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AN ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON THE WATER SECTOR IN THE CARIBBEAN

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INTRODUCTION:

The Caribbean is most vulnerable to the anticipated effects of global climate change on sea level, sea surface temperature, and precipitation as well as wind and ocean currents. The environmental impacts resulting from these changes will affect many economic sectors including tourism, agriculture, fisheries and water resources.[4] Availability and quality of water supplies, floods and droughts, are closely related to climate and its variations, as it is increasingly recognized that human activities are changing the climate on a global scale. This paper presents preliminary results from of the effects of climate change on the water sector from some regional climate change projects, suggests possible adaptation options and identifies possible areas for future activities in the area of adaptation.

BACKGROUND:

The regional CPACC (Caribbean Planning for Adaptation to Global Climate Change) project, implemented during the period 1998 – 2001, was designed to support Caribbean countries in preparing to cope with the adverse effects of global climate change, particularly sea-level rise in coastal and marine areas through vulnerability assessment, adaptation planning and related capacity-building initiatives.[5] The activities included the establishment of a regional network of sea-level/climate monitoring stations, establishment of a coastal resources inventory system (CRIS); coral reef monitoring; coastal vulnerability and risk assessment; economic valuation and regulation of the use of coastal resources; and inventories of greenhouse gases. In addition CPACC has improved the accessibility to climate data and methods and created a regional network of agencies and expertise involved in addressing the issues associated with climate change.[6]

Mainstreaming Adaptation to Global Climate Change (MACC) is a five-year project funded by the Global Environmental Facility (GEF), which is expected to build on the achievements of CPACC and aims to integrate climate change concerns, into sectors such as tourism, agriculture, water, and fisheries. To ensure that the critical programmes initiated under CPACC are sustainable beyond the life of the project the regions' political directorate and the donor community has supported the establishment of the Caribbean Community Climate Change Centre (CCCCC) which will be responsible for the implementation of the MACC project.

To further support the cause of post-CPACC sustainability and to provide a bridge between CPACC and MACC, the CIDA funded project entitled *"Adapting to Climate Change in the Caribbean"* is being implemented for a period of three years (2001-2004). Key elements of the project will focus on the formulation of implementation strategies for adaptation in the water sector. The project will also ensure that the regional climate centre becomes a sustainable institution, aid in the development of capability for

[4] MACC Brochure (2002)
[5] OAS/RPIU (2002)
[6] Walling (2002)

definitive regional and local climate change projections and examine risk management approaches to climate change issues.

THE CHANGING CLIMATE:

Global changes and projections for the future

Burning of fossil fuels, predominantly in the industrialized countries, and other human activities has already greatly increased concentrations of greenhouse gases (especially carbon dioxide) in the global atmosphere. This has resulted in increased global mean temperatures and changed rainfall distributions. It is expected that these effects will be accelerated as emissions of greenhouse gases continue to rise in many countries of the world, in spite of the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC)[7].

Scenarios of future climate change are based upon mathematical models that simulate the behaviour of the climate system under forcing factors such as greenhouse gases and aerosols. These are used to project climatic conditions into the future. There are two uncertainties of about equal importance that have to be taken into consideration when making such projections. There are difficulties in predicting the future evolution of economies and technologies in various parts of the world, and thus the future emissions of greenhouse gases. In addition, there are many global climate models (GCMs), each with slightly different parameterizations of the hydrologic cycle and feedback processes in the climate system each giving different results for the future. Nevertheless, the direction of change in all projections is consistent: - a warmer world with higher mean sea level. Given the two main uncertainties, however, it is wise to plan for a range of future outcomes and the sensitivity of water systems should be tested against that full range of likely outcomes in a risk assessment exercise.[8]

Climate change in the Caribbean and projections for the future

The induced climatic changes to date in the Caribbean vary somewhat from country to country but an average can be summarized as follows:

- Mean temperature increases of about 1^0C (1976-2000) (and thus increased evaporation on average)[9],
- Maximum and Minimum Temperatures ~ 5% increase (1958-1999) in % of days >90^{th} percentile (of 1977-1997 period)[10]
- Reduction of annual rainfall in most countries except northern parts of the Caribbean, (1900-2000) [11]
- Increase in frequency of high intensity rains, 3% increase in heavy rain events (1958-97) above 95^{th} percentile (based on 1977-97) [12]

[7] IPCC (2001)
[8] IPCC (2001)
[9] IPCC (2001)
[10] Peterson *et al*. (2002)
[11] IPCC (2001)
[12] Peterson *et al*. (2002)

- Maximum number of Consecutive Dry Days (1958-99) declined by 6 days [13]
- Sea level increases of up to 20 cm in the last century in the north, ranging to small amount in the southern Caribbean.

The above points are based on observational data from the past century, with the most rapid changes being observed in the last three decades.

Tables 1, 2 and 3 below show the possible changes in temperature, precipitation and sea level, averaged for the Caribbean region, derived from the findings of the IPCC. These projections are summarized for the average of two-decade periods centred on 2050 and 2080. The low scenario assumes lowest emissions of greenhouse gases and aerosols and the lowest GCM output, whilst the high scenario is based on the highest of both factors.

[13] Peterson *et al* (2002)

Table 1
Temperature Increases by Season

	Temperature Increase (^{0}C) Scenario 1 (low)	**Temperature Increase (^{0}C) Scenario 2 (high)**
Dec. – Feb.		
2050	1.4	2.0
2080	2.0	3.3
June – August		
2050	1.5	1.9
2080	2.0	3.3
Note: A decrease in the daily temperature range of 0.3^{o}C to 0.7^{o}C is projected with greater warming at night than during the day.		

Table 2
Precipitation Changes by Season

	Precipitation Change % Scenario 1 (low)	**Precipitation Change % Scenario 2 (high)**
Dec. – Feb.		
2050	-1.5	+13.1
2080	-4.4	+24.4
June – August		
2050	-18.4	+17.1
2080	-25.3	+8.9

Table 3
Mean Sea Level Rise

SRES Mean Sea Level Changes		
	Scenario 1 (low)	**Scenario 2 (high)**
2050	0.08m	0.44m
2080	0.13m	0.70m
Eventual	0.5 m	2.0m

The historical record indicates that the:

- Number of hurricanes plus tropical storms (that did not reach hurricane intensity) in Atlantic-Caribbean basin has increased from 7 to 10 per year since 1886.[14]
- Number of hurricanes alone shows no long-term trend, but annual numbers are affected by the state of ENSO (fewer during El Niño more during La Nina conditions).
- Number of hurricanes reached the unprecedented number of 4 during 1999.

The climate change scenarios with respect to tropical storms and hurricanes are presented in Table 4. The trend in the number of tropical storms and hurricanes is uncertain, so the number remains at 7 - 10 per year for both scenarios. The number of severe hurricanes (category 4 and 5 storms) is assumed to be 2 in the low scenario and to equal the 1999 level of 4 in the high scenario. The intensity (maximum wind speed) of the strongest hurricanes is projected to rise by 5% in the low scenario and by 10 - 15% in the high scenario, based on the assessment by IPCC (2001) and the study by Knutson et al (2001).

Table 4
Tropical Storms and Hurricanes

	Scenario 1 (low)	**Scenario 2 (high)**
Number of tropical storms and hurricanes per year, 2050 and 2080	7-10	7-10
Number of severe hurricanes per year, 2050 and 2080	2	4
Increased wind speed of the strongest hurricanes, 2050 and 2080	5%	10 - 15%

There is a large degree of uncertainty with regards to global models, and there is a need for downscaling of the resolution of climate models. As part of the ACCC programs, refinement of future climate scenarios for specific countries of the Caribbean are being undertaken by statistical downscaling techniques, which will assist water managers with more specific scenarios against which the resilience of their systems can be tested. There is also ongoing work at the University of the West Indies, Physics Department by the Climate Studies Group who are investigating the mechanisms responsible for the mean climate and for extremes in climate in Jamaica and the wider Caribbean as well as the use of this information to predict climate on a seasonal and an annual basis

[14] Martin and Weech (2001).

IMPLICATIONS OF CLIMATE CHANGE FOR THE CARIBBEAN WATER SECTOR:

Potential Impacts in Water Sector

Studies have shown changes in precipitation in the Caribbean, for example in Nassau, Bahamas rainfall over the past 95 years has decreased at a rate of 4.2 inches per 100 years. However, since 1959 the rainfall has been increasing at a rate of 21.8 inches per 100 years. In Long Island and Inagua since 1959, rainfall has been decreasing at rates of 10.2 and 16.8 inches per year respectively[15]. Current climate change models simulate an increase in most equatorial regions but a general decrease in subtropics. Potential changed in rainfall frequency and intensity are difficult to determine from the GCM's because of their coarse resolution, however, the indications are that the frequency of heavy rainfall events and the consequent flooding is likely to increase with global warming.

On the broad scale, for water resources it will be noted that on average, evaporation and evapotranspiration will increase as temperatures rise; in central and southern parts of the region annual rainfall would likely fall in the low scenarios, although with very large global changes, under the high scenario, rainfall may increase. That increase is likely not enough to offset the much increased evaporation in the high scenario so the net effect in both scenarios is a decline in net water supply but more so in the low scenario. Sea level rise would increase salt-water intrusion into coastal aquifers, and when sea level rise is combined with tropical storm induced storm surges, such salt-water contamination can occur further inland.

Increased intensity of heavy rain events suggests more rapid runoff and flash floods. Thus, if more of the rain that does fall is of a short duration and heavy, as is already occurring, a lower percentage will infiltrate to increase soil moisture and replenish aquifers. Increases in heavy rain events would also increase soil erosion and runoff of contaminants from town and country lands with adverse effects on water quality. This would cause further adverse effects on coastal waters and coral reefs.

Through the component 6 (Coastal Vulnerability and Risk Assessment) of the CPACC project there were preliminary investigations on the effect of rising sea levels on the water sector in Guyana, Grenada and Barbados. Scenarios of 0.2m sea level rise (slr) by 2020, 0.5m slr by 2050 and 1m slr 2100 were utilized to examine the possible effects on freshwater supply on selected pilot areas, within the three countries.

For Barbados it was noted that the St Michael and St. Philip aquifers which provide 75% of the island water are safe from saline intrusion due to sea level rise, however the west coast catchments shows increased vulnerability to saline intrusion under the given sea level rise scenarios. The west coast aquifers in Barbados, already showing signs of saline intrusion, provide an estimated 5 million gallons of water per day to approximately 51,000 persons in the northern parishes. These supply areas for these wells include the

[15] Martin and Weech (2001)

vital luxury west coast tourist centre. The west coast aquifers also provide an additional 7 million gallons daily for agricultural and recreational uses[16].

In Grenada sea level rise would have little effect on the water supply in the North East of the island, but a 0.5m slr would cause severe hydrological impacts, in Carriacou, with the wells at Playfield (Hillsborough), Church and Health Center (Windward), White Man (Belleview) and Sabazan being inundated, as these wells are within 150m of the coast. Salinization of boreholes and wells in the areas Bailes and Chemin on the southeast peninsula of Grenada will occur with a slr of 1m[17]

The Mahaica, Demerara and Essequibo rivers in Guyana are tidal for great distances, ranging from in excess of fifty kilometers for the larger creeks to more than one hundred and fifty kilometers for the bigger rivers. These rivers are therefore very much susceptible to salt water intrusion. During the dry season brackish water has been known to penetrate into the Mahaica River for more than sixty kilometers. With sea level rise the situation will be further aggravated. Sensitivity analyses done for a range of low flows indicate that intrusion can be up to four times as great as for the mean conditions analyzed. Water for domestic and agricultural purposes is extracted from these rivers, thus changes in the salt/brackish water extent will cause adverse effects for the population[18].

In Guyana large numbers of coastal aquifers are already experiencing salt-water intrusion caused by both natural and man-induced processes. Sea level rise will only aggravate such situations. The coastal plain of Guyana, which lies below high tide level of the Atlantic Ocean, will be subjected to severe adverse consequences as a result of sea level rise. The high level of dependence on the coastal aquifers for domestic water supply renders the population extremely vulnerable to the effects of salt-water intrusion as a result of sea level rise[19].

Caribbean countries through the development of national reports to the United Nations Framework Convention on Climate Change have addressed water issues. For example in St Kitts and Nevis , initial studies using climate models have shown that sugar yields will decrease significantly with a changing climate[20]. In Dominica it was noted that a decrease in available precipitation will have negative consequences for domestic and commercial use. Hydro-electricity generation will be adversely affected. Alternatively increased precipitation from climate change will result in flooding and landslides[21].

Issues of concern for the Water Sectors

Almost all the countries of the region specifically identified the impact of climate change on water resources as an important issue as it is predicted that changes in the frequency

[16] Moore (2002), Ifill (2001)
[17] Moore, Charles (2002)
[18] Moore (2002),Narayan (2001)
[19] Narayan (2001)
[20] National Communications Report of St.Kitts and Nevis (2001)
[21] National Communication Report of Dominica

and distribution of rainfall is likely to take place. [22] In most countries no systematic water management programmes exists which make it difficult to accurately assess vulnerability. However, the impacts of climate change combined with the high demand for water, particularly during the tourist season, may make it increasingly difficult to deal with current demands especially in water-scare regions. Climate change can also present additional water management problems such as increase flooding, blocked drains and elevated water tables. Fresh water supplies are highly susceptible to normal climate variability therefore such added natural disasters would further exacerbate already existing conditions.

Water resources are already under threat in most of the Caribbean due to increasing demand from domestic, industrial and agricultural purposes as well as from poor land use practices, deforestation and pollution. Direct impacts of climate factors on water resources will result in a general reduction in the availability of this commodity. In countries such as the Bahamas and Antigua & Barbuda water scarcity is already and issue that climate change is expected to exacerbate. Low-lying island such as the Bahamas, Grenada and St Lucia are facing the threat of salinization of their ground water resources as result of sea level rise. Changes in rainfall patterns and the availability of water for export crops such as bananas, sugar cane, arrowroots as well as for domestic crops is expected to affect all the islands in the region. In low-lying islands (e.g. the Bahamas) it is predicted that coastal agricultural lands will be loss as a result of saline intrusion. The fisheries sector, which is an important source of employment on the island of St Kitts & Nevis, Antigua & Barbuda and Trinidad & Tobago, is also expected to be adversely affected.

As water resources come under increasing pressure conflicts between competing sectors, particularly tourism, industry, agriculture and domestic will have to be addressed. For St Kitts and St Lucia, for example the provision of water for the tourist industry is already an issue. Superimposed on these issues are the negative impacts of storms and extreme events on human settlement, infrastructure and human health resulting from flooding, landslides and erosion.

Many of the studies which have looked at water issues and climate change have noted the uncertainty in the climate models, the need for additional data and comprehensive water assessments. The problems of the Caribbean countries have some degree of commonality as the water resources area likely to impact significantly by climate change. Potential impacts on the water sector and their corresponding implications are outline in Table 5 below. As a result of the commonalities it may be feasible in some instances for adaptation strategies to be developed to present common solutions to the countries of the region.

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[22] Moore (2002)

Table 5
Vulnerability Impacts in the Caribbean

Climate Change Factor	Impacts	Implications
Drought, decrease in precipitation	Intensification of water scarcity Reduced base flow Increased evapotranspiration rates	• Reduced availability of water would have direct and indirect impacts on other sectors (agriculture, tourism, public health, industry) which could lead to conflicts over water resources • Reduced precipitation would lead to heat stress and loss of soil moisture causing reduced crop production (eg banana in Barbados and Grenada, sugar yields in St Kitts) • Impacts on livestock would include, loss of body weight, increase incidences of disease, lower fertility, delayed maturation and increased juvenile mortality • Increased demand for cooling water
	Decrease in hydroelectric potential	• Loss of hydro electric power potential would decrease productivity or increase the reliance on diesel power (loss of foreign exchange) (Dominica, Guyana, St Vincent) • Along with increase temperatures, will result in increase energy demand from various economic activity especially for cooling
	Shift in biodiversity	• Impact on the forest and terrestrial resources, alteration of soil conditions (Dominica, Guyana, Trinidad)) • Changes in altitudinal zonation, species type, vegetation type and location of endemic fauna and flora (St Vincent)
Increase frequency and intensity of rainfall events	Increased flooding and landslides	• Sedimentation, increased coastal vulnerability to erosion • Watercourses are prone to siltation. During dry periods water levels fall drastically while during periods of heavy rainfall rivers quickly overflow their banks. • Damage to cropland through soil erosion and leaching • Affect economy through the disruption of the economic activities, especially tourism
Increased frequency and intensity of hurricanes and	Coastal storm damage Storm surges	• Storm activity impacts would affect the entire economy and foreign exchange earning potential. • Will negatively impact the arrival of tourist from both air and sea, as islands would become less attractive tourist destinations

tropical storms		• Damage to coastal infrastructure, including health facilities • Hurricane damage to vegetable crops, poultry and ruminants and farming infrastructure • Flooding of sewerage systems leading to exposure to untreated sewage and contamination of the marine waters. • Destruction and alteration in the geographic extent of forests as well as extent of habitat for flora and fauna (St Lucia) • Potential loss of rain forest, biodiversity and endemic species (St Lucia)
Seal Revel Rise		• Elevated water table bringing fresh water lens closer to the surface which can lead to increase loss through evaporation • Loss or reduction of fresh water resources through over extraction and inundation by storm surges • Increase contamination of near surface lenses due to surface run-off of contaminated water • Saline intrusion will contaminate underground aquifers and thus reduce the availability of groundwater leading to the abandonment of wells (Grenada) • Salinization of agricultural soil (St Kitts)

Table 6 Generic Adaptation Options[23]

SECTOR	Stage I: Planning (short term)		Stage II: Preparation (medium term)	Stage III: Initiation (long term)
	General Capacity Building: Impact Studies; Identification of Vulnerable Areas	Identification and General Assessments of Policy Options	Further Capacity Building in Vulnerable Regions; Development of Appropriate Adaptation Plans	Formulation of Measures to Facilitate Adaptation in Vulnerable Areas; Feasibility Studies; Insurance
Water	Regional climate change predictions: • Change in precipitation rates Impact on water supply: • Water quality • Water quantity Predictions on water demand: • Non-climate-change-induced	Supply management options: • Invest in reservoirs and infrastructure • Optimize systems (interregional water transfers) • Recycle water for lower-quality use Demand-side management	Create institutions and train staff: • Create water supply agencies • Develop hydrological models R&D into desalination and water recycling schemes Education/information for households	Pilot studies for supply measures Pilot studies for demand measures Efficient water management • Develop drought management plans • Formulate water quality standards • Remove market distortions

[23] Adapted from Fankhauser, S, (1996)

SECTOR	Stage I: Planning (short term)		Stage II: Preparation (medium term)	Stage III: Initiation (long term)
	General Capacity Building: Impact Studies; Identification of Vulnerable Areas	Identification and General Assessments of Policy Options	Further Capacity Building in Vulnerable Regions; Development of Appropriate Adaptation Plans	Formulation of Measures to Facilitate Adaptation in Vulnerable Areas; Feasibility Studies; Insurance
	(population growth) • Climate-change-induced (increased irrigation)	• Invest in water-saving technologies • Change water use practices		(subsidies)

ADAPTATION OPTIONS:

Generic adaptation options based on the staged approach to adaptation outlined in the UNFCCC process, have been suggested and are outlined in Table 6. In the Caribbean many generic adaptation options for the water sector have been suggested through component four of the Caribbean Planning for Adaptation to Climate Change, Formulation of Initial Adaptation Policies. These include:-

1. The need to undertake a comprehensive inventory of all climate and water resources data and identify likely longer-term trends and short-term impacts arising from climate change
2. The need for further research on the impact of climate change on water quality and quantity, both surface and under ground including saltwater intrusion.
3. The need for a systematic water monitoring programme to be able to accurately assess vulnerability
4. The need to introduce conservation programmes and devices (e.g. low use appliances, reduced cosmetic lawn watering, better metering and pricing) through economic incentives to hotel and residential property owners
5. The adoption of integrated watershed management approaches in collaboration with agricultural agencies and towns to reduce soil erosion and other contaminants from the land.
6. Increase water storage capacity to accommodate longer dry spells as well as harvesting rainfall on roofs and cisterns.
7. The need for extensive public education programmes to inform people of the potential impacts of climate change on the water sector[24]

Through the national report process to the United Nations Framework convention process Caribbean countries have identified potential adaptation options and management interventions and these are indicted in Table 7 below.

[24] Trotz (2002)

Table 7[25]

Selected Adaptation and Management Interventions for the Water Sector

Country	Selected Adaptation and management Interventions
Barbados	• Management and conservation techniques • Desalination
Dominica	• Water conservation techniques • Public Awareness • Reduction • Data collection • Development of multi-sectoral National Water Management Plan
Guyana	• Water conservation • Long term planning • Seasonal forecast and rationing in dry years
Grenada	• Improved water resources assessment and monitoring • Planning and management of water resources • Desalination • Education and awareness
Jamaica	• Water conservation practices • Reduce unaccounted for water • Improved integrated watershed management
St Kitts and Nevis	• Rational use of available water enforced by national water authority • Minimizing runoff of freshwater to ocean environment
St Lucia	• Reduction in line loss of water • Water conservation • Public awareness • Forestry management • Development of a national water plan
St Vincent and the Grenadines	• Protection of water supply source • Improved harvesting and distribution systems to accommodate competing uses
Trinidad and Tobago	• Adaptation opportunities in the implementation of integrated water resources planning and management measures

[25] Adapted from Moore (1) (2002)

WAY FORWARD AND FURTHER WORK

Challenges faced

While the countries of the region are able to highlight their concerns with respect to vulnerability and the adverse impacts of climate change there is a lack of hard scientific data to support the deductions as expert judgment has been used in the most part to formulate conclusions. Except for Barbados, Guyana and Grenada who have carried out comprehensive vulnerability assessment most of the countries of the region have identified this as a need. The major challenges faced by the region can be summarized as follows;

1. The lack of sufficient primary scientific and monitoring data.
2. The inadequacy of global climate models as they do not provide enough specific information with regard to future climate in the region, as the resolution of these models does not show many of the Caribbean islands.
3. The needs for expanding the number of monitoring sites within the region.
4. The need for capacity building in vulnerability assessment and adaptation planning.
5. The need for a comprehensive public awareness programme to ensure the success of specific adaptation options.

Under component 6 of the ACCC project 'Implementation ***Strategies for adaptation in the Water Sector***" is expected to establish a comprehensive set of adaptative strategies in the water sector and the establishment of a pilot project in a select country. Such a strategy has been identified as a critical need in many countries in the Caribbean. The activities that will be implemented over the next eight months will incorporate the following elements.

1. Identify downscaled future climate scenarios for individual countries.
2. Develop and have tested by a pilot water agency in the region, a template for incorporation of climate change into water resource planning and management, using results and methodologies employed in the CPACC Vulnerability and Assessment studies and the ACCC Risk Management workshops.
3. Provide an input to the Caribbean Region report to the International consultation on water and climate change in Kyoto, 2003.
4. Prepare a final report for widespread consideration and use of water managers in the region.

In providing these outputs the project is mindful of the need for built in flexibility to respond to the varying needs of the countries of the region

One possible approach to adaptation of the water sector to climate change is the utilization of the risk management approach. Under the ACCC project the Risk Management Guidelines for Decision Makers (National Standard of Canada – CAN/CSA Q850-97)[26] has been introduced as a guide for use in the public policy context to deal with climate change impacts. This method focuses on stakeholder participation as an

[26] Canadian Standards Association (1997)

integral part of the decision making process. Water managers of some countries have participated in the analysis and training workshops designed to instruct participants in the use of the risk management process as a planning and management tool is making optimal decisions about how the water sector of the Caribbean can adapt to changing climate. Another method that were highlighted during these workshops were the Comprehensive Hazard and Risk management (CHARM) process used by the South Pacific Islands (adapted from the Australian/New Zealand risk management standards)[27]. It must be recognized however that need for scientific data and comprehensive water vulnerability assessments hold the key for effective adaptation to climate change in the water sector.

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[27] ACCC (2002)

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LIST OF ACRONYMS

ACCC	Adaptation to Climate Change in the Caribbean
CARICOM	Caribbean Community of Nations
CIDA	Canadian International Development Agency
CCCCC	Caribbean Community Climate Change Centre
CPACC	Caribbean Planning for Adaptation to Climate Change
CRIS	Coastal resources Information System
ENSO	El Nino Southern Oscillation
GEF	Global Environment Fund
GCM	Global Climate Models
IPCC	Inter-Governmental Panel (of Experts) on Climate Change
MACC	Mainstreaming Adaptation to Climate Change
RPIU	Regional Project Implementing Unit

SLR	Sea Level Rise
UNFCC	United Nations Framework Convention on Climate Change