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Sea Level Rise: Some Debates on Global and Bangladesh Perspective

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Abstract: *Among the various discussions on climate change and its consequences, the debate on sea level rise has contributed the most. The differences in scientific assumptions have made the issue most disputed. The scientists have divided into their opinion on the history, causes and impacts of sea level rise. The causes of sea level rise in Bangladesh have also got involved in this debate. Despite the fact, that the coastal region of the country is facing disasters due to frequent cyclone and inundation of land, the reason of climatic change has not been established scientifically. Such ambiguity in scientific assumptions may have more impact on the environment of this region than the real impacts of sea level rise.*

1.0 Introduction

Over the last two centuries, global temperature has increased significantly. Particularly in the last 100 years (1906-2005) global temperature has increased around 0.74°C. Such temperature rise is warming the global atmosphere and increasing the air and ocean temperature as well as is melting ice sheets in polar region. As a result of these, sea level is continuing to rise (IPCC, 2007). It is predicted that global warming might raise the sea level over 2m in the next 100 years (Castro Ortiz, 1994). According to IPCC (2007), sea level rise due to global warming would bring disaster to human life and might destroy the ecosystem of the earth. Low laying developing countries are the most vulnerable under this scenario ((Douglas, 2001) due to huge economic loss and less adaptive ability. But the probability of such vulnerable future is diminished by the uncertainties embedded in the predictions. Also, compare to the other natural calamities like earthquake, cyclone or volcanic eruption; a long term effect of sea level rise appears to be less threatening. Such controversies have given rise of the debate, whether sea level would rise significantly to threat the human civilisation or not. Still,

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scientific analysis and recent trend in climate system shows clear indication of change (IPCC, 2007). This paper will focus on the history, scientific analysis and the effects of sea level rise considering the global scenario as well as on the perspectives of Bangladesh.

2.0 Climate Change and Sea Level Rise: Global Scenario

2.1 History of sea level rise

IPCC (2001) report reveals that during the last 20,000 years sea level has risen by over 120 m. This rise was mainly due to melting of glacial ice sheets. During the earlier phase of last glacial period (20,000-12000 years ago) the hydrological system of earth was interrupted by cool weather, resulting accumulation of sea water to icesheets. In the milder-glacial period (12,000-6000 years ago), a relative warm climate reversed the cycle and thus started melting ice sheets; significant sea level change occurred during this period. Last 6000 years can be considered as a period of Holocene, where the relationship between land and sea level was more or less stable (Bird, 1993, Morner, 1995). Since 1961, global sea level rose at an average rate of 1.8 mm per year. Rate of sea level rise in the last decade is even higher (3.1 mm) than the average rate. Scientific data also reveals that the rise in sea level is higher in 20th century compare to the rise in 19th century (IPCC, 2007). Figure 1 shows the trend of sea level change with temperature and snow cover.

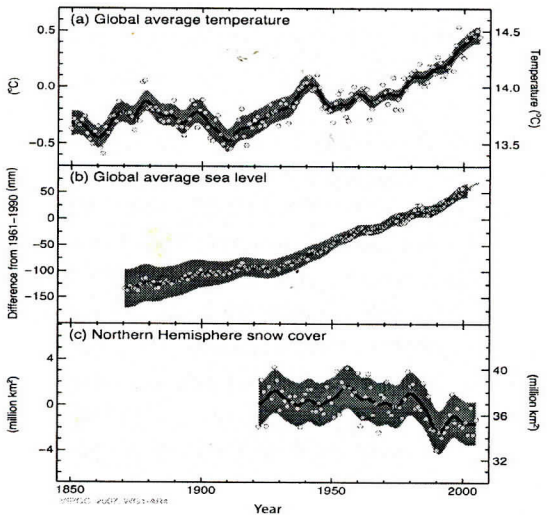

Figure 1: Sea level rise and snow cover decrease with the increase in temperature (Reproduced from IPCC (2007a), WG1 Fourth Assessment report, pp 6)

The graph represents a clear trend of sea level rise over the last 50 years with the increase in temperature. The snow cover is also showing a decreasing trend.

2.2 Causes of sea level rise

Sea level changes on different time scales; from seconds to million years. It also varies from region to region. The main reason for sea level change is the short term and long term changes in the climate system such as increase in ocean volume. Sea water rises when the volume of the water increases and falls when the volume reduces (Bird, 1993). Different factors contribute to the increase of sea water volume. Ocean volume can increase due to warming of ocean water and the water mass can increase due to melting of ice. Scientific observations reveal that global rise in temperature has increased the heat absorption rate of the oceans which has affected warming of sea water even to depths of 3000 m (IPCC, 2007). Such warming causes expansion of sea water, resulting to sea level rise. Moreover, salinity also plays a vital role in the expansion of sea water. With the increase in salinity in sea water the volume diminishes, and increases with the decrease in salinity (Bird, 1993, Wigley and Raper, 1993). Saline water does not exhibit maximum density at 4°C (Pugh, 2004). Rather sea water does not have a temperature of maximum density. Thus sea water at the colder region will have more density than sea water at the warmer region. If we consider the universal relationship among mass, volume and density i.e. volume= mass/ density; it reveals that a less dense water will have higher volume than that of a higher dense water. This is why; sea water at warmer tropics will expand more than the sea water at the cooler regions in a given temperature.

Along with thermal expansion, ice and snow melting in Greenland and Antarctic regions are also contributing to sea level rise (Hoffman, 1984, Warrick et al., 1996).Here, only melting of grounded ice should be considered because floating ice displaces its equivalent volume to the sea water (according to Archimedes principle). So melting of floating ice does not have impact on sea level change (Pugh, 2004). It is also necessary to consider that the mass of the sea water is controlled by the balance in ice forming and ice melting. Table 1 shows different sources and their contribution to global sea level rise

Table 1: Individual contribution to sea level rise

Sources of Sea Level Rise	Contribution (mm per year) (1961-2003)
Thermal Expansion	0.42±0.12
Glaciers and ice caps	0.50±0.18
Greenland ice sheet	0.05±0.12
Antarctic ice sheet	0.14±0.41
Total Sea Level Rise	**1.1±0.5**

Source: Reproduced from IPCC (2007), WG1 Fourth Assessment report, pp 7

Antarctica contains 91% of all the ice of the world. Greenland contains 8% of the total ice and the remaining 1% is stored in mountain tops as ice caps. The melting rate of ice sheet around Antarctica will largely depend on the availability of warm water in the local sea. The warm water will melt the glaciers around Antarctica which will pave the way for more warm water to reach the ice shelves beneath and eventually accelerate melting (Pearce, 1989). Snow and ice cover in the polar region reflects most of the sunlight. A decrease in snow and icesheet will increase more sunlight to be absorbed in the earth system and thus a warmer atmosphere (Pugh, 2004). Table 2 shows the sea level rise due to total melting of icesheet from different sources.

Table 2: Sea Level Rise Due to Total Melting of Iicesheet

Source	Increase in sea level due to total melting
Glaciers and small ice caps	0.4 m
Greenland ice sheet	7 m
Antarctic ice sheet	61 m

Source:(Pugh, 2004)

There are other contributors to sea level rise. Sea level also changes due to vertical land movements which includes isostatic adjustment, tectonic effects, sedimentation, human factors (groundwater and oil extraction) (Warrick et al., 1996). Tectonic movements caused sea level change in Algeria, Izmir region of Turkey, Timor and in New Guinea (Bird, 1993). Water removed from the sea and stored in other places like mountain ice cap or stored in underground or as permafrost or even sediment deposition contributes to sea level change. Some human activity like

using more underground water for irrigation and building reservoirs would even have effect in the change in sea level (Sahagian et al., 1994, Gornitz, 2001, Milliman and Mei-e, 1995).

There are also logics against the prediction of past and current sea level change. It is argued that global warming will not necessarily lead to a considerable sea level rise. Pugh (2004) stated different views about sea level rise; such as-

- Melting of mountain glaciers only contribute to 0.50 m sea level rise. Although a significant portion of mountain glaciers will remain on top even in warm conditions.
- Thermal expansion of sea water can only generate few centimetre rise of sea water. Only the surface water may become warm. It takes at least 1000 years to warm the bottom layer of sea water.
- During the warmer conditions of mid Holocene era, when the climate temperature was 1°C higher than the present temperature, sea water level was almost similar as present sea level. Moreover, Antarctica experienced glacial expansion during the mid Holocene warm period.
- There is no evidence that the land base glaciers in Greenland and Antarctica melted completely in the past two million years.
- A warmer atmosphere would evaporate more water to keep the sea level static (Pearce, 1989).

Despite such arguments, and the debate regarding the causes of sea level change, latest observation in the climate system reveals that the world is getting warmer day by day. Different low coastal regions are already facing flood, salinity and inundation of wet lands due to higher sea level (Schuurmans, 1995).

2.3 Consequences of Sea level rise

The consequences of sea level rise can be divided into two groups; physical consequences and environmental effect. Physical consequences include shoreline retreat, temporary flooding and salt intrusion. The most serious environmental effect would be inundation of wetland and marshlands and the ecological hazards therein (Titus et al., 1984). IPCC (2007) has expressed their concerns about the future disasters to human civilisation due to sea level rise particularly in the major river basins and

mega deltaic regions. Increased flooding with inundation of coastal low lands might force millions of people to migrate.

Sea level rise may cause coastal erosion especially in the sandy or shingle beaches (Wells, 1995, Bird, 1995). Although there are other factors involved in coastal erosion, but there are evidence that such beaches are eroding in recent years (Pugh, 2004). Coral reefs are also vulnerable to sea level rise. As coral polyps grow best at near surface water where there is better availability of sunlight. Their upward growth rate may not coup up with the continuous sea level rise and thus may result in less growth (Douglas, 2001, Pugh, 2004, Edwards, 1995). Coastal wetlands (mangroves) and marshlands acts as a sediment trap which stabilise sedimentary coastline. A study suggests that the rate of sediment accumulation in coastal wet lands is 2-3 mm/year depending on the availability of sediment (Pugh, 2004). A higher rate of sea level rise may bring disaster to this ecosystem by inundating the entire region.

Change in sea level will contribute a little to the tidal system. This change may have a larger impact in shallow water. Different factors along with sea level rise are also responsible for tropical storm; sea water temperature is on of those. It is evident that an increase in sea water temperature would increase the severity of storms which may cause flooding and other damages (Pugh, 2004).

3.0 Case Study: Sea Level Rise and Bangladesh

3.1 Sea level rise scenario and Causes

The climate system of Bangladesh is influenced by the existence of Himalayan range in the north and the Bay of Bengal in the south (Ali and Ahmad, 1992). The sea level movements of the coastal zone of Bangladesh are mostly dominated by local and regional factors including regional climate change and sediment accumulation (Islam and Tooley, 1999, Ahmad et al., 1996). Over the last 100 years the coastline of Bangladesh experienced both subsidences due to the pressure of thick layer of accumulated sediments as well as rise of sea level due to increased sedimentation. Both the effects virtually balanced the coastline from any gradual inundation (Kausher et al., 1996). A recent study reveals the fact that the sea level at western coastline of Bangladesh is raising around 7mm/year, which is far above the world average of 1-2 mm/year. There is no specific regional scenario for the mean sea level rise due to global climate change (Karim and Mimura, 2008). But from

different study it has anticipated that the sea level in the Bay of Bengal may rise at a range 30-100 cm by the end of 2100 (DOE, 1993, Agrawala et al., 2003). Thus, for predicting the future sea level change in the Bay of Bengal, it is important to analyse the vertical movement of land in this region as well as the impacts of global sea level change.

Bangladesh is located between two major tectonic faults of the earth. The active tectonic movements contribute to uplifting as well as subsiding of land areas in Bangladesh. Formation of the land area of Bangladesh is mostly dominated by sedimentary process over the last two million years. From a study it has revealed that some 5000 years ago the then Bengal region was a shallow sea or a lagoon (Fergusson, 1863). Due to uplift in the Himalayan region, erosion causes rocks and sediments to flow through different water ways towards the Bengal basin. Sediments accumulate in the sea bed which gives rise of the sea level and forms new land. At the same time new sediments also put pressure on the older sediments and thus cause land subsiding (Warrick et al., 1996).

Although sediment accumulation plays a vital role in determining the future sea level of Bangladesh, global climate change may also contribute to this. A study by National Adaptation Programme for Action (NAPA) on the basis of 3rd IPCC report and predictions of SAARC Meteorological Research Centre (SMRC), has established the likely climate change and sea level rise scenarios for Bangladesh. Table 3 illustrates those scenarios.

Table 3: Climate Change and Sea Level Rise Scenarios for Bangladesh

Year	Temperature Change mean (°C)		Precipitation change (%) mean		Sea level rise (cm)		
	Monsoon season	Dry season	Monsoon season	Dry season	3rd IPCC (upper range)	SMRC	NAPA
2030	0.8	1.1	+6.0	-2.0	14	18	14
2050	1.1	1.6	+8.0	-5.0	32	30	32
2100	1.9	2.7	+12.0	-10.0	88	60	88

Source: (NAPA, 2005)

Observed sea level is a combination of three factors: tidal level + surge level (weather effect) + mean sea level (MSL) (Pugh, 2004). For Bangladesh the rise in tidal level is very important due to its impact on the coastal socioeconomic activities and ecosystem. A study shows that there is a close relationship between surge duration and sea level rise (As-

Salek and Yasuda, 1995). Also, relationship has been found between southern oscillation index (SOI) and mean tidal level (MTL) of the main estuary (Meghna Estuary) of the country. An increase in rainfall due to El Nino Southern Oscillation (ENSO) will affect the tidal level at the estuaries of the main rivers of Bangladesh (Singh, 2002) resulting a significant sea level rise.

3.2 Effects of Sea level rise and possible responses

Bangladesh has an approximate 710 km long coastline. 21% people of the country live in the coastal region (Singh, 2002). This coastline is already facing the negative impacts of sea level rise. In the last few decades the problems regarding salinity intrusion, inundation of coastal low lands, cyclones as well as erosion became more severe than before (Sarwar and Khan, 2007). Due to global sea level rise, Bangladesh may loose one fifth of the land area. Table 4 shows the possible inundation of coastal land due to different range of sea level rise.

Table 4: Possible Inundation of Coastal Land Due to Different Range of Sea Level Rise

Sea Level Rise (m)	Inundation (Km^2)	Inundation of Sunderbans	% of total area
10 cm	2500	15%	2%
25 cm	6300	40%	4%
1.00 m	25,000	100%	17.5%

Source: (World Bank, 2000)

Coastal cyclones and surges are one of the major problems of Bangladesh (Ali and Ahmad, 1992, Ali and Chowdhury, 1999, Singh, 2002). Although the relationship between cyclone and sea level rise is uncertain (Ali, 1996), a study has shown that the severity of cyclone may increase due to temperature and sea level rise. Taking the April 1991 cyclone as base case, a model has been formulated to find the relationship among sea surface temperature, wind speed and sea level rise. Table 5 represents the outcome of the model in a brief.

Table 5: Outcome of the Model in Brief

	Current Temp. (27°C)	2°C Increase	4°C Increase
Wind (kmh-^{1})	225	248	275
No Sea level Rise Surge Height (% change)	7.6 m (0%)	9.2m (21%)	11.3m (49%)
Sea level rise 0.3m Surge Height(% change)	7.4 m (-3%)	9.1m (20%)	11.1m (46%)
Sea level rise 1.0m Surge Height(% change)	7.1 m (-7%)	8.6m (13%)	10.6m (40%)

Source : Reproduced from: (Ali, 1996)

The table shows that in a given temperature and wind speed; sea level rise decreases the surge height. At the same time temperature rise in sea water also affects the rise in wind speed and surge height. Comparing the effects of sea level rise and temperature rise on wind speed and surge height, it is clear that temperature rise plays a vital role in determining the severity of cyclone power and surge heights (Ali, 1996, Karim and Mimura, 2008). The future sea level rise may also offset the sediment accumulation in the coastal sea beds by "back-water effect". The ability of the rivers to carry sediments may decrease due to rise in water level at the bay (Kausher et al., 1996).

Mitigation as well as adaptation could be the two main categories for the responses of sea level rise (Smit et al., 1999). Preparation for future possible disaster, community involvement, research on salinity adaptive species (fisheries and crops) and corresponding policy implications like preparing Flood Action Plan is important for facing the upcoming challenges (Sarwar and Khan, 2007, Ericksen et al., 1996). Afforestation, carbon reduction scheme and steps to ensure normal flow of water in the rivers may also help to mitigate the effects of sea level rise.

4.0 Conclusion

Climate issues like sea level rise are complex in terms of prediction (Douglas, 2001). A number of factors are involved in this process. Current data and climate trend do not explain the exact contribution of each factor (Pirazzoli, 1993, Schuurmans, 1995). This is why a number of assumptions take place to interpret the trend. Such assumptions give rise of some debates as well. Despite the debates, the changes in ice cover in the polar region and the gradual inundation of low lands around the world alongwith increased cyclone in the sea shows a clear indication of some change. To manage an increase in sea level of 1m, would take $12 billion for the Netherlands, $74 billion for Japan and around $400 billion for USA (Leatherman, 2001). Such a huge amount of investment may not be possible for countries like Bangladesh; but a clear understanding of scientific advancements regarding sea level rise may help to take proper adaptation and mitigation program (Douglas, 2001). The future of the next generation remains in the timely and appropriate action of current generation.

Reference:

Agrawala, S., Ota, T., Ahmd, A. U., Smith, J. & Aalst, M. V. (2003) Development and climate change in Bangladesh: Focus on coastal flooding and the Sunderbans, OECD Publication.

Ahmad, Q. K., Warrick, R. A., Ericsen, N. J. & Mirza, M. Q. (1996) The implications of climate change for Bangladesh: A synthesis. IN WARRICK, R. A. & AHMAD, Q. K. (Eds.) The implications of climate and sea level change for Bangladesh. Dordrecht, Kluwer Academic Publishers.

Ali, A. (1996) Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. Water, Air and Soil Pollution, 92, 171-179.

Ali, A. & Ahmad, A. A. Z. (1992) Impact of sea level rise on other disasters in Bangladesh. Workshop on impact of sea level rise due to global warming for the South Asian region. Dhaka, IOC/UNEP.

Ali, A. & Chowdhury, J. U. (1999) Tropical cyclone risk management for special reference to Bangladesh. Mausam, 48, 305-322.

As-Salek, J. A. & Yasuda, T. (1995) Comparative study of the storm surge models proposed for Bangladesh: Last developments and research needs. Journal of Wind Engineering and Industrial Aerodynamics, 54-55, 595-610.

Bird, E. C. F. (1993) Submerging Coasts: The effects of a rising sea level on coastal environments, West Sussex, John Wiley & Sons Ltd.

Bird, E. C. F. (1995) Present and future sea level: The effects of predicted global changes. In Eisma, D. (Ed.) Climate Change: Impact on Coastal Habitation. Boca Raton, Lewes Publishers.

Castro Ortiz, C. A. (1994) Sea-level rise and its impact on Bangladesh. Ocean & Coastal Management, 23, 249-270.

DOE (1993) Assessment of the vulnerability of coastal areas to sea level rise and other effects of global climate change, pilot study Bangladesh. Dhaka, Department of Environment, Government of Bangladesh.

Douglas, B. C. (2001) An introduction to sea level. In Douglas, B. C., Kearney, M. S. & Leatherman, P. S. (Eds.) Sea level rise : History and consequences. London, Academic Press.

Edwards, A. J. (1995) Impact of climate change on coral reefs, mangroves and tropical sea grass ecosystems. In Eisma, D. (Ed.) Climate Change: Impact on Coastal Habitation. Boca Raton, Lewes Publishers.

Ericksen, N. J., Ahmad, Q. K. & Chowdhury, A. R. (1996) Socio economic implications of climate change for Bangladesh. In Warrick, R. A. & Ahmad, Q. K. (Eds.) The implications of climate and sea level change for Bangladesh. Dordrecht, Kluwer Academic Publishers.

Fergusson, J. (1863) On recent changes in the delta of the Ganges. Q.J. Geological Society, 19, 321-354.

Gornitz, V. (2001) Impoundment, Groundwater Mining, and other Hydrologic Transformations : Impacts on global sea level rise. In Douglas, B. C., Kearney, M. S. & Leatherman, P. S. (Eds.) Sea level rise: History and consequences. San Diego, Academic Press.

Hoffman, J. S. (1984) Estimates of future sea level rise. In Barth, M. C. & Titus, J. G. (Eds.) Greenhouse effect and sea level rise: A challenge for this generation. New York, Van Nostrand Reinhold Company Inc.

IPCC Working Group 1, 2007a. Climate change2007: The physical science basis. Summery for policymakers, Cambridge, Cambridge University Press.

IPCC Working Group 2, 2007b. Climate change 2007: Impacts Adaptation, and Vulnerability. Summary for policymakers, Cambridge, Cambridge University Press.

IPCC Working Group 1, 2001. Summery for policymakers, Third assessment report of the Inter Governmental Panel on Climate Change, Cambridge, Cambridge University Press

Islam, M. S. & Tooley, M. J. (1999) Coastal and sea-level changes during the Holocene in Bangladesh. Quaternary International, 55, 61-75.

Karim, M. F. & Mimura, N. (2008) Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. Global Environmental Change, In Press, Corrected Proof.

KAUSHER, A., KAY, R. C., ASADUZZAMAN, M. & PAUL, S. (1996) Climate change and sea level rise: The case of the coast. IN WARRICK, R. A. & AHMAD, Q. K. (Eds.) The implications of climate and sea level change for Bangladesh. Dordrecht, Kluwer Academic Publishers.

LEATHERMAN, P. S. (2001) Social and Economic costs of Sea level rise. IN DOUGLAS, B. C., KEARNEY, M. S. & LEATHERMAN, P. S. (Eds.) Sea level rise: History and consequences. London, Academic Press.

MILLIMAN, J. D. & MEI-E, R. (1995) River flux to the sea : Impact of human intervention on river systems and adjacent coastal areas. IN EISMA, D. (Ed.) Climate change: Impact on coastal habitation. Boca Raton, Lewes Publishers.

MORNER, N. (1995) Recorded sea level variability in the Holocene and expected future changes. IN EISMA, D. (Ed.) Climate Change : Impact on coastal habitation. Boca Raton, Lewis Publishers.

NAPA (2005) Formulation of Bangladesh Program of Action for Adaptation to Climate Change Project: Dhaka, Bangladesh.

PEARCE, F. (1989) Turning up the heat: our perilous future in the global greenhouse, London, Paladin Books.

PIRAZZOLI, P. A. (1993) Global sea level change and their measurement. Global Planet. Change, 8, 135-148.

PUGH, D. (2004) Changing Sea Levels : Effects of Tides, Weather and Climate, Cambridge, Cambridge University Press.

SAHAGIAN, D. L., SCHWARTZ, F. W. & JACOBS, D. K. (1994) Direct anthropogenic contribution to sea level rise in the twentieth century. Nature, 367, 54-56.

SARWAR, G. M. & KHAN, M. H. (2007) Sea level rise: A threat to the coast of Bangladesh. Internationales Asienforum, 38, 375-397.

SCHUURMANS, C. J. E. (1995) The world heat budget: Expected changes. IN EISMA, D. (Ed.) Climate change: Impact on coastal habitation. Boca Raton, Lewes Publishers.

SINGH, O. P. (2002) Predictability of sea level in the Meghna estuary of Bangladesh. Global and Planetary Change, 32, 245-251.

SMIT, B., BURTON, I., KLEIN, R. J. T. & STREET, R. (1999) The science of adaptation: A framework for assessment. Mitigation and Adaptation Strategies for Global Change, 4, 199-213.

TITUS, J. G., BARTH, M. C., GIBBS, M. J., HOFFMAN, J. S. & KENNEY, M. (1984) An overview of the causes and effects of sea level rise. IN BARTH, M. C. & TITUS, J. G. (Eds.) Greenhouse effect and sea level rise : A challange for this generation. New York, Van Nostrand Reinhold Company Inc.

WARRICK, R. A., BHUIYA, A. K. A. H., MITCHELL, W. M., MURTY, T. S. & RASHEED, K. B. S. (1996) Sea level changes in the bay of bengal. IN WARRICK, R. A. & AHMAD, Q. K. (Eds.) The implications of climate and sea level change for Bangladesh. Dordrecht, Kluwer Academic Publishers.

WELLS, J. T. (1995) Effects of sea level rise on coastal sedimention and erosion. IN EISMA, D. (Ed.) Climate change: Impact on coastal habitation. Boca Raton, Lewis Publishers.

WIGLEY, T. M. L. & RAPER, S. C. B. (1993) Future changes in global mean temperature and sea level. IN WARRICK, R. A., BARROW, E. M. & WIGLEY, T. M. L. (Eds.) Climate and sea level change: Observations, projectiuons and implications. Cambridge, Cambridge University Press.

WORLDBANK (2000) Bangladesh: Climate change and sustainable development. Dhaka, Report no. 21104 BD.