Modelling Approach in Climate Impact Assessment for the Bangladesh Coastal Area

J. Md. Abdul Hye and Md. Mahboob-ul-Kabir,

Surface Water Modelling Centre SWMC, Dhaka, Bangladesh (jalal@swmc.bangla.net)

Abstract The sea level along the Bangladesh Coast is rising about 3 millimetres a year, and the sea surface temperature is showing a rising trend. The landmass of Bangladesh is connected to the Bay of Bengal through a 700km long coastline. The coastal region is marked by a network of river systems, an ever dynamic estuary, interaction of huge quantities of fresh water that are discharged by the river systems, and a saline waterfront – penetrating inland from the sea. The estuarine zone has ample bio-diversity, vast vegetated land and, above all, an agriculture dependent massive population. Climate change can impart the impacts on the coastal region in respect of drainage, fresh water availability, morphological processes, and extreme events. In respect of assessing the climate change impacts on the mentioned fields numerical modelling is a useful and versatile approach. A suite of one dimensional and two dimensional models based on MIKE11 and MIKE21 software of the Danish Hydraulic Institute has been used to assess the following impacts on the coastal area of Bangladesh due to climate change: (1) Change in drainage and water logging problems in the coastal area due to combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher river bed levels and reduced sedimentation in flood protected areas (2) Availability of fresh water due to low river flows and increased evapo-transpiration combined with sea level rise, saline water intrusion in estuaries and into the groundwater and (3) Bank erosion and bed level changes of rivers and estuaries as well as the balance between river sediment transport and deposition in rivers, floodplains and coastal areas.

Keywords: Climate; Coast; Bay of Bengal; Numerical modelling; Floodplains; Saline; Rivers; Drainage

1. INTRODUCTION

This paper presents the impacts of climate change scenarios on coastal hydrology and salinity as obtained from the results of two dimensional and one dimensional numerical models as developed by Surface Water Modelling Centre (SWMC).

Climatic change due to global warming is a reality for Bangladesh. The coastal zone will be affected by all the key risks. These include drainage congestion due to higher water and river bed levels, and reduced sedimentation in floodplains; salinisation of land and water resources due to lower river flows during dry season, and higher relative sea levels aggravated by subsidence; increased morphological dynamics with erosion of rivers and coasts not compensated by accretion of land of equal quality; more intense disasters including cyclones and storm surges with higher risks because of higher water, and lower land levels in protected areas.

A World Bank Report [World Bank, 2000] has documented likely scenarios for Bangladesh, based on IPCC (Intergovernmental Panel on Climate Change) Assessment Report [IPCC, 1996]:

- A 0.7^0 C surface temperature rise in monsoon and a 1.3^0 C rise in winter by 2030
- Increasing monsoon precipitation and decreasing dry season precipitation. A 10% increase in precipitation may increase run-off depth by one-fifth, and the probability of an extremely wet year by 700%. This will alter hydrological behaviour of the GMB (Ganges-Meghna-Brahmaputra) basin.
- Sea level along the coast is rising by about 3 millimetres a year. With linear estimates, the sea level rise could be 15cm by 2050. Even a very cautious projection of 10cm rise would inundate 2500sq.km of Bangladesh.
- The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher river bed levels and reduced sedimentation will gradually increase water logging problems and impede drainage. This

effect will be particularly strong in coastal zone.

- Due to low river flows and increased evapo-transpiration, fresh water availability will be a serious problem. In the coastal zone, additional effect of saline water intrusion in the estuaries and in the ground water will be significant.
- Increased intensity of disasters including cyclones/storm surges, floods and droughts will become evident with climate change.

On the basis of Global Circulation Model (GCM) (Geophysical Fluid Dynamics Lab (GFDL), ver. 3.0, 1% transient model, 1995) Bangladesh Unnayan Parishad (BUP) [BUP, 2001] has assessed that for rainy season (June to October) the precipitation in 2025 and 2050 would be approximately 106% and 116% of the base year (1998-99) respectively. No appreciable change in evapotranspiration would occur during the rainy months. However, over the year the evaporatranspiration would increase by 2.08% and 5.67% in 2025 and 2050 respectively.

2. MODELLING APPROACH

Climate impact assessment for the Bangladesh coastal area has been carried out on the basis of the application of a two-dimensional Bay of Bengal Model (BoBM) [SWMC, 2001] and updated one-dimensional South West Region Model (SWRM) [SWMC, 1996]. BoBM and SWRM have been developed based on MIKE 21 and MIKE 11 software of the Danish Hydraulic Institute.

Application of hydraulic models can provide an indication to engineers and policy makers on the impact of climate change due to global warming and eventually establish guidance for undertaking or planning development actions. The role of mathematical model can be extremely crucial in the context of Bangladesh, where very large rivers carrying huge sediment-water mass to the bay and meteorological forces frequently turn into devastating shape. A reliable model can be very useful if the uncertainties involved are carefully studied and reduced.

2.1 Bay of Bengal Model

The Bay of Bengal Model developed under Meghna Estuary Study (MES) Phase II covers the northern half of the Bay of Bengal and runs with three model domains of different grid resolutions; 600m (fine), 1800m (intermediate) and 5400m (regional) grid spacing and they are nested so that the finest grid resolves the estuarine dynamics (Figure 1). Bathymetric information for the seabed has been obtained from MESI&II field surveying campaign and from Admiralty maps.

Water level at the deep ocean boundary in the south has been specified based on predicted tidal levels at Baruva in the Orissa coast, India and at Searle Point in the Arakan coast, Myanmar. The prediction has been made based on constituents defined in the British Admiralty Tide Table (ATT). A linear interpolation between the water levels has been made to define the southern boundary. The northern boundary was specified by adequately adjusted water level that was measured at the nearest station, Chandpur.

The model has been calibrated and validated for dry period 1999 and monsoon period 1997.

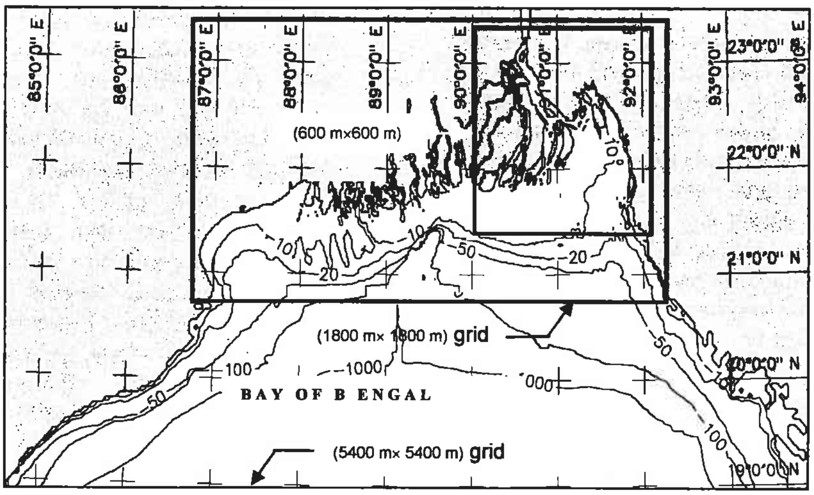

Figure 1. Nested model setup and boundary locations of Bay of Bengal Model.

2.2 South West Region Model

The South West Region Model (SWRM) is one of the six regional one dimensional river models of Bangladesh. This regional model has an extensive coverage of the river system including the tidal channels and estuaries extending upto the Bay of Bengal. The South West Region Model area is bounded on the north by the Ganges, Padma and Meghna, on the east by the Lower Meghna and Shahabazpur, on the west by the Indian border and on the south by the Bay of Bengal (Figure 2). The region model covers approximately 37,330-km^2. The SWRM has been validated on yearly basis since 1994 up to the hydrological year of 1997-98.

3. IMPACT ON MONSOON FLOW SPEED AND STORM SURGE

The Bay of Bengal Model as mentioned above has been applied in assessing the impact of climate change on flow speed and storm surge.
Two simulations were carried out with the changes as mentioned in Table 1 due to global warming and sea level rise as obtained from the Report on Considering Adaptation to Climate Change in the Sustainable Development of Bangladesh for monsoon 1997 and cyclone 1991.

The impact of climate change scenarios for Bangladesh in 2030 on the flow speed for monsoon 1997 condition is shown in Figure 3. It is seen that flow speed is increased by 5 to 15 percent in the bay area.

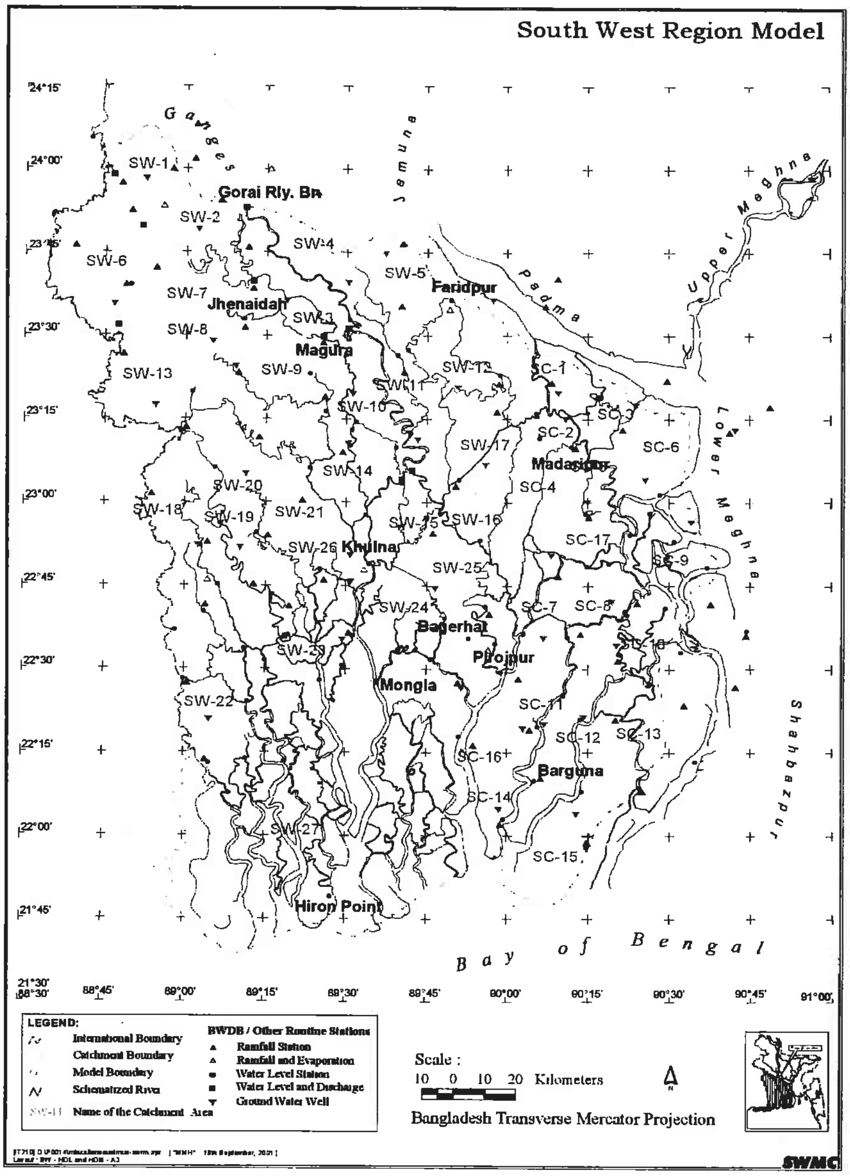

Figure 2. South West Region Model area.

Table 1. Simulation for climate change scenario for Bangladesh in 2030 during monsoon

Year	Sea Level Rise (cm)	Increase in discharge in the Meghna estuary in percentage	Increase in precipitation in percentage
2030	30	14 % during monsoon	7.5 % during monsoon

The simulation for 1991 cyclone shows that the surge height will be increased by 5 to 20 percent in the bay area.

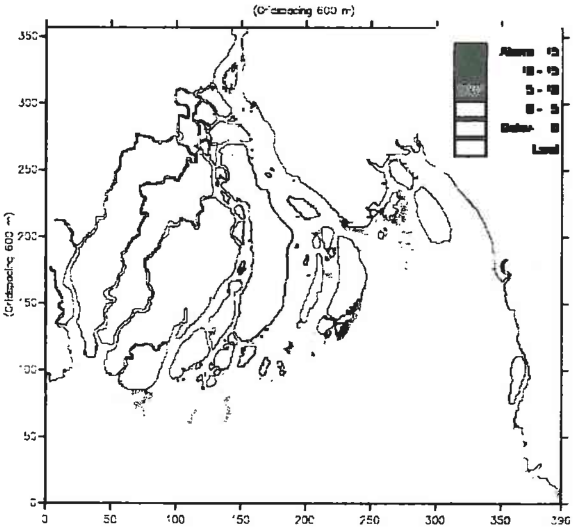

Figure 3. Impact of climate change on flow speed for 1997 monsoon.

4. IMPACT ON SALINITY

Climate change impact on salinity in the bay area has also been assessed with the help of the BoBM. Figure 4a and 4b presents the maximum salinity intrusion in the bay area under base condition and with climate change situation. Figure 4a shows that under base condition a large area maintains lower salinity level outside the river mouth while Figure 4b shows that the climate change has forced to increase the salinity level outside the river mouth.

5. IMPACT ON RUNOFF

A recent rainfall-runoff model study with the GCM predictions as mentioned above has been carried out for the south west region of Bangladesh. The rainy summers of 2025 and 2050 were represented in the model by increasing the base year rainfall (1998-99) by 6% and 16% respectively.

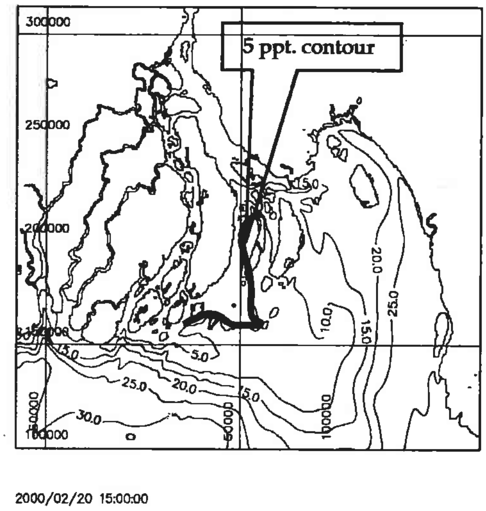

Figure 4a. Simulated maximum salinity intrusion for February 2000 for base condition.

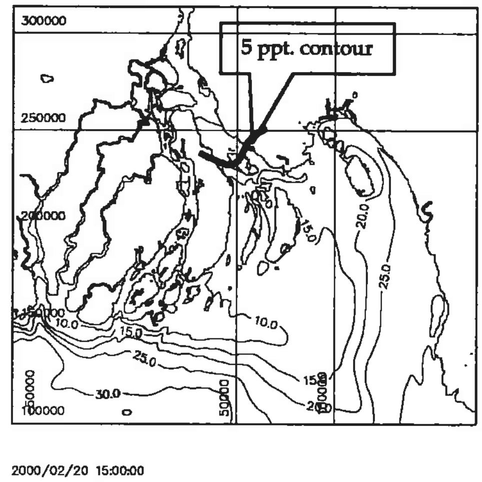

Figure 4b. Simulated maximum salinity intrusion due to climate change.

The same base year evapotranspiration was used for 2025 and 2050 as no considerable change in evapotranspiration is expected during the rainy months. The model simulates that there will be significant increase in runoff from the catchments; average increase of 8% in 2025 and 24% in 2050 compared to the base year. Of particular interest would be the increase in base flow, which continue for a longer period in the dry months of 2025 and 2050. A comparison of runoff from one of the catchments (SW-1) of south west area for the years 1998, 2025 and 2050 is shown in Figure 5 in the next page.

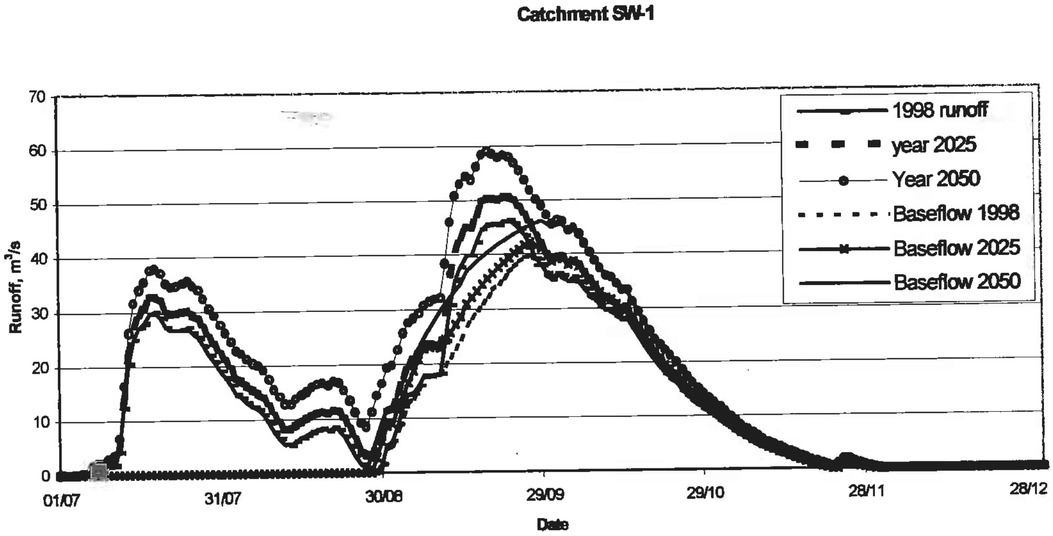

Figure 5. Comparison of runoff.

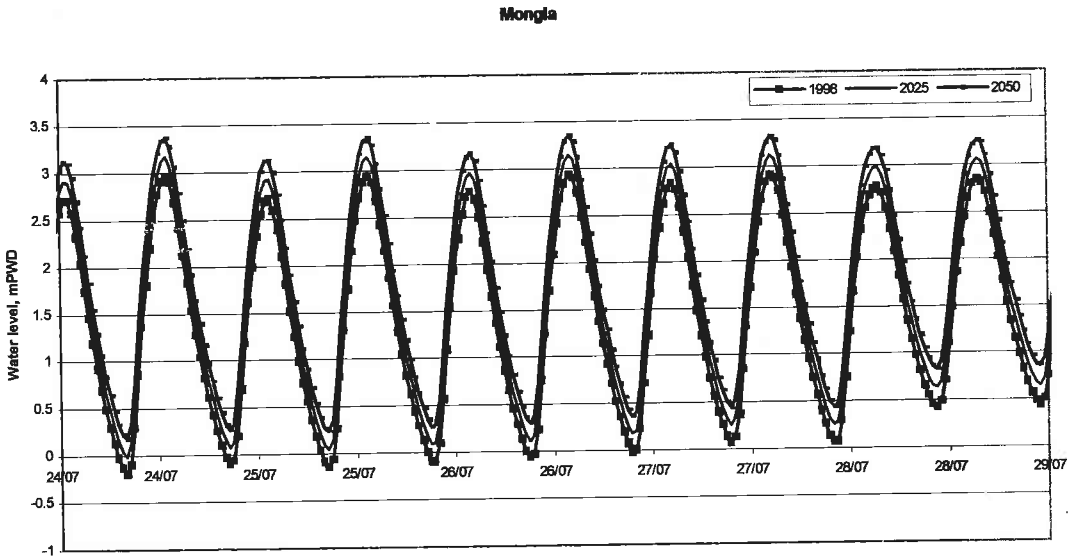

Figure 6. Comparison of water levels.

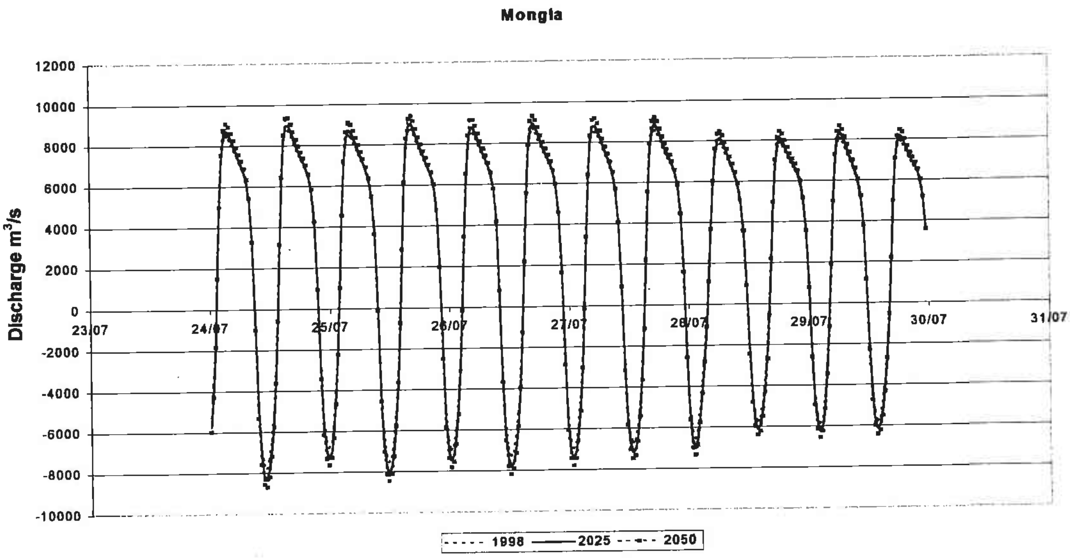

Figure 7. Comparison of discharges.

6. IMPACT ON WATER LEVEL AND DISCHARGE

The Global Circulation Model as mentioned above predicts that the sea level will rise by 0.23m and 0.44m in 2025 and 2050 respectively. One dimensional model simulations were performed with updated SWRM by adding the predicted rise to 1998 tidal boundary water levels and runoff simulated with increased rainfall for 2025 and 2050. The combined effect of sea level rise and increase in runoff volume has considerable impact on water levels and discharge in the area. Figures 6 and 7 in the previous page show a comparison of water level and discharge respectively at Mongla.

7. CONCLUSION

The Bay of Bengal Model has been applied to assess the impact of climatic change on storm surge, monsoon flow and salinity intrusion in the coastal area. It has been found that climate change would increase the 1991 surge height by 5 to 20 percent in the bay area. The change will also increase the monsoon flow speed by 5 to 15 percent. The climate change will force the salinity intrusion further in the estuary resulting higher salinity at the river mouths.

The updated South West Region Model shows that the climate change will increase the runoff of the area on average by 8% in 2025 and by 24% in 2050 in comparison to the base year of 1998. A significant impact will also be on water levels and discharge of the rivers of the area.

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