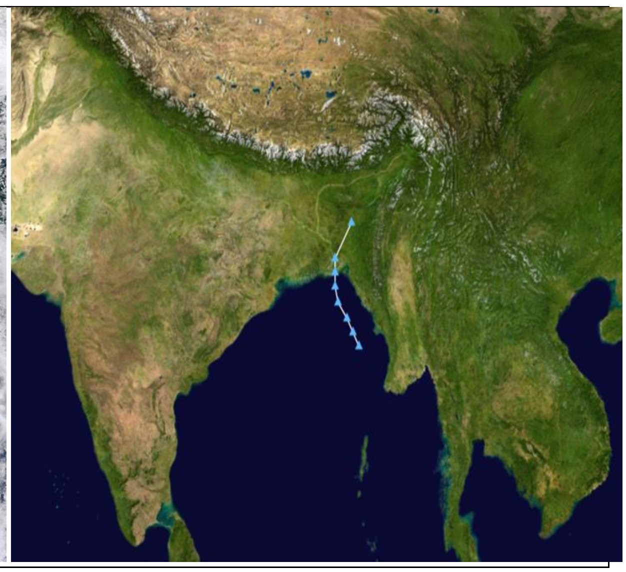


Figure7.2 : BOB 01 Oct 10 2012Figure7.3: BOB01 2012, Source: Wikipedia, 2012
Source: Wikipedia, 2012

Assessment of warning system: The Bangladesh Meteorological Department (BMD) failed to warn beforehand the people living in the country's coastal areas of the storm that battered them in the early hours of Thursday (news.priyo.com, 2012). Bangladesh's weather office forecast heavy rain in the coastal region and advised fishermen to approach the shore and take care. But there was no major storm warning.

On 11 October 2012, Bangladesh Meteorological Department issued warning message advising to keep hoisted local cautionary signal no. THREE (R). The coast crossing Monsoon depression of Chittagong coast near Hatiya – Sandwip has completed crossing the coast at 0900 of 11 October 2012 (reliefweb.int, 2012).

The Met office which had advised the coastal districts to hoist the number 3 local cautionary signal because of active movement of clouds accompanied by wind having a speed of 30 to 40 kilometers per hour. But indifferent met officials failed to notice the depression that was brewing in the Bay of Bengal for the last couple days and showing signs of gaining further strength. But the Bulletin issued by the Indian Met office at 22.00 hours on Wednesday (October10) warned about the depression intensifying further (news.priyo.com, 2012)

The Bulletin, put at the website with satellite imagery, read: The latest satellite imagery indicates that a depression has formed over northeast Bay of Bengal and lay centred at 20.30 hours IST (Indian standard time) of today, the 10th October, 2012 near latitude 21.00N and longitude 91.0 OE, about 350 km northeast of Kolkata (WB), 150 km southeast of Khepupara (Bangladesh) and 150km south of Hatia (Bangladesh). The system is likely to intensify further, move northwards and cross Bangladesh coast near Hatia by tomorrow, the 11th October, 2012 morning (news.priyo.com, 2012).

Experts said had the BMD officials followed the satellite images keenly Wednesday evening that could have warn people in the coastal areas to take adequate preparation against the impending danger. Fishermen in the coastal belts alleged that they had received no warning from the local administration or the Red Crescent about the impending danger. This has led to the missing of hundreds of fishermen in the Bay, he said (news.priyo.com, 2012).

7.3 Case Study 3: Tsunami Warning on 11th April, 2012 and 12 September, 2007

In recent years, two Tsunami warning messages came for Bangladesh. The first one is on 12 September 2007 and the other one is on 11th April, 2012.

Tsunami warning was announced on 12 September, 2012 in Cox's Bazaar district in southeast Bangladesh. Among those who evacuated, most people heard the warning announced through loud speakers or 'miking'. Around 74% of the inhabitants on the mainland and 75% on the islands reported that the tsunami alert and evacuation message reached to them through miking (Table 4). The telephone was least used on both the mainland and the islands. Other media included radio or television and neighbours. Total time required to evacuate is a matter of concern because it determines effective evacuation process to move households to shelters as soon as they receive the tsunami warning. It was found that on average, households took 1 hour 15 minutes to evacuate. The average time the respondents on the mainland took to evacuate was 1 hour 11 minutes, while it was 1 hour 18 minutes for island inhabitants to evacuate. This is of significant concern since people need to be able to evacuate within 20 minutes of hearing a warning of a local tsunami according to experts at the Earthquake and Tsunami Preparedness project as mentioned in the beginning of the report (bdnews24.com, 2012).

Another false Tsunami warning was issued by The PWTC and the JMA that the costal district of Chittagong may experience a tsunami wave at 10:51 pm Wednesday (on 11th April, 2012)
The tsunami warning came in the wake of an earthquake followed by aftershocks that jolted various parts of the country, including the capital, triggering widespread panic among people.
According to the PWTC, the earthquakes of this size have the potential to generate a widespread destructive tsunami that can affect coastlines across the entire Indian Ocean basin (bdnews24.com, 2012).

Though the Pacific Tsunami Warning Center (PWTC) and Japan Metrological Agency (JMA) issued a tsunami warning for the country's coastal belt, local experts said Bangladesh is unlikely to be affected by any tsunami wave (bdnews24.com, 2012).

Prof Dr Humayun Akter, head of the Earthquake Observatory Centre, told UNB after Wednesday's earthquakes that Bangladesh will remain safe from any devastating tsunami. "The tsunami route is East-West. Bangladesh is situated at the north of Indonesia. So, Bangladesh will remain safe from tsunami," said Dr Humayun (Samad, 2012).

Assessment of Warning System: an attempt by BRAC (RED) was made to assess the impact of an inaccurate tsunami warning on 12 September, 2012 as well as whether the impact made any difference on the mainland as opposed to islands assuming that those living on islands are more vulnerable because of their geographical location. Overall, most people in the area were evacuated after hearing the tsunami warning over miking. This suggests that miking is perhaps the most efficient way to reach people. It also suggests that most people are risk averse, and therefore, would pay heed to the warning. Inhabitants in the tsunami prone areas need assistance to respond to warnings, particularly those on islands and large families. Unfortunately, evacuees did not receive any help from cyclone preparatory programme (CPP) but relied on neighbours for assistance. CPP should play a greater role since they are more likely to be efficient in providing help (Tasneem and Chaudhury, 2007).

For Tsunami Warning on 11 April, 2013, the Bangladesh Meteorology Department asked all related agencies to be watchful from 3 pm to midnight for the sake of precautionary and safety of the coastal people. The Dhaka met Office has withdrawn tsunami alert on Tuesday at about 6:40am after it had issued in Bangladesh after a major earthquake of magnitude 7.6 struck in the Indian Ocean off India's Andaman Islands (Tasneem and Chaudhury, 2007).

7.4 Case Study 4: Cyclone Mahasen on 16th May, 2013

The recent cyclone Mahasen hit the coastal areas of Bangladesh, destroying thousands of huts and forcing up to a million people to flee.Officials had prepared for a cyclone, but the storm, called Mahasen, weakened considerably before making landfall. The United Nations had warned that 8.2 million people were at risk from Mahasen in Bangladesh, Burma and north-east India.Several Indian states issued storm alerts and warned people to take precautions against severe weather conditions (BBC, 16th May, 2013). It affected Chittagong, Noakhali, Borguna, Patuakhali, Bhola, Pirozpur, Laxmipur, Satkhira and killed a total number of 17 people (CDMP, 17th May, 2013).

Assessment of Warning System:

The key feature of this cyclone Mahasen was that it changed its track at the end moment.

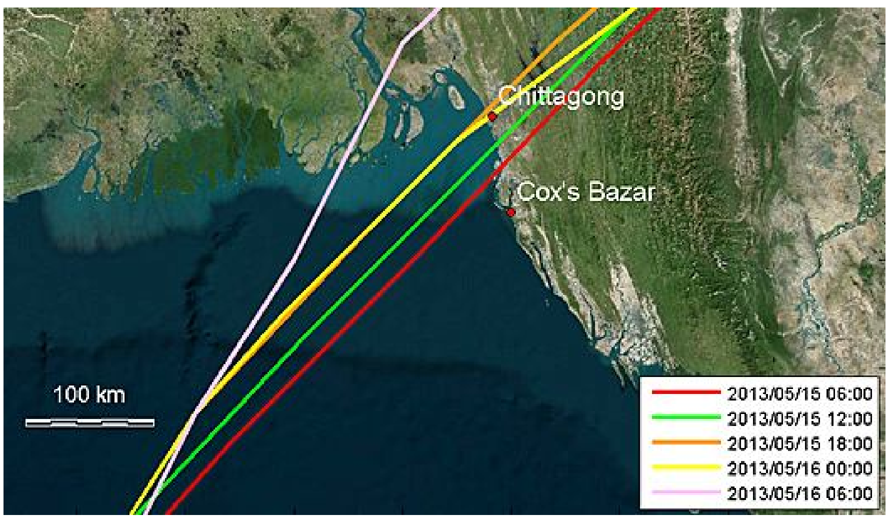


Figure 7.4: During the final 24 hrs before landfall at 06.00 hrs, the cyclcone's track changed 100 km to the west (map by Deltares)

International: Just before landfall the cyclone changed its track some 100 km to the west. "That would have resulted in a higher tide in the Meghan river delta, if not for the landfall to coincide with the low tide", says Maarten van Ormondt of the research institute Deltares.Ormondt followed the cyclone's track and made some simulations of the storm surge: "The surge lies somewhat right of the track and would have pushed more water up the funnel-shaped Bay of Bengal, and into the river delta.".Mahasen was predicted to head for the more eastern coastal city Chittagong. Here the cyclone had hardly any influence on the high tide. The tidal monitoring data of Chittagong the cyclone only shows up during the low tide. Because of the conjunction with the storm surge, the low tide was a little less than normal (Dutchwatersector, 2013).

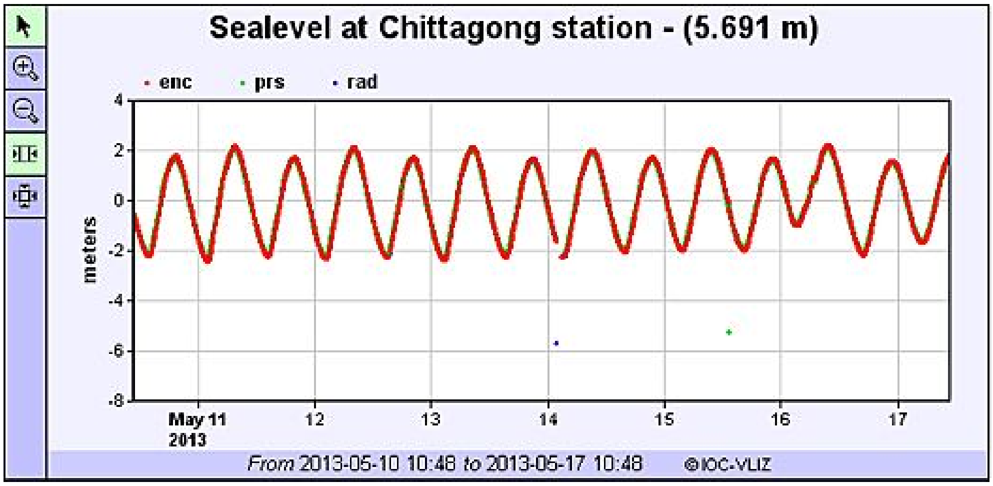


Figure 7.5: Mahasen made landfall in the early morning of 16 May some 100 km west of the coastal city of Cittagong where the low tide was a little less than normal (Source: Dutchwatersector, 2013).

Constantly changing storm surge

Mahasen showed how difficult it is to predict the impact of a storm surge. Changes in wind speed, track and conjunction with the high tide have a big influence. Mathijs van Ledden of engineering consultant Royal HaskoningDHV was involved in the activities during the aftermath of hurricane Katrina that hit New Orleans in 2005. He affirms the difficulty for emergency authorities to react to the constantly changing situation. According to Van Ledden such a quick assessment is of crucial importance when it comes to taking preventive measures (Dutchwatersector, 2013).

Uncertainty over precise track

During the week different weather models predicted different tracks for the cyclone.Most recent forecasts show a track more to the north and resulting in the Deltares model to an even lower storm surge.

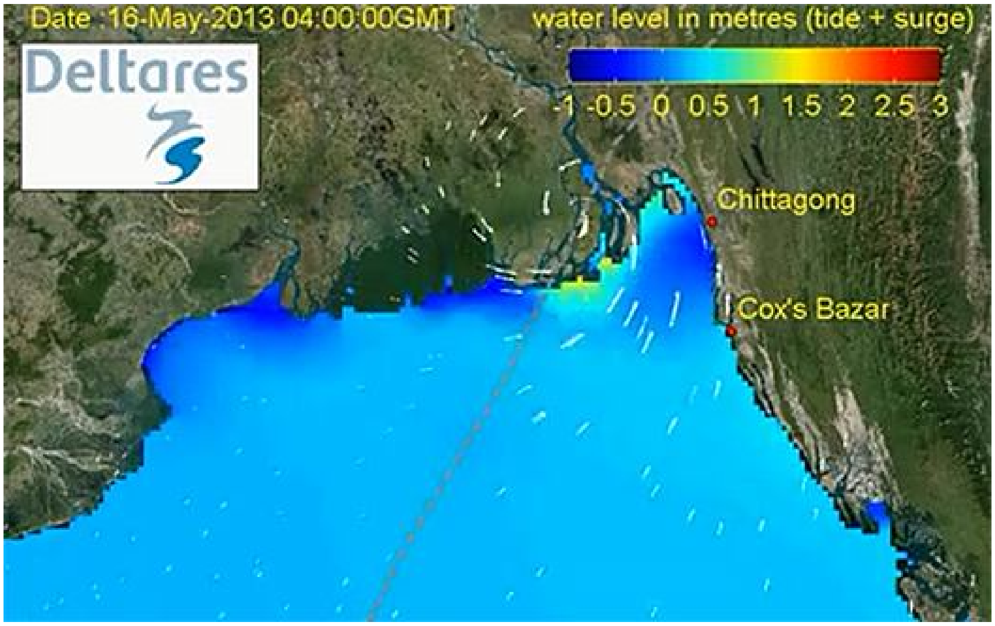


Figure 7.6: Deltares Model output for cyclone Mahasen

According to the latest model calculation by Dutch research institute Deltares the cyclone Mahasan will produce a storm surge of 1 to 1.5 meter along the coast between Chittagong and Cox-Bazaar.Earlier this week when the cyclone was building up over the Northern part of the Indian Ocean a storm surge of 5 meter was predicted (Deltares, 2013).

Assessment of BMD: BMD has also failed to detect cyclone path.

The Bangladesh Meteorological Department have advised maritime ports of Chittagong and Cox's Bazar to keep hoisted danger signal number seven (r) seven.

- The BMD have also advised the coastal districts of Cox's Bazar, Chittagong, Noakhali,
  Laxmipur, Feni, Chandpur, Bhola, Borguna, Patuakhali, Barisal and their offshore islands
  and chars to keep hoisted danger signal number seven (r) seven.
- Maritime port of Mongla has been advised to keep hoisted danger signal number five (r)
  five.
- The coastal districts of Pirozpur, Jhalokathi, Bagherhat, Khulna, Satkhira and their offshore islands and chars will come under danger signal number five (r) five.

CHAPTER 8
CONCLUSION AND RECOMMENDATION

8.1 Review of warning disseminations

Weather, cyclone and agro-meteorological warnings issued by BMD and floods warning by the FFWC of BWDB are reviewed. The following initial key findings can be made from this ongoing study-

- Flood forecasting has maximum lead time of 72 hours (3 days). However, the present flood warning system is provided only for the rivers. No information is available for the location specific land inundation due to floods.

- Long and medium durational flood forecasting information is essential for farmers and fishermen.

- Weekly agro-meteorological forecast is presently circulated from BMD. However, the information was not found adequate and not provided for specific locations.

- There exists no long term agricultural calendar considering weather information. Development of such calendar is crucial for the sustainability of agriculture sector and for food security of the country.

- BMD is able to deliver the cyclone forecasting information to the local people. However, there accuracy of information suffers greatly. At present no operational storm surge information has been provided for the coast areas of Bangladesh.

- The present cyclone warning system is for the marine and rivers only. However, adequate information and warnings on the impact of cyclone over land are missing.

- The seasonal rainfall forecasting is essential for farmers for selecting crop types, plantation and harvesting time. It can also help decision makers and planners which can ensure food security of the country. Present agro-climate forecasting is only for one week which is not sufficient.

- The flood forecasting provides water level above danger level. However, transferring this information to the local administrative level with respect to local datum is important. It is also essential to improve lead time of flood forecasting.

- As Bangladesh is located lower riparian of the Ganges-Brahmaputra-Meghna delta, cooperation with the neighboring countries (e.g. India, Nepal) for data and information sharing is essential for accurate flood forecasting. Under the present agreement with FFWC, water level information is available for the Ganges and

Brahmaputra River for a few upstream locations. Basin-wise real time data sharing and exchange are essential to manage flood related disasters.

8.2 Suggestions to improve warning messages:

The following suggestions can be made based on initial finding of this study:

- The warning system should be designed to provide useful information about the devastations on the land.
- It is essential to developed institutional capacity for providing accurate information using high speed cluster or super computers to simulate numerical weather, storm surge and flood predictions models. Recently, IWFM, BUET has taken initiatives to simulate real time weather information using WRF model and storm surge information using FVCOM model. These couple models will provide location specific weather forecasting and storm surge height information over Bangladesh coast with a lead time of 5-days.
- Flood forecasting presently provide short durational warning for the major rivers of the country. However, translating the information from the technical people to the local community is important. Signal/flag can be mounted on the top of tower/ tall buildings.
- Mobile Technology such as Voice Message, SMS (in Bengali) could be some effective ways warning dissemination system.
- It is also important to increase lead time of flood forecasting for agriculture and other sectors. Seasonal forecast is essential for the farmers. BMD currently provided weekly agro-meteorological forecast for various regions of Bangladesh. However, location specific agro-meteorological weather forecasting is needed for farmers.
- Information about risks and hazards for the community is essential. It often doesn't provide information about the preparedness for the weather hazards. Although a number of NGOs and volunteers are working during the cyclone, it is essential for providing such kinds of services for other weather related disasters (e.g. floods, droughts etc.).
- Basin-wise flood forecasting information system for Bangladesh is essential for major rivers: The Ganges, Brahmaputra and Meghna.

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