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Climate Change Data and Risk Assessment Methodologies for the Caribbean

Environmental
Safeguards Unit

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ACRONYMS AND ABBREVIATIONS

ASICDOM	Asociación de Ingeniería y Consultoría Dominicana
AOGCM	Atmosphere-ocean General Circulation Model
CAPRA	Central America Probabilistic Risk Assessment
CARDIN	Caribbean Disaster Information Network
CCKP	Climate Change Knowledge Portal
CCORAL	Caribbean Climate Online Risk and Adaptation Tool
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDMP	Caribbean Disaster Mitigation Project
CEDRIG	*Climate, Environment, and Disaster Risk Reduction Integration Guidance*
CIMH	Caribbean Institute for Meteorology and Hydrology
CMIP	Coupled Model Intercomparison Project
CMIP3	Coupled Model Intercomparison Project Phase 3
CMIP5	Coupled Model Intercomparison Project Phase 5
DPC	Direction de la Protection Civile
ESG	Environmental Safeguards Unit
GCM	Global Climate Model
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLOSS	Global Sea Level Observing System
HAZUS	Hazards U.S.
IDB	Inter-American Development Bank
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
MET	Meteorological
NARCCAP	North American Regional Climate Change Assessment Program
NOAA	U.S. National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
PRECIS	Providing Regional Climates for Impacts Studies
PSMSL	Permanent Service for Mean Sea Level
RCM	Regional Climate Model
SLOSH	Sea, Lake, and Overland Surge Hurricane
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperatures
UNEP	United Nations Environment Programme
UNESCO/IOC	United Nations Educational, Scientific and Cultural Organization/Intergovernmental Oceanographic Commission
UNISDR	United Nations Office of Disaster Reduction
USAID	U.S. Agency for International Development
WCRP	World Climate Research Programme

KEY CONCEPTS

This Technical Note draws upon key concepts from both the climate change and disaster risk reduction communities of practice. As each community has developed distinct definitions related to risk assessment and risk management, it is prudent to define key concepts and specify the terminology that will be used here.

- **Adaptive capacity**: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (NRC, 2010).
- **Climate variability:** Variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events (IPCC, 2007).
- **Climate change:** The United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. See also Climate change commitment, Detection and Attribution.
- **Climate change risk management** is used here as interchangeable with the definition of **adaptation**, which is: "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014).
- **Disaster**: the occurrence of an extreme hazard event that impacts vulnerable communities causing substantial damage, disruption and possible casualties, and leaving the affected communities unable to function normally without outside assistance (Benson and Twigg, 2007).
- **Disaster preparedness:** Activities and measures taken in advance to ensure an effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (IDB, 2008). Contingency planning is part of disaster preparedness.
- **Disaster risk management:** The systematic process that integrates risk identification, prevention, mitigation and transfer, as well as disaster preparedness, emergency response and rehabilitation/reconstruction to lessen the impacts of hazards (IDB, 2008).
- **Disaster risk reduction**: The systematic development and application of policies, strategies and practices to minimize vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development (UN, 2004 in IDB, 2008).
- **Exposure**: The presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected by climate change effects (IPCC, 2012).
- **Financial protection:** *Ex ante* activities to prepare financial mechanisms or instruments for risk retention and transfer in order to have *ex post* access to timely economic resources, which improves the response capacity in the event of disasters.

- **Hazard** is the "potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources." (IPCC, 2014). This definition recognizes that hazards exist under current conditions, and may be exacerbated under future climatic conditions.
- **Mitigation** is defined here as "a human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC, 2014). It should be noted that the term mitigation is often used in the disaster risk reduction lexicon as reducing (e.g., mitigating) the impacts of hazards.
- **Resiliency** is defined as "the capability of a system (such as a community) to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimal damage to social well-being, the economy, and the environment" (NRC, 2010). This concept recognizes that climate change adaptation and disaster risk reduction are complementary.
- **Rehabilitation:** Provisional repairs of damaged infrastructure, social services or productive capacity to facilitate the normalization of economic activities (IDB, 2008).
- **Reconstruction:** Construction of new facilities to replace those that were destroyed or damaged beyond repair by a disaster, to standards that avoid the rebuilding or increasing of vulnerability (IDB, 2008).
- **Risk**: A combination of the magnitude of the potential consequence(s) of hazard and the likelihood that the consequence(s) will occur (NRC, 2010). In the context of this report the hazards of interest are those that are exacerbated by climate change.
- **Risk reduction:** The systematic development and application of policies, strategies and practices to minimize vulnerabilities, hazards and the unfolding of disaster impacts throughout a society, in the broad context of sustainable development. Includes mitigation and prevention. *Mitigation (reduce the existing risk):* Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards. *Prevention (prevent new conditions of risk):* Activities to avoid the adverse impact of hazards and means to minimize the impacts of related disasters.
- **Risk transfer:** The process of formally or informally shifting the financial consequences of particular risks from one party to another. Insurance is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer.
- **Sensitivity**: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise).
- **Slow onset versus rapid onset hazard**: Slow onset hazards are those that occur over months or years (such as sea level rise or drought), and rapid onset hazards occur over shorter time intervals, such as hurricanes, floods, or storm surges.
- **Vulnerability**: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (NRC, 2010).
- **Weather**: The atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future.

1.0 Purpose and Approach

The Inter-American Development Bank (IDB) Environmental Safeguards Unit (ESG) initiated this study to address the need to better understand how to assess and address climate change related risks in IDB-funded projects. The Caribbean region is uniquely sensitive to natural hazards such as hurricanes, extreme precipitation events, and coastal storm surges due to the relatively small size and low elevations of the island nations that make up the region. Climate change is expected to exacerbate the threat of natural hazards. As a result of climate change, average temperatures and sea levels are rising, precipitation patterns might change, and hurricanes could intensify. Many of these changes are already occurring, and are projected to become more severe in the future.

Climate change risk is acknowledged within Directive A.6 of the Environmental and Social Safeguard Compliance Policy (OP-703, 2006) and its Implementation Guideline (2007a), as well as in Policy Guidelines 1.7 and 1.8 of the Disaster Risk Management Safeguard and Policy (2007b) and its Implementation Guideline (2008). Climate change could adversely affect the intended outcomes of development operations, as well as impact the economic and financial rates of return of IDB investments. Effective disaster and climate change risk assessment is critical to guide IDB's development financing and (1) to assist its borrowers in reducing risks from natural disasters and climate change and (2) to support the attainment of their social, environmental, and economic development goals.

The purpose of this paper is to: (1) propose a step-wise process to assess disaster and climate change risks to IDB projects and (2) identify tools and methodologies to support the risk assessment process specific to the Caribbean region.[1] The pilot risk assessment process focuses on the direct and indirect risks to projects from three climate-induced hazards: sea level rise, hurricanes (including storm surge), and flooding (both coastal and riverine) because these hazards are considered to pose the greatest threat to the Caribbean region. Further consideration was given to the types of projects most vulnerable to climate change risk, including infrastructure projects; projects that involve investments in, or rely substantially on, natural resources (such as water and agriculture); and projects that rely on other infrastructure (such as national transportation infrastructure for tourism).

Significant work has been undertaken in recent years to understand climate variability and change and related risks in the Caribbean, including that conducted under the Caribbean Community Climate Change Centre and the IDB-World Bank Pilot Program for Climate Resilience in the Caribbean. This paper builds on these efforts by identifying and summarizing information that is most salient to evaluating site-specific climate risks. It is important to note that this paper relied on existing information and did not involve field research.

This paper is organized into the following sections:

- Section 2: Overarching Climate Change Risk Framework
- Section 3: Climate Change Risk Assessment Methodology (Steps 1–3) and Tools for the Caribbean
- Section 4: Conclusions
- Section 5: Recommendations for Next Steps

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[1] We are aware that it is very difficult— if not impossible in the short term —to differentiate between risks caused by climate variability and climate change. Thus, this document addresses both types of risks under the term "climate change risk" and emphasizes that risk assessment has to take into account the possible additional risks caused by climate change.

- Section 6: References

Of note, the tools and resources identified in this paper are included along with their respective hyperlinks in Annex 1. A fact sheet has also been developed that summarizes the combined disaster risk and climate change risk management screening process and recommended tools presented in this paper. The objective of the fact sheet is to help project proponents better understand and conduct the recommended climate risk assessment. Given the vast amount of relevant information available on the Internet, to the extent feasible, links to other documents/data resources are provided as hyperlinks in the electronic version of this file.

The intended audience of this paper is individuals who may need to develop disaster and climate change risk assessments for specific public or private sector investments and those who need to evaluate/review such risk assessments performed in support of environmental impact documentation.

2.0 Overarching Climate Change Risk Framework

The Caribbean includes relatively small island nations that typically have low elevations and high population densities located in the coastal zone. These factors make the Caribbean region particularly susceptible to natural hazards, which are anticipated to pose a greater risk under future climate scenarios. The Caribbean is also characterized by its heavy dependence on tourism and agriculture; both of these sectors are highly vulnerable to climate change risk. Underscoring this vulnerability, from 1975 to 2002 natural disasters caused $3.2 billion in physical losses in the region—more than half the level of annual loan commitments by the IDB (IDB 2004). However, the projected losses to the region under future climate change are anticipated to be much greater. Bueno et al. (2008) found that if no adaptation measures are implemented to mitigate climate risk, damages in the region could total $22 billion annually by 2050 and $46 billion by 2100.[2]

Climate change will thus exacerbate the current financial risks to IDB-funded projects in the Caribbean, with the potential to damage infrastructure and cause long- and short-term disruptions to supply chains, services (e.g., water supply), and markets. Impacts to natural resources, such as coral reefs and beaches, will adversely affect private sector investments in the tourism sector. Both directly and indirectly, climate impacts could adversely affect the financial, economic, environmental, and social performance of current and future IDB investments in the region.[3] Figure 2-1 illustrates some of the primary climate risks to Caribbean nations.

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[2] The study considered increased hurricane damages, loss of tourism revenue, and infrastructure damages on 24 island nations in the Caribbean. Refer to <http://ase.tufts.edu/gdae/pubs/rp/caribbean-full-eng.pdf> for additional information.

[3] For additional information related to climate science and projected climate change impacts, refer to the IPCC Assessment Reports: <http://www.ipcc.ch/publications_and_data/publications_and_data.shtml#.UwPAQ_ldWrg>, as well IDB Technical Notes developed on the topic (Iqbal and Suding, 2011; Simpson et al., 2011).

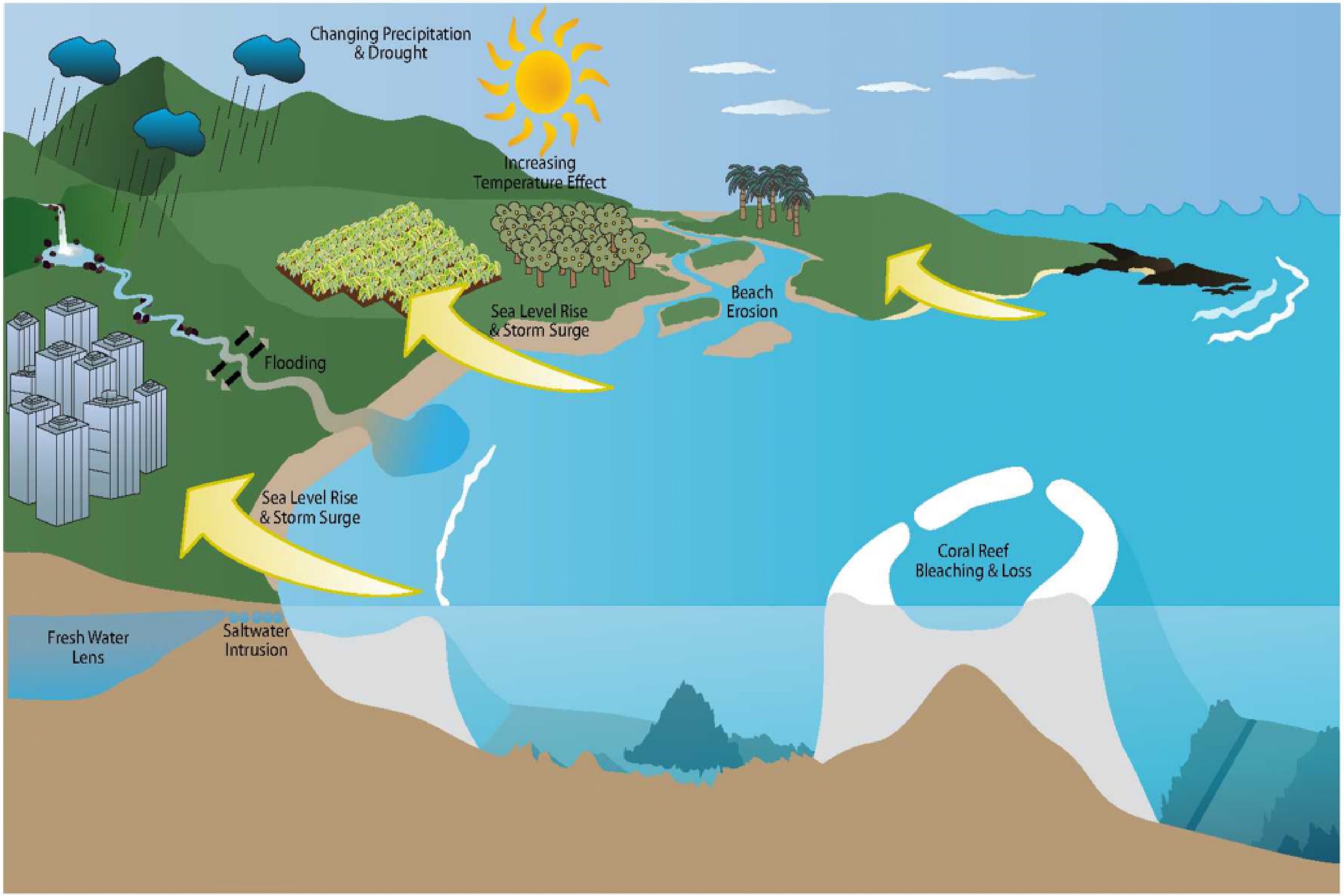

Figure 2-1. Illustrative climate risks to Caribbean nations.

Climate change can affect projects in many different ways. In the box below, a general impact chain is presented using the disaster risk concept.[4] In this view, two groups of climate change manifestations are distinguished, those which affect **rapid onset natural hazards** and those which impact **slow onset natural hazards**.[5]

According to this, climate change may increase rapid onset disasters by greater climate variability**,** i.e. increase in the frequency and/or severity of natural hazards such as intense storms, heavy rainfall, long and deep drought periods etc. and the respective impacts. Climate change also may cause long term slow onset change in the project region such as changes in mean average, maximum and minimum temperatures, and changes in precipitation amount, onset, duration, and geographic distribution. These changes contribute to follow-on impacts such as sea level rise, changes in water availability and its timing, and changes in crop yields.

Climate Change

Affects rapid onset natural hazards and slow onset natural hazards

Depending on exposure of project and area of influence

and vulnerability / Resilience of project, area and society

Disaster Risks are high, moderate or low
for project itself (scenario Type 1) and/or
for human life, property, environment (scenario Type 2)

Disaster and Climate Change Risk Management
reduces exposure, mitigates vulnerability and/or makes provisions in order to achieve an acceptable level of risk.

From: IDB draft guidance notes

Depending on intensity of the change, exposure of project and area of influence and the vulnerability or resilience of the project, the area and the society, the impacts of the natural hazards may be extreme, significant, moderate or low. With respect to the objects of the impact, a distinction is made between the project itself (scenario type 1) and the environing systems (scenario type 2). In the text box below further sub- distinctions of the scenarios in the impact chain are made and examples given.

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[4] IDB's Disaster Risk Management Policy (OP 704) has been adopted as the framework for incorporating climate change risks in the project cycle. A rather wide definitions of hazards is used including slow onset changes.

[5] In an IDB options paper from 2011(*Iqbal and Suding 2011)*, these groups are called Category A and Category B climate change manifestations*, available at:* <http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=37671112>*.* In IDB, this classification has been developed further in the course of incorporating climate change risk with disaster risk assessment and management in the project cycle.

Integrated Classification of Disaster and Climate Change Risks to IDB Development Projects

Type 1 Disaster Risk Scenario: The *project itself* could be adversely impacted by natural hazards. This may occur in two forms:

1. Direct impact of a hazard on assets and operations, including damage and destruction of assets, and modification or shutdown of operations, e.g., developments located in coastal zones of the Caribbean are likely to be affected by hurricanes, tropical storms and coastal flooding due to storm surges;
2. Direct impact of a hazard on area of influence, from where resources for the project originate with economic repercussions on project; e.g., an irrigation system that relies on water runoff from glaciers that are shrinking, or an agricultural processing project that relies on produce from a region where suppliers are switching to other crops that are more suited to changing climatic conditions.

Type 2 Disaster Risk Scenario: The operation has a potential to exacerbate hazard risk *to human life, property, the environment* or the operation itself. This may occur in two ways:

1. The natural hazard poses risks through the project for people and the environment in the area of influence (knock-on effects from damages or changes in operation in the project). Examples include: damage to a dam results in its failure to retain water mass; spillways of hydropower projects are not sufficient to regulate the water flow in case of extreme hydrological events and could increase risks of overflow and downstream flooding; a damaged pipeline or storage tank leaks toxic substance into the environment; a loose part of a damaged structure in motion (on slope or in the sea) destroys adjacent structures; etc.
2. The project reduces resilience to natural hazards of people and the environment in the area of influence: construction, implementation and operation activities of a project may increase the vulnerability. Examples include: removal of vegetation by a project in mountainous terrain could weaken the soil stability and initiate a landslide in heavy precipitation events or could exacerbate erosion, leading to flooding; removal of vegetation or earth for a coastal project may exacerbate coastal erosion, which reduces the resilience of the coast and its infrastructure against storm surges; obstruction of floodplains by project works could lead to blockage of drainage flows and diversion of floods, exacerbating the impact of inland floods.

From: IDB Safeguards Policy Filter (project screening tool)

2.1 Existing Risk Assessment Methodologies

This section identifies key risk assessment methodologies that have been developed at the international and regional level to provide a general climate risk framework. This list is not meant to be exhaustive; rather, it reflects the most relevant and internationally respected guidance documents developed to date. This paper discusses the following key guidance documents:

- *Caribbean Risk Management Guidelines for Climate Change Adaptation Decision Making* (Caribbean Community Secretariat 2008)
- *Shaping Climate-Resilient Development: A Framework for Decision-making* (Economics and Climate Adaptation Working Group 2009)
- *Climate Risk and Business* (IFC 2010)

- *Climate Proofing for Development: Adapting to Climate Change, Reducing Risk* (Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ] 2011)
- *Climate, Environment, and Disaster Risk Reduction Integration Guidance* (Swiss Agency for Development and Cooperation 2010)

Although it is anticipated that the World Bank and IDB Pilot Program for Climate Resilience in the Caribbean will also yield valuable lessons learned regarding risk assessment methodology, the program has only recently begun; therefore, limited data on results are available.

Each of the guidance documents listed above identifies a framework for evaluating climate change risk that includes several steps and guiding principles. The specific steps identified in each guidance document are identified in Table 2.1. The variance reflects the different levels of analysis (e.g., institutional, national, local) and interventions (e.g., development aid, national adaptation planning, private sector investment) that the individual guidance document was developed to target. Table 2.1 identifies the target audience for the guidance documents.

Table 2.1 Climate Change Risk Assessment Methodology Steps

Summary of Climate Change Risk Assessment Methodology Audience and Steps					
	Caribbean Risk Management Guidelines	**Shaping Climate Resilient Development**	**Climate Risk and Business**	**Climate Proofing for Development**	**Climate, Environment, and Disaster Risk Reduction Integration Guidance**
Target Audience	Decision Makers in Caribbean Region	Development Banks	Private Sector	Development Banks	Development Banks
Step Identified in Subject Document					
Step 1	Get Started	Comprehensive Approach and Objective	Identify Problem/ Objectives	Prepare	Assess Risks
Step 2	Analyze the Climate Variability or Climate Change Hazard	Prioritize Hazards and Locations	Establish Decision-making Criteria	Analyze	Identify Adaptation and Risk Reduction Options
Step 3	Estimate the Risk	Recognize Uncertainty of Climate Change	Assess Risk	Identify Options for Action	Select Adaptation and Risk Reduction Options
Step 4	Evaluate the Risk	Identify Cost-Effective Priority Measures	Identify Options	Integrate	Define Monitoring and Evaluation Indicators
Step 5	Adapt, Control Risk and Financing	Focus on Addressing Development Bottlenecks	Appraise Options	Prepare	
Step 6	Implement and Monitor	Encourage Funding from International Community	Make Decision	Analyze	
Step 7		Mobilize Stakeholders	Implement Decision		
Step 8			Monitor		

Note: Not all methodologies have the same number of steps. For example, the *Climate, Environment, and Disaster Risk Reduction Integration Guidance* (CEDRIG) identifies 4 steps; thus, cells 5–8 are blank. See text above identifying the organizations that have prepared these risk assessment documents.

It is useful to consider the different climate risk methodologies and audiences of the available guidance documents to develop a targeted step-wise methodology that will be specific to the IDB private sector portfolio in the Caribbean. In general, each of the methodologies recommend the following steps: (1) undergo an initial screening to identify climate risk and define parameters, (2) conduct a risk assessment, (3) identify and implement adaptation options, and (4) monitor and evaluate the results. The importance of stakeholder engagement to better understand site-specific concerns and more effectively identify and implement adaptation options is also identified as a cross-cutting issue.

The International Finance Corporation's (IFC's) *Climate Risk and Business* methodology is the most relevant guidance for this paper, given the multilateral and private sector focus. In the compendium documents, the IFC methodology is further tailored to sector-specific climate risk assessments; for example, it considers the project's exposure, sensitivity, and adaptive capacity as part of the vulnerability assessment. (IFC's pilot projects will be further discussed in later sections.) With the exception of the IFC pilot studies, an overarching finding of this literature review is that available methodologies are very general and lack guidance on the specific steps, models, and tools that are needed to conduct a project-specific risk assessment. IFC has an ongoing program to prepare sector-specific guidance; however, this guidance will not be completed until late 2014.

2.2 Proposed Climate Change Risk Assessment Methodology

Based on an evaluation of existing work, and an understanding of IDB's current needs and policies, the following climate risk assessment methodology steps have been developed for use by IDB clients; expected to provide the most robust, yet flexible framework for assessing climate change risk:

- Step 1: Screen for climate and climate change risk. Review the project to determine whether further climate change related analysis is necessary.[6]
- Step 2: Define the assessment parameters. This includes defining the site and planning horizons and identifying and gathering relevant data to better understand what type of vulnerability assessment will be conducted.
- Step 3: Assess climate and climate change risk and identify risk management strategies. Conduct a basic vulnerability or detailed risk assessment to identify how susceptible the project is to climate and climate change hazards (such as sea level rise, hurricanes, flooding, and drought). Identify strategies to address identified risks, vulnerabilities, or impacts.
- Step 4: Implement, monitor, report. Implement climate and climate change risk management strategies. Evaluate the effectiveness and efficiency of the measures implemented (on the ground *ex post* evaluation[7] and comparison with the *ex ante* evaluation[8] done in step 3)

The approach is structured as a tiered process with the flexibility to stop after project screening (Step 1) or determine if a basic vulnerability assessment or more complex risk assessment is necessary for the proposed project (Step 3).

As IDB has integrated climate change risk assessment in the disaster risk management procedures for projects proposed for IDB financing, the present framework has been developed so that the findings of the risk assessment can be directly incorporated into documents required by the Bank as part of its project appraisal.

While the climate change risk management guidance included in this document can be considered generally applicable to addressing climate change risk; the guidance has been developed specifically to

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[6] Please note that this screening is different from the IDB project Environmental and Social Safeguard Screening completed by IDB project teams during the early appraisal of projects proposed for IDB financing.

[7] The *ex post* evaluation of operations at the Bank aims to assess the extent to which the development objectives of IDB-financed operations have been attained. The *ex post* evaluation of operations also aims to assess the efficiency with which those objectives have been attained. It is called an *ex post* evaluation since the purpose is to evaluate the results of an operation, particularly in terms of its outcomes and/or impact, after it has been completed. For more refer here: <http://www.iadb.org/en/about-us/evaluation-of-idb-operational-objectives,6242.html>

[8] The *ex ante* evaluation is conducted pre-intervention and describes the situation prior to an intervention, against which progress can be assessed or comparisons made. Baseline data are collected before a program or policy is implemented to assess the "before" state.

inform Steps 1 through 3, but stops short of providing guidance on risk management strategies. A separate Technical Note, *Addressing Climate Change within Disaster Risk Management: A Practical Guide for IDB Project Preparation*,[9] identifies climate change risk management options that can be incorporated into IDB investments. The primary purpose of this Technical Note is to help identify climate change risk management measures to minimize the risk posed by climate change to IDB investments.

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[9] Technical Note No. IDB-TN-806, *Addressing Climate Change within Disaster Risk Management: A Practical Guide for IDB Project Preparation*, is available here: https://publications.iadb.org/handle/11319/6910?locale-attribute=en.

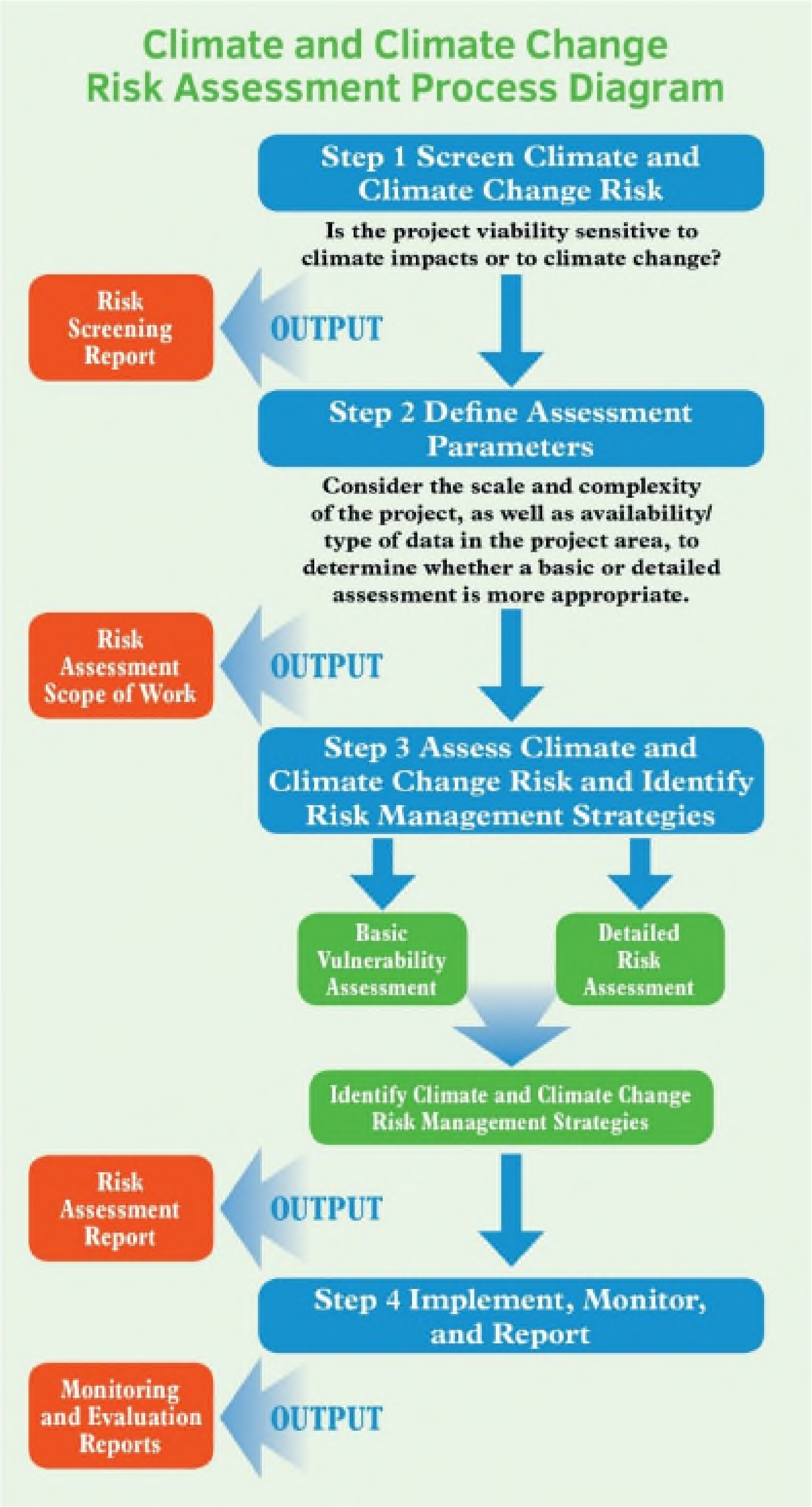

Figure 2-2. Climate and climate change risk assessment framework diagram.

2.3 Climate Change Risk Assessment in the IDB Project Cycle

Climate-related risks to IDB-financed projects should be addressed per the Environmental and Social Safeguards Compliance Policy (Directives A.3, A.6, and B.4) and the Disaster Risk Management Safeguard and Policy (Guidelines 1.7 and 1.8 and Directive A-2).

The proposed climate change risk assessment methodology is intended for use by the IDB and their borrowers to help assess and reduce climate-related risks to acceptable levels. The project proponents will conduct the climate change risk assessment in the framework of the disaster risk assessment to meet the borrowing requirements.

As envisioned in this paper, the climate change risk assessment will be implemented in the project preparation stage, and the findings carried throughout the IDB project cycle phases and compliance requirements. This approach is supported through the Organization for Economic Cooperation and Development (OECD, 2009) recommendations of using a "climate lens" as a comprehensive framework for mainstreaming adaptation into policy and planning processes, whereby analysis of climate change risks and interventions are mainstreamed throughout the life of the project or program.[10]

Since IDB has adopted the integration of climate change risk assessment in the disaster risk management procedures, the present methodology has been developed so that it could be directly incorporated into both the Environmental and Social Safeguards Compliance Policy requirements (OP-703) and Disaster Risk Management Policy (OP 7-4) requirements. For example, the climate change risk assessment could be inserted directly as a section in a Disaster Risk Management Plan or included as an appendix to an Environmental Impact Assessment, and referred to in the Disaster (and Climate Change) Risk Management Summary. IDB asks the borrowers of projects which show high or moderate disaster risks to prepare a disaster (and climate change) risk management summary. The content of this summary is presented in the text box below. The specific climate change risks will be addressed in section 3 of this summary.

The distinction between impacts on the projects (type 1 scenario) and the human life, property and environment around it (type 2 scenario) made in section 2.0 is important, since it allocates the responsibilities in the further project risk management process. Whereas the risks for the project itself is a matter particularly important for credit risk management, the risk for human life, property, and environment is rather a matter of the environmental and social safeguards process.

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[10] A *climate lens* is further defined as "an analytical tool to examine a strategy, policy, plan, programme or regulation. The application of such a climate lens at the national or sectoral level involves examining: (i) the extent to which a measure – be it a strategy, policy, plan or programme – under consideration could be vulnerable to risks arising from climate variability and change; (ii) the extent to which climate change risks have been taken into consideration in the course of the formulation of this measure; (iii) the extent to which it could increase vulnerability, leading to maladaptation or, conversely, miss important opportunities arising from climate change; and (iv) for pre-existing strategies, policies, plans and programmes which are being revised, what amendments might be warranted in order to address climate risks and opportunities." The full document is available at <http://www.oecd.org/dac/43652123.pdf>.

Outline of Disaster Risk Assessment Summary

1. **Summary of initial disaster risk profile of project**; identification of pertaining (high or moderate) natural hazards; exclusion of low risk hazards

2. **Disaster Risk Assessment (DRA)** for relevant rapid onset hazards (conventional analysis, without considering climate change;
    - 2.1. Specification of rapid onset natural hazards (type, intensity, frequency) for the particular project area (exposure);
    - 2.2. Potential impact of event (at likely recurrence level) on project and area of influence during implementation and operation of project (scenario type 1), including exacerbated impacts when project is implemented and operating, on human life and integrity, property, social systems and environment (scenario type 2) for given vulnerability levels and coping capacities;
    - 2.3. Risk reduction options for identified project risks, using industry standards and standard methodology (without considering potential additional impacts exerted climate change), alternatives;

3. **Revision of Disaster Risk Assessment, addressing Climate Change**
    - 3.1. Modification of hazards, vulnerability and potential impacts by climate change (mainly for hydro-meteorological events)
        - 3.1.1. Frequency and intensity of rapid onset hazards modified by Climate Change,
        - 3.1.2. New Climate Change related risks; slow onset hazards and shifting of averages /patterns:
    - 3.2. Risk reduction options that also deal with additional risks posed by climate change; decision making under (compounded) uncertainty (probability given by historical trends; additional uncertainty from anticipated climate change); project design at an acceptable level of natural hazard risks

4. **Disaster Risk Management Plan**
    - 4.1. Disaster risk reduction (siting, investment choice, engineering)
    - 4.2. Disaster risk preparedness (e.g., contingency planning) and response
    - 4.3. Financial protection (transfer, retention)

From: IDB draft guidance note

Stakeholder involvement is considered cross-cutting across the project cycle. It is therefore recommended that climate change issues be incorporated in all stakeholder engagement activities per OP-703 of the Environment and Safeguards Compliance Policy.

3.0 Climate Change Risk Assessment Methodology (Steps 1–3) and Tools for the Caribbean

This section will focus on steps 1 to 3 of the proposed methodology and will identify the state of knowledge specific to the Caribbean as well as the tools and data sets available for performing these steps.[11]

3.1 Step 1: Screen the Project

This step requires screening the project for vulnerability to climate hazards based on the type of project and its location/exposure. The overarching question is whether the project is sensitive to climate change impacts, including increases in climate-related rapid onset natural hazards or to slow onset gradual, long-term changes of climate variables. The location will determine exposure and the likelihood of climate hazard occurrence and severity. For example, screening a coastal infrastructure project will consider increased inundation risk based on a location's elevation compared to future sea level plus storm surge. Projects that rely on critical supply chains should consider the location of those manufacturing or production centers.

Because a great deal of projected climate change information is readily available, often through relatively easy-to-use Web interfaces (identified below), information on key future conditions at a specific location can be obtained with minimal effort and user expertise. This stage of the evaluation should also consider the risk to the project under the current range of climate variability and extremes as estimated through current observations. Current variability may or may not be related to climate change, but the specific cause is not as important as the need to understand the project response.

The following climate change manifestations must be considered in the project screening, all of which are supported by observational and modeling studies:

- Increased temperature, including extremes
- More uncertain precipitation and greater extremes in precipitation
- Droughts, and reduction in water availability
- Increase in mean sea level
- Increased risk of coastal and riverine flooding
- Increased hurricane intensity, including extreme wind speeds
- Loss of coral reef area
- Erosion of beaches

Given the above impacts, the screening should include (but is not limited to) the following first pragmatic questions:

> How far is the project from the shoreline? Proximity to the coast almost always increases potential risks due to coastal flooding and hurricanes.

> What is the project elevation? Projects at elevations substantially higher than sea level and storm surge estimates are expected to be at lower risk from ocean-related impacts.

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[11] Additional guidance is available on step 3 in Technical Note No. IDB-TN-806, *Addressing Climate Change within Disaster Risk Management: A Practical Guide for IDB Project Preparation*, available here: https://publications.iadb.org/handle/11319/6910?locale-attribute=en.

How far is the project from an inland water body? Inland water bodies can be subject to flooding from extreme precipitation events, and proximity to streams might be a potential risk.

How much fresh water will the project need to operate? Water resources are expected to become more constrained and dependence on large water withdrawals is a potential risk.

What natural resources does the project's success depend on (beaches, coral reefs, agricultural products)? Natural resources (including agricultural resources) can be an indirect component of a project's success, and adverse impacts to these resources might affect the success of the related project.

Where are critical supply chain locations? Projects could depend on products or services in other parts of the country or region. Understanding the potential exposure of the supply chain to climate impacts is also important. Answering the questions above for all critical supply chain locations and associated activities will help determine exposure to climate impacts.

Climate change impacts, such as changes in precipitation or increased intensity of hurricanes, could impact a project's integrity and result in negative effects to the surrounding environment or community. For example, increased hurricane intensity could lead to increased storm surge to an oil pipeline project or other coastal infrastructure. If the storm surge is higher than the pipeline was designed to withstand, the pipeline could fail, causing a spill which could in turn affect local communities and ecosystems.

These questions do not have simple answers, but the assumptions that are used to justify a project must be evaluated in light of the climate change impacts identified above. If the assumptions appear questionable, then a more detailed assessment with more local, on-the-ground information and more detailed modeling might be warranted. A detailed assessment almost always requires resources greater than those required for a rapid assessment (often an order of magnitude or more). The project screening, therefore, is a good first step before conducting a more detailed analysis.

There are several Web-based tools that could assist with the project screening, including the following:

- The Caribbean Climate Online Risk and Adaptation TooL (CCORAL) is an online, open-source tool that guides users through several steps, helping them identify whether climate change is likely to influence their activity.
- The World Bank's Climate Change Knowledge Portal (CCKP) is an online tool for access to global, regional, and country-level data related to climate change and development. The World Bank's CCKP includes environmental, disaster risk, and socio-economic data sets. (The portal will be described in further detail in the next sections.)
- The effects of climate change on the coast of Latin America and the Caribbean project database is a geographic information system (GIS)-based database that contains information on coastal dynamics in Latin America and the Caribbean, climate variability, coastal vulnerability and exposure to climate change, the impact of climate change in the area, and an estimation of predictable risks in the future.

A proposed classification filter for the project screening step is included below, with potential impacts identified as low, moderate, or high risks (Table 3.1).

Table 3.1 Proposed Classification Filter for Climate Risk Project Screening

Proposed Classification Filter		
Proposed Project Screening Questions	**Additional Considerations**	**Illustrative Classification**
How far is the project from the shoreline?	• Identify/assess current coastal floodplain. • Identify/assess projected future floodplain. • Identify/assess potential impacts from coastal flooding (includes risk from sea level rise, coastal erosion, and storm surge) and anticipated time horizon.	**High risk:** Project is in the current coastal floodplain (or < 3 miles from shore with minimal elevation). **Moderate risk:** Project will be in the future floodplain in the near-term (20 years) (or < 5 miles from shore with minimal elevation). **Low risk:** Project is not in the coastal floodplain or future floodplain (or is located > 5 miles from shore, or elevated from flood risk).
What is the project elevation?		
How far is the project from an inland water body?	• Identify/assess current riverine floodplain. • Identify/assess projected future floodplain. • Identify/assess potential impacts from riverine flooding (includes risk from sea level rise, coastal erosion, and storm surge) and anticipated time horizon.	**High risk:** Project is in the current riverine floodplain (or < 1 mile from bank with minimal elevation). **Moderate risk:** Project will be in the future floodplain in the near-term (20 years) (or < 2 miles from shore with minimal elevation). **Low risk:** Project is not in the riverine floodplain or future floodplain (or is located > 2 miles from shore).
How much fresh water will the project need to operate?	• Identify/assess all fresh water requirements for the project, including any seasonal variability. • Identify/assess available fresh water supplies, including any seasonal variability and emergency water agreements/supplies. • If relying on municipal or shared resources, or both, consider projected water demand. • If relying on aquifers, consider distance from the shoreline and potential for saline intrusion.	**High risk:** Current or projected water availability is insufficient for project operations or a short-term, temporary disruption of water resources would be detrimental to operations. **Moderate risk:** Project relies on aquifer that is at-risk for salinization; or a shared water resource that has high water demand relative to supply; or a short-term, temporary disruption of water resources would impact operations. **Low risk:** Project has adequate water supply and is not exposed to short-term disruptions.
What natural resources does the project's success depend on?	• Identify/assess all natural resource requirements for the project, including any seasonal variability.	**High risk:** Critical natural resource for project operations is at major risk of impact. **Moderate risk:** Natural resource that supports project operations (but is not considered critical) is at risk of impact. **Low risk:** The project does not rely on natural resources, or it has redundant systems in place.
Where are critical supply chain locations?	• Identify/assess all critical supply chain locations, including location and vulnerability, as well as alternative transportation routes should one route be impacted.	**High risk:** Supply chains are in at-risk areas or a short-term, temporary disruption would be detrimental to operations. **Moderate risk:** Supply chains are in moderately at-risk areas or a short-term, temporary disruption would impact operations. **Low risk:** The project does not rely on supply chains, or it has redundant systems in place.
Could climate risks to the project result in significant negative impacts to the surrounding environment or community?	• Identify/assess whether climate-induced hazards could cause project failures that would harm the surrounding environment and community. • Identify/assess vulnerability of the surrounding environment. Are there at-risk endangered species or protected areas? • Identify/assess vulnerability of the surrounding community. Are there at-risk vulnerable populations?	**High risk:** Potential for significant impact as designed, and moderate to high likelihood of climate risk. **Moderate risk:** Potential for impact as designed, but low likelihood of climate risk. **Low risk:** The project would not harm or exacerbate the risk to the surrounding environment or community.
Are there other climate-related concerns not addressed through the above questions?	• Based on local/site specific information explore whether other considerations are important.	**Classify risk as for the questions above.**

The goal of the project screening is that the project's vulnerability to the climate change impacts is considered alongside other hazards and considerations already assessed in the Environmental and Social Safeguard Screening process. Thus, considered alongside the Disaster Risk Management Policy OP-704, the following two questions should be answered in the screening process:

- Whether there is a natural hazard risk that will be exacerbated by climate change that might have a consequential impact on human life, property, and environment.
- Whether the project could exacerbate disaster risk for human life, property, and environment by increasing vulnerability to the climate risk in the area of impact, even if the project itself might not be affected.

If the answer to one or both of the above questions is yes, and a high level of risk is identified for one or more of the classification filter questions, then the project proponent should move to the next step of the climate and climate change risk assessment process.[12] If the project is screened as a low climate risk, the project proponent can stop at this stage. It is recommended that screening be conducted as a "project-centric" process, as opposed to a "prescriptive" process, so that there is flexibility to assess climate change risk according to the unique project attributes.

3.2 Step 2: Define the Assessment Parameters

Once a project is determined to require further evaluation, the parameters of the climate change risk assessment must be defined. The key steps associated with this step include the following:

1) Identify location or region of interest, and planning horizon for climate change impact evaluation.
2) Based on the project screening, identify the climate change risks that warrant further evaluation.
3) Determine what climate-relevant data is available to support further evaluation of the climate risk in the geographic area of interest. This could include:
    a. Temperature data and metrics (e.g., maximum temperature, average temperature, etc.).
    b. Precipitation data and associated metrics (e.g., annual precipitation, precipitation during a growing season, highest precipitation over a specified period, etc.).
    c. Upper and lower bounds of sea level rise using recent estimates.
    d. Change in hurricane frequency and intensity.
    e. Storm surge estimates, which can be combined with the sea level rise estimates for a point in time and land elevation to estimate areas that are subject to inundation during storms and hurricanes under future sea level conditions.

The geographic boundaries for the assessment should include locations of all project-related infrastructure. This includes consideration of the project's physical infrastructure as well as the locations of critical support infrastructure (e.g., airports, ports, wastewater utilities) and associated natural resources (e.g., water supplies, beaches, agricultural production) identified in the screening process. To determine the time horizon of the climate change risk assessment, the life cycle of both the investment and infrastructure should be considered.

The screening process should identify the priority hazards that pose risk to the project. In this step, the key types of data related to the climate hazard and available for the project-specific location(s) should be identified. There is a great deal of projected climate data available in the Caribbean region because these are often produced through global climate models. However, there is also a need for local, measured data on various climatic and sea level features that provide an understanding of the range and variability of these drivers. These measured data are less commonly available in the Caribbean or are not in the public domain. Examples of these variables include daily precipitation and wave heights.

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[12] The study team recommends that the IDB further define the project screening questions and that threshold considerations for whether a project proponent should proceed to the next step in the climate change risk assessment are identified.

A climate risk assessment can be limited by the availability of data relevant to the location of interest and planning horizon. Identifying what data is available will inform the level of analysis that can be conducted. For example, extreme precipitation may be a factor affecting riverine flooding. Although climate change is expected to increase the intensity of extreme precipitation events (IPCC, 2013), local data are needed to perform a quantitative assessment of the potential flooding under current or more extreme conditions.

A full discussion of the available data sets for the Caribbean and how to access that data is included below to help facilitate the climate risk assessment process.

3.2.1 Overview of Climate Data and Tools for the Caribbean

The goal of this section is to provide the reader with sources of information that can be used to perform a climate change risk assessment. Following a brief background on climate change projection modeling, climate-related data collection—for historical and current conditions as well as future projections—is demonstrated at various locations in the Caribbean where the IDB might have a funding role. The data compilation is presented in a general manner, and is not focused on a specific region or type of project. The description of pertinent climate data is divided into three categories: (1) temperature and precipitation changes, (2) sea level rise, and (3) incidence of hurricanes and tropical storms. Also of interest are geographical data on elevation and socioeconomic features that help characterize impacts in specific regions. For completeness, these sources of data are also presented. The sections that follow provide sample results, and where appropriate, screenshots of websites that illustrate how a user can obtain similar data for other locations.

3.2.1.1 Background on Climate Projections

A variety of models and greenhouse gas emission scenarios has been developed to simulate global climate over the past quarter century. To standardize some of the output generated by diverse modeling groups from around the world, the Coupled Model Intercomparison Project (CMIP) was begun to serve as a repository of model runs with consistent emission scenarios. The World Climate Research Programme (WCRP) develops climate projections every 5 to 7 years. These projections have informed Intergovernmental Panel on Climate Change (IPCC) Assessment Reports that summarize the state of climate science and are published every 5 to 7 years. [13] The last published IPCC report (in 2007) used the CMIP Phase 3 (CMIP3) projections. Because the CMIP projections are readily accessible on the Internet, they are commonly used for various research and impact assessment activities related to climate change. WCRP released global climate projections from CMIP Phase 5 (CMIP5) during 2012–2013. Over the coming years it is expected that CMIP5 data will be used for climate change analysis. A crucial difference between CMIP3 and CMIP5 projections is that they use somewhat different emissions pathways for the future. The most recent IPCC report (termed the *Fifth Assessment Report,* IPCC 2013) uses CMIP5 data. At the time of development of this paper, CMIP3 data were more widely available for the Caribbean, but it is anticipated that this will change in the coming months as CMIP5 data are incorporated.

The CMIP climate data are in the form of outputs from atmosphere-ocean general circulation models (AOGCMs), or, in more common and recent usage as global climate models (GCMs). Because the spatial scale of GCM output, typically 200–500 kilometers, is too large to characterize climate over small and topographically complex areas, downscaling to a finer resolution is necessary. This can take two general forms: statistical and dynamical downscaling (Benestad 2001; Mearns et al. 2001). While

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[13] Note that Representative Concentration Pathways will be used as the set of standards to model climate data in the upcoming Fifth IPCC Assessment (AR5) in 2014. Representative Concentration Pathways refer to four greenhouse gas concentrations. They are the third generation of IPCC scenarios. The first set (IS92) was published in 1992. In 2000, the second generation (SRES) was released.

dynamical downscaling has the advantage of simulating fine-scale physical processes, and therefore is capable of capturing non-linear feedbacks, it requires intensive computational effort, which renders its use impractical for extended transient simulations of multiple emissions scenarios. Limited dynamical downscaled projections are available for the Caribbean region. Statistical downscaling uses long sequences of observed climate to establish statistical relationships between large- and fine-scale climate features. These are then applied to future projections to infer the fine-scale response implicit in the large-scale GCM projections. Statistical downscaling, while computationally efficient, has the principal drawback of assuming a similar relationship between large- and fine-scale climate features, the validity of which becomes less certain as the climate warms to levels not observed in the historical record. Despite this limitation, statistically downscaled climate data are widely used for climate change risk assessment studies.

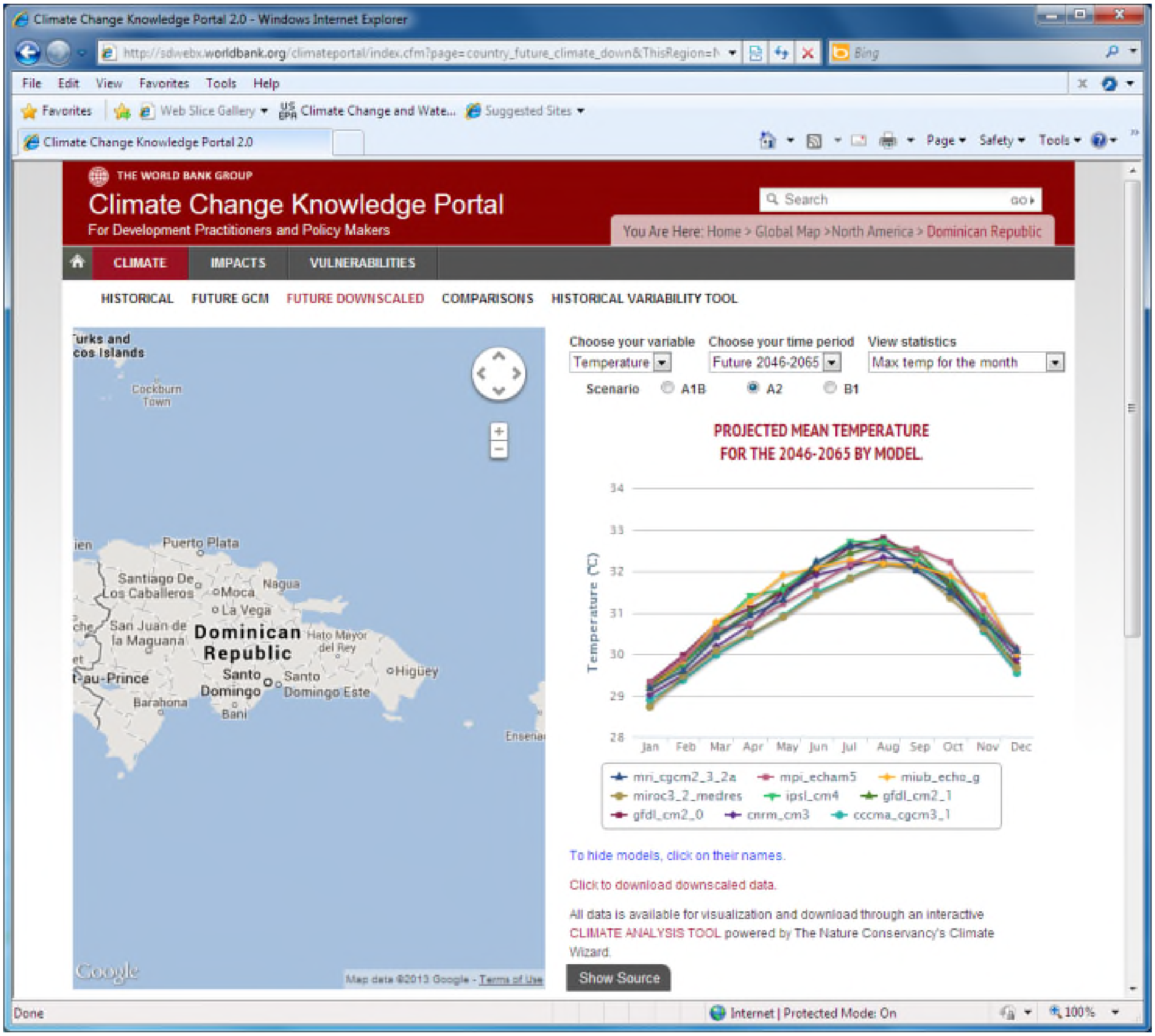
3.2.1.2 Temperature and Precipitation

The most readily available information for future climate scenarios in the Caribbean region is in the form of statistically downscaled values and is discussed below. For completeness, the dynamical downscaling data currently available is also summarized.

Statistically downscaled temperature and precipitation values, both historical and projected, are available from the CMIP3 projections from the World Bank's CCKP in a form that is easily accessible. For example, historical and projected data for temperature and precipitation are shown in Figure 3-1 through Figure 3-3 for the Dominican Republic for a mid-21st century period. These values show a pattern that is typical among GCMs: greater agreement on temperature projections than on precipitation projections. In this case, all models indicate an increase in temperature, and most models indicate a decrease in precipitation in the future time period. A regional, map-based view of the data can also be generated using the same underlying online tool, and is used to display mid-21st century precipitation in Figure 3-4**.**

It is important to evaluate how climate has varied and changed in the past. The monthly mean historical rainfall and temperature data can be mapped to show the baseline climate and seasonality by month, for specific years, and for rainfall and temperature. The chart above shows mean historical monthly temperature and rainfall for Dominican Republic during the time period 1960-1990. The dataset was produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA).

Figure 3-1. Historical temperature and precipitation for the Dominican Republic from the World Bank's CCKP at <http://sdwebx.worldbank.org>.



Choose your variable: Temperature

Choose your time period: Future 2046-2065

View statistics: Max temp for the month

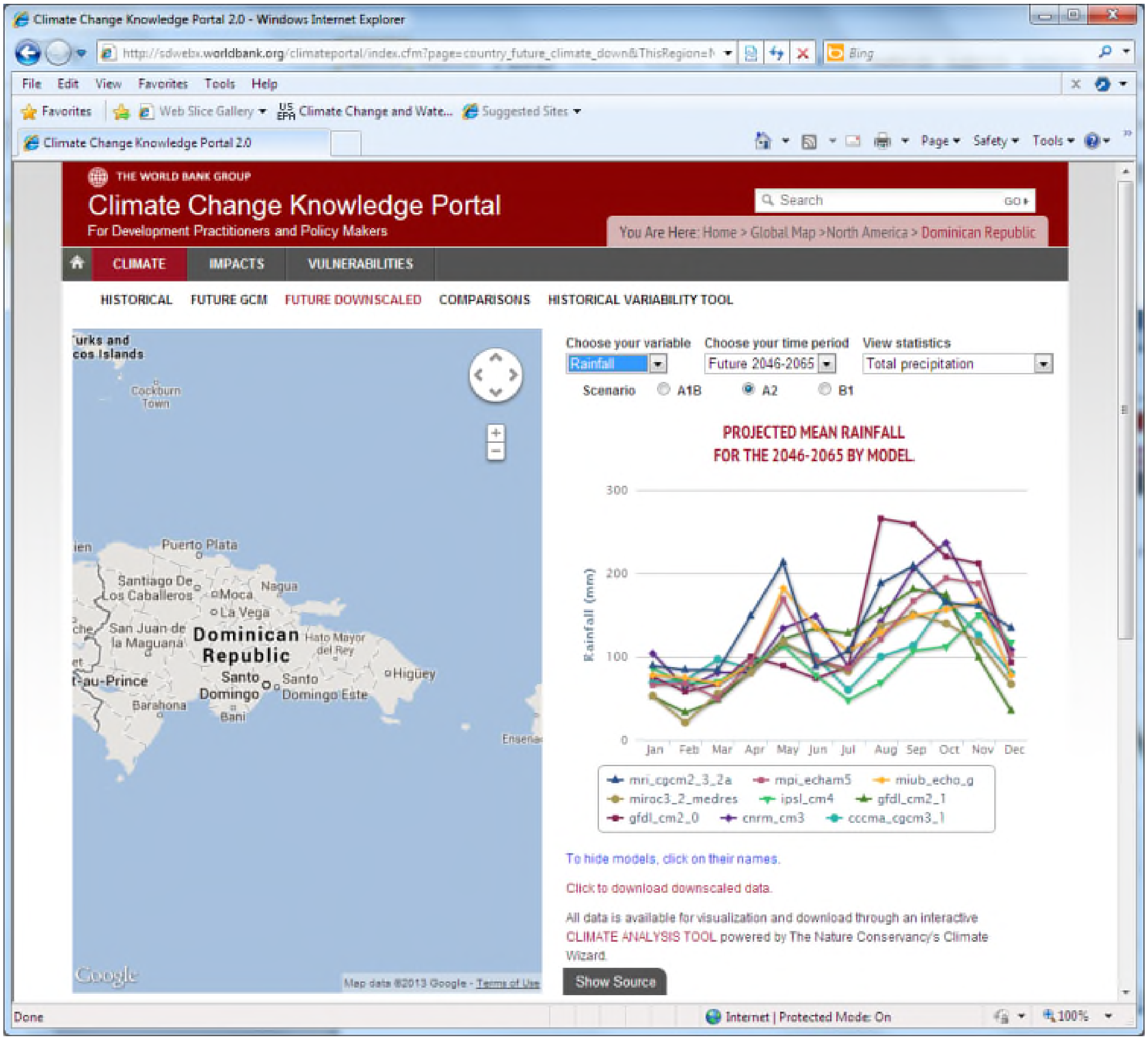
Scenario ○ A1B ● A2 ○ B1

To hide models, click on their names.

Click to download downscaled data.

All data is available for visualization and download through an interactive CLIMATE ANALYSIS TOOL powered by The Nature Conservancy's Climate Wizard.

Figure 3-2. Projected mean temperature for the Dominican Republic for 2046–2065 from the World Bank's CCKP at <http://sdwebx.worldbank.org>. The plot on the right shows projections for 9 different GCMs.



You Are Here: Home > Global Map > North America > Dominican Republic

Choose your variable: Rainfall

Choose your time period: Future 2046-2065

View statistics: Total precipitation

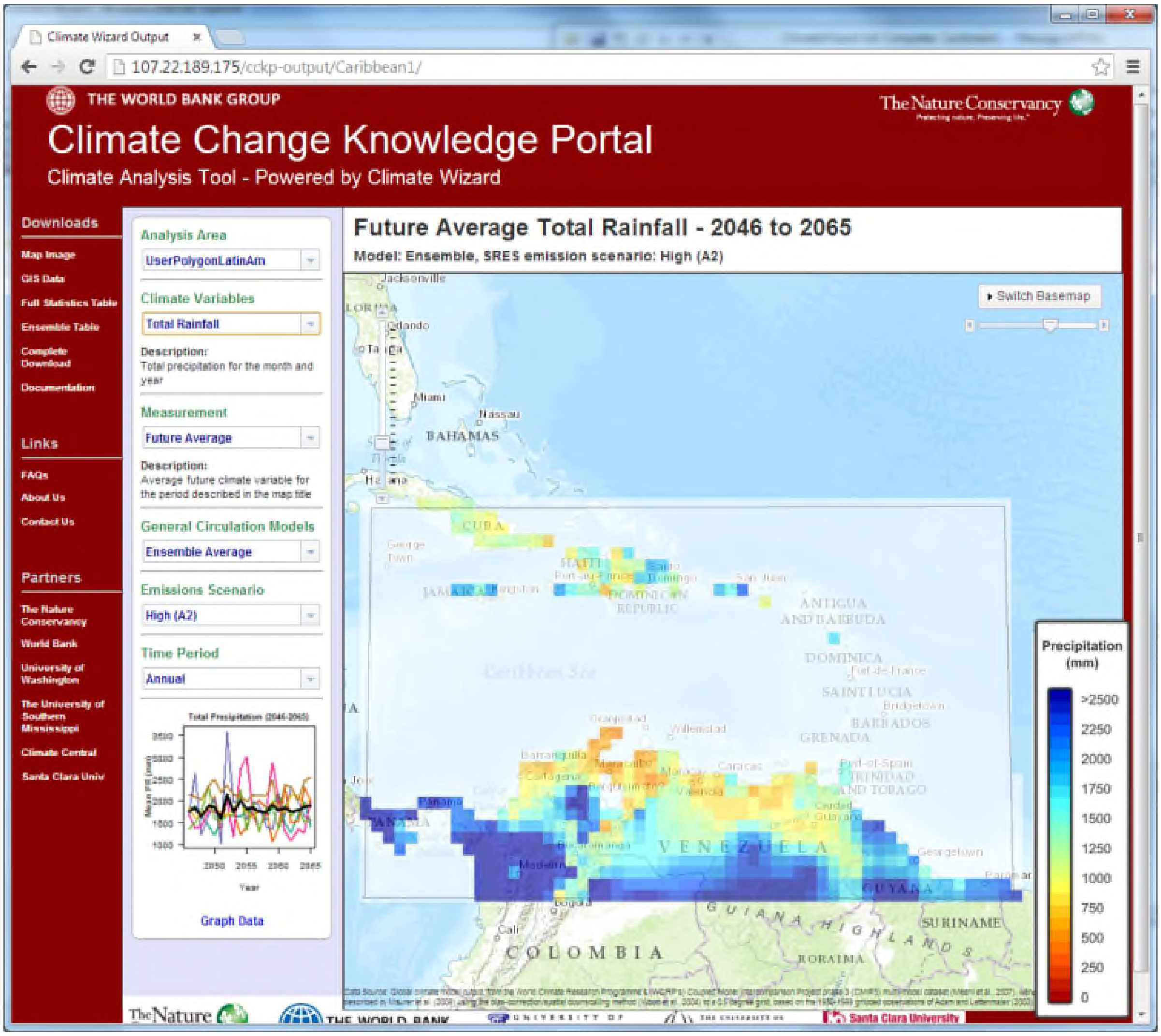
Scenario ○ A1B ● A2 ○ B1

To hide models, click on their names.

Click to download downscaled data.

All data is available for visualization and download through an interactive CLIMATE ANALYSIS TOOL powered by The Nature Conservancy's Climate Wizard.

Figure 3-3. Projected mean precipitation for the Dominican Republic for 2046–2065 from the World Bank's CCKP at <http://sdwebx.worldbank.org>. The plot on the right shows projections for 9 different GCMs.



Future Average Total Rainfall - 2046 to 2065

Model: Ensemble, SRES emission scenario: High (A2)

Analysis Area: UserPolygonLatinAm

Climate Variables: Total Rainfall

Description: Total precipitation for the month and year

Measurement: Future Average

Description: Average future climate variable for the period described in the map title

General Circulation Models: Ensemble Average

Emissions Scenario: High (A2)

Time Period: Annual

Figure 3-4. Projected precipitation for the Caribbean region for 2046–2065 using CMIP3 data and a mapping tool called ClimateWizard that has been customized for the World Bank's CCKP at <http://sdwebx.worldbank.org>.

If, however, CMIP5 projections are desired, a different source of data might need to be used. At this time, the CMIP5 globally downscaled data can be obtained from WorldClim, a set of global climate layers (climate grids) with a spatial resolution of about 1 square kilometer. The interface for this data source is oriented toward researchers and does not have the simple country-by-country functionality of the World Bank site. A regional summary of the precipitation in the Caribbean region over the 20th and 21st centuries from the CMIP5 data is shown in Figure 3-5. It is possible that the World Bank site will also be updated in the coming months, however, many completed and ongoing studies are based on CMIP3 projections that were considered the best information available at the time of the study. Even though CMIP5 is newer, it is not considered a more reliable product, and for some time, it is likely that climate impact studies will be performed using both CMIP3 and CMIP5 projections. From a practical standpoint, there are great uncertainties in climate change projections, and if a risk assessment indicates concerns using the available CMIP3 data, these concerns are also likely to occur using CMIP5 data.

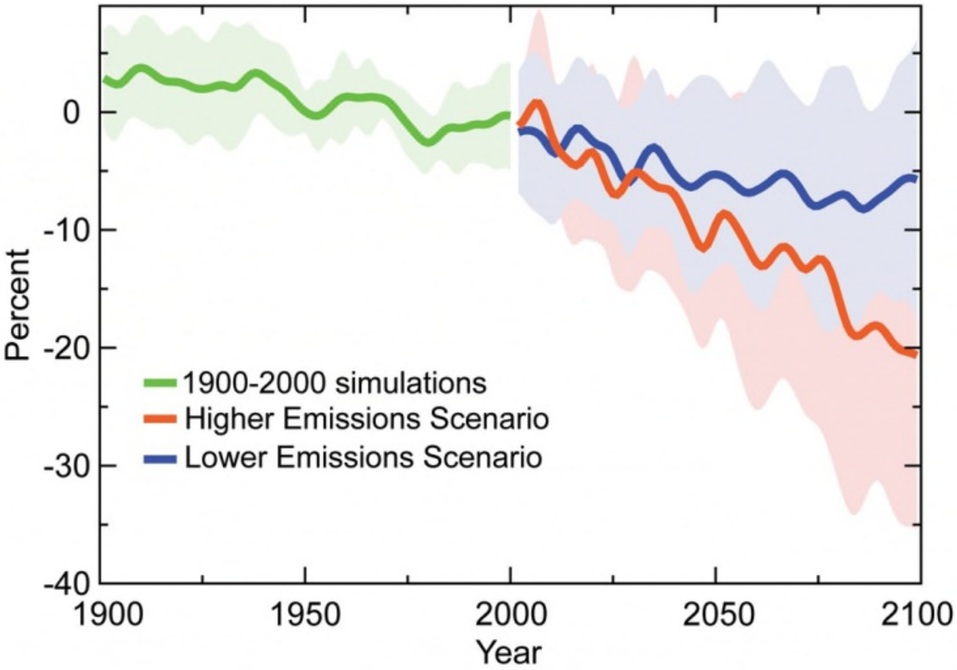


Figure 3-5. Projected precipitation for the Caribbean region for the 20th and 21st century from the CMIP5 data. summary plot obtained from <http://www.worldclim.org>.

In addition to the data sources above, two major sources of dynamically downscaled information can be considered. The first is a North America-wide modeling effort with multiple GCMs and regional climate models (RCMs) to produce high-resolution climate change simulations called the North American Regional Climate Change Assessment Program (NARCCAP). The model domain here includes the Western Caribbean, and the data can be downloaded for specific climate change scenarios for use in impacts research. An example of precipitation outputs from NARCCAP is shown Figure 3-6; the data shown compares the results from the global-scale model with the regional-scale model. As with the statistical downscaling results, these data are available for multiple models. A Caribbean-specific RCM, developed using a modeling framework called PRECIS (Providing Regional Climates for Impacts Studies), provides projections for a wider range of variables and for specific time periods. The United Kingdom Meteorological (MET) Office developed PRECIS.[14] An example of future precipitation for the mid-21st century obtained from this tool is shown in Figure 3-7. While these data are more focused on the region of interest as compared to NARCCAP, the available output only pertains to a single model, which is limiting given the uncertainty across different climate models (discussed further below). The Caribbean Institute for Meteorology and Hydrology (CIMH) also collects climate data and is considered a regional resource; however, their data is not available online and must be requested.

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[14] This data is also available from the Caribbean Community Climate Change Centre.

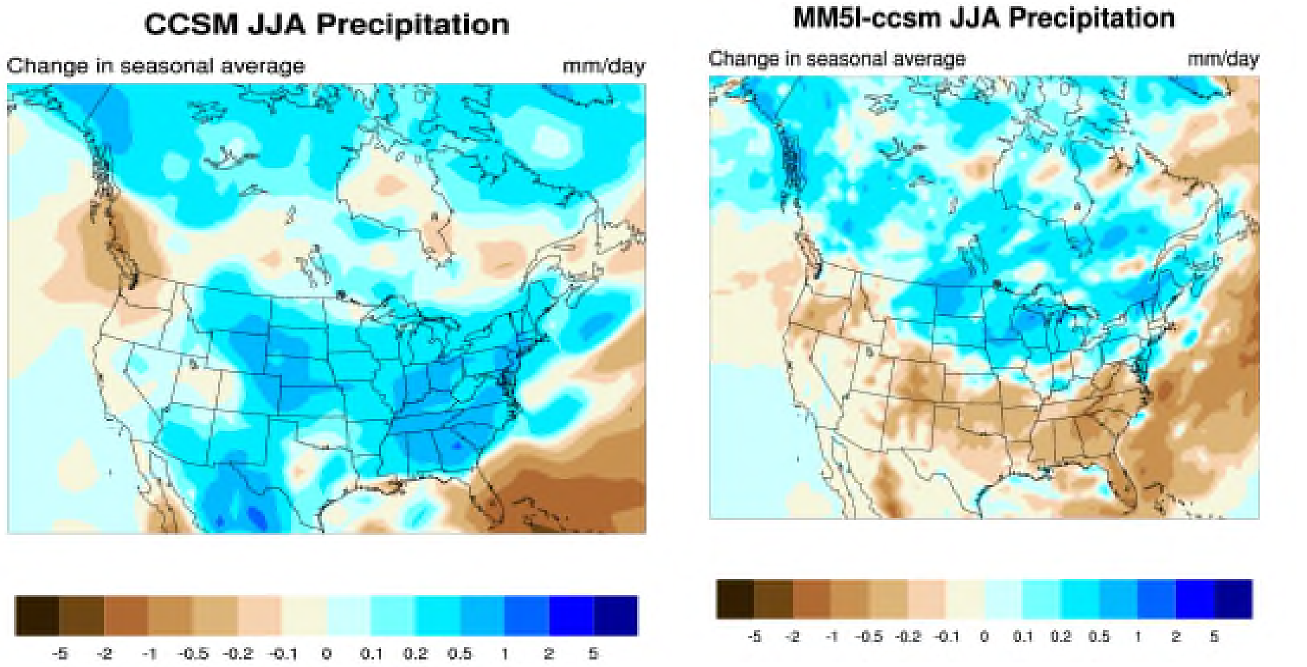
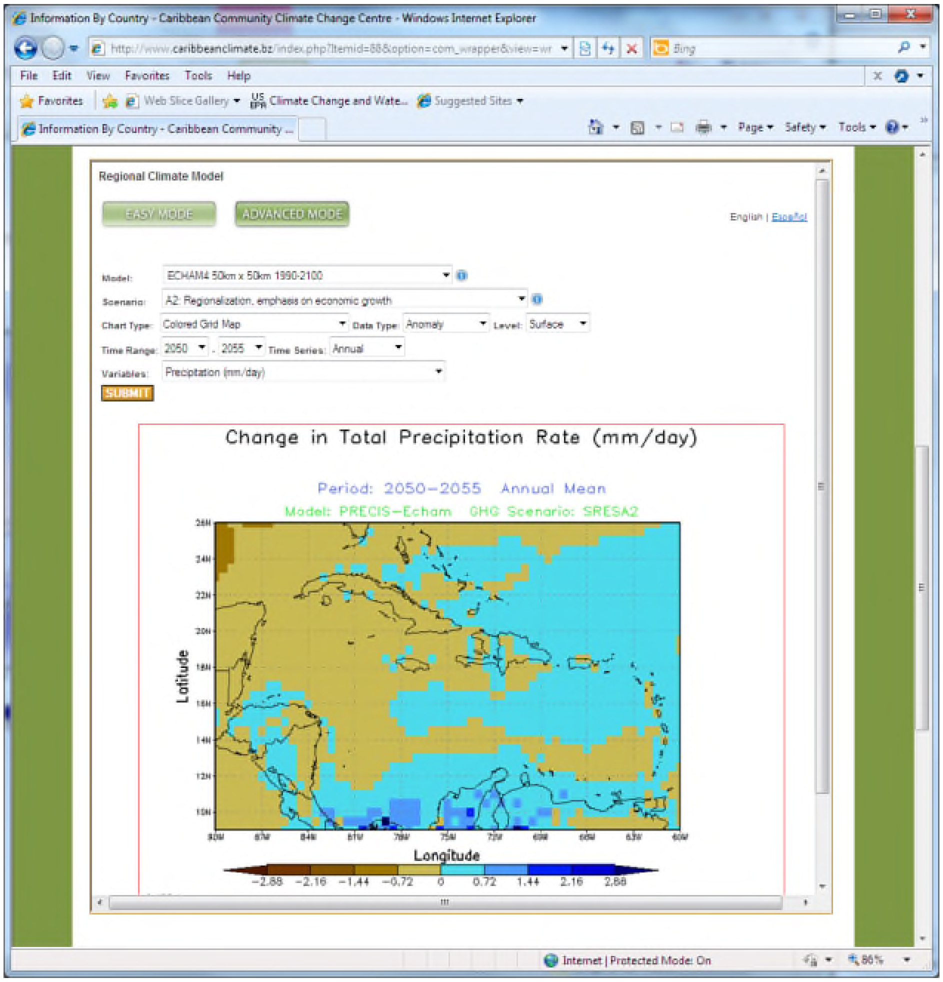


Figure 3-6. Projected changes in June, July, and August (JJA) precipitation through a GCM (left) and through an RCM (right). The lower panel is for dynamic downscaling for North America (including parts of the Western Caribbean region) for the mid-21st century. These results are based on a specific pairing of a GCM and an RCM. The GCM used is CCSM, the RCM used is MM5I. (*Source*: http://www.narccap.ucar.edu/results/tmsl-results.html). Although the results do not match, both indicate a decrease in precipitation in the portion of Caribbean that falls in the model domain.



Model: ECHAM4 50km x 50km 1990-2100
Scenario: A2: Regionalization, emphasis on economic growth
Chart Type: Colored Grid Map
Data Type: Anomaly
Level: Surface
Time Range: 2050 - 2055
Time Series: Annual
Variables: Precipitation (mm/day)

Figure 3-7. Projected changes in precipitation through a Caribbean-specific RCM (PRECIS). This Web interface can be used to develop maps for specific variables for different time periods, and can also be used to download numerical data. (*Source*: http://www.caribbeanclimate.bz/index.php?Itemid=88&option=com_wrapper&view=wrapper)

In summary, several data sources are currently available for climate projections in the Caribbean. The World Bank site appears to the most comprehensive and easy-to-use resource currently, and is suitable as a data source on projected future climate for both basic and detailed risk assessments.

3.2.1.3 Sea Level Rise

There is a close correspondence between mean sea level and global temperatures, and this aspect of climate change is of particular importance to the Caribbean because of numerous small island nations and extensive exposed coastlines throughout the region. Changes in sea level are due to a complex interaction of climatic and geologic factors. The climatic factors are global; sea levels are rising largely because global temperatures are rising, causing ocean water to expand and land ice to melt. Besides this global trend, regional changes are also occurring in ocean and atmospheric circulation patterns that are affecting sea level. The geologic factors (subsidence, rebound, and uplift) are also regional. For these reasons, actual sea level rise varies by location. Local sea level projections for the Caribbean are not available and global estimates are appropriate for use in the region.

The global 20th century sea level rise was 1.7 ± 0.5 millimeters per year (IPCC 2007). Over a more recent period, 1993–2003, the global increase has been reported to be 3.1± 0.7 millimeters per year using satellite altimetry data (National Academy of Sciences 2012).

In the Caribbean region long-term tide gauge data are relatively sparse. The best available data are from Permanent Service for Mean Sea Level (PSMSL). PSMSL is a data repository for long-term sea level change information from tide gauges and bottom-pressure recorders. PSMSL has been responsible for the collection, publication, analysis, and interpretation of sea level data from the global network of tide gauges. Active sea level gauges in the Caribbean are shown in Figure 3-8. Typical trends in sea level for a station in Cristobal (in Panama) are shown in Figure 3-9. This is one of the longest publicly available continuous records in the Caribbean region. Most available gauges are less than 30 years old and do not provide sufficient data to identify a trend in sea level. For example, the Tsunami Alert System has recently started collecting tide data and establishing additional tide gauges.

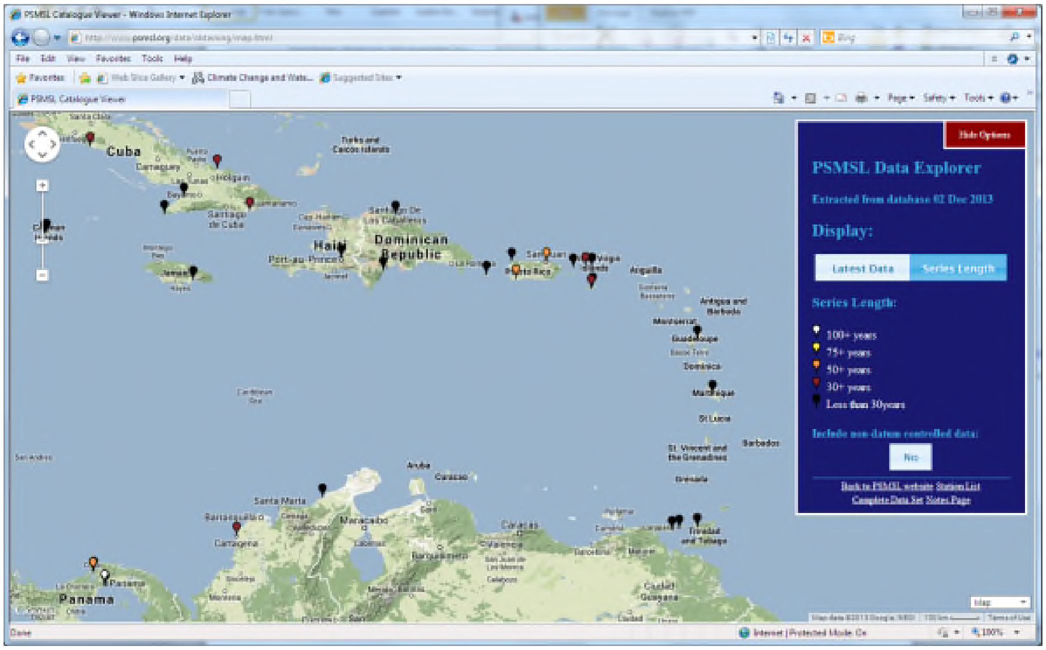
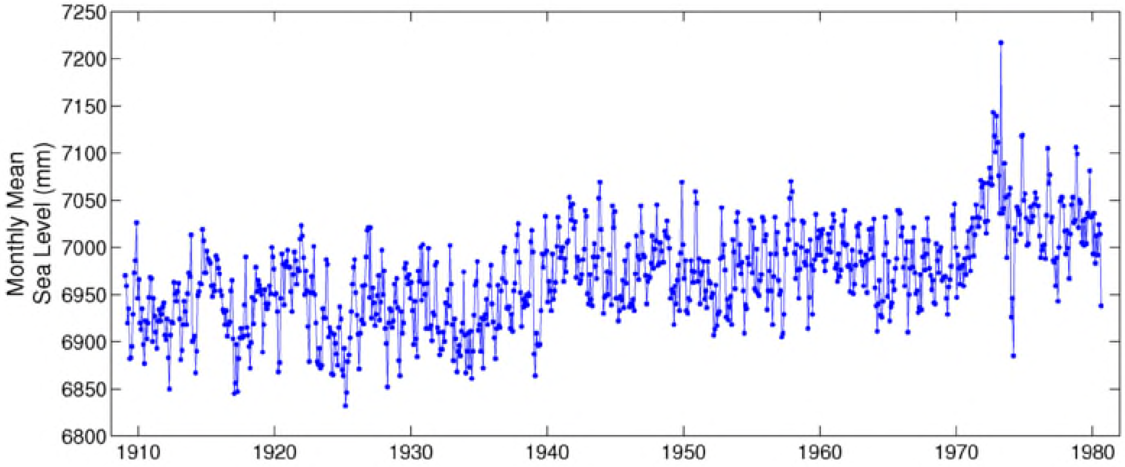


Figure 3-8. Active sea level gauges in the Caribbean, as reported by the PSMSL. The colors of the symbols indicate the length of record, and most are 30 years or less.



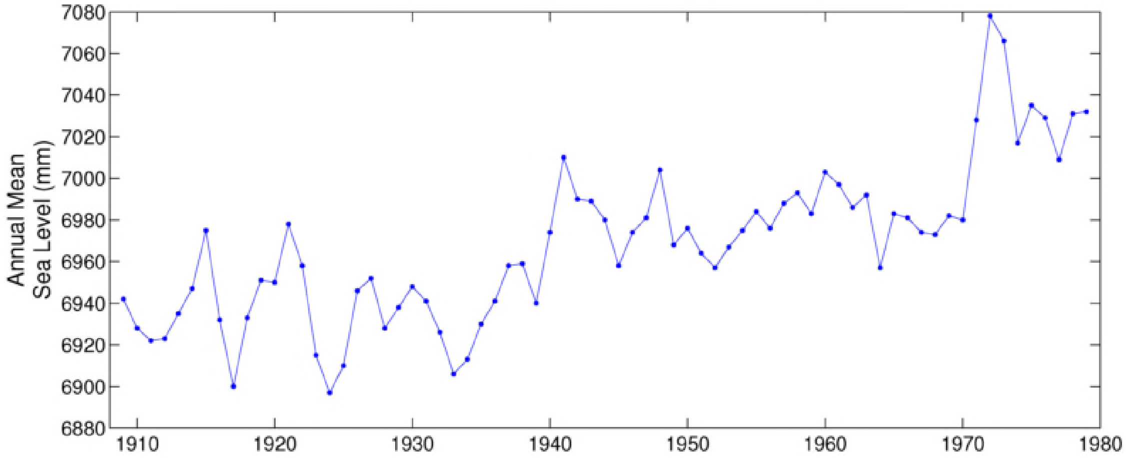


Figure 3-9. Sea level (monthly and annual mean) for a gauge in Cristobal (Panama). This is one of the longest periods of record in the Caribbean region in the PSMSL database.

Recent global sea level rise estimates for the 21st century suggest a considerably larger increase than had been projected a few years ago in the 2007 IPCC report, and show an increasing rate compared to the 20th century rate of change (Figure 3-10). Based on an assessment of calculations using multiple GCMs as well as empirical methods, a recent comprehensive review reported that global sea level is estimated to rise 8–23 centimeters by 2030 relative to 2000, 18–48 centimeters by 2050, and 50–140 centimeters by 2100 (National Academy of Sciences 2012). This information is summarized in plot form in Figure 3-11, and can be used to select ranges of sea level rise for specific time periods. The most recent IPCC report suggests a somewhat lower range of sea level rise, ranging from 17-38 centimeters over 2046-2065, and from 26-82 centimeters over 2081-2100 relative to a baseline of 1986-2005 (IPCC, 2013). Both are scientifically credible sources of information, and the differences are indicative of fundamental scientific uncertainties driving sea level rise estimates. Given the international focus of the IPCC reports, the IPCC results may be used in preference to the National Academy of Sciences review.

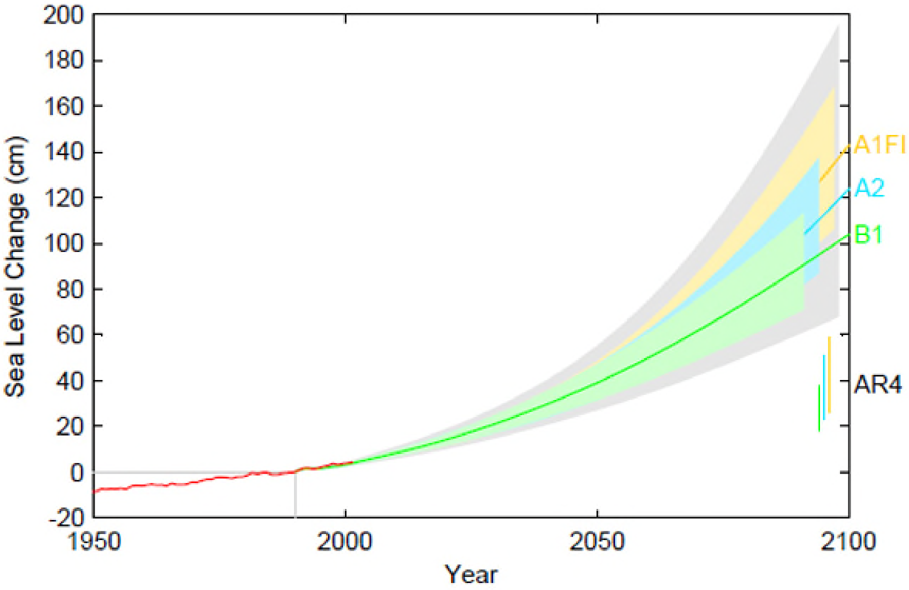


Figure 3-10. Sea level rise from 1950 to 2100 based on a semi-empirical model (Vermeer and Rahmstorf 2009) and three emission scenarios (A2, B1, and A1FI). AR4 refers to projections made in the IPCC 2007 report. The increase seen over the historical period is expected to accelerate significantly based on this model.

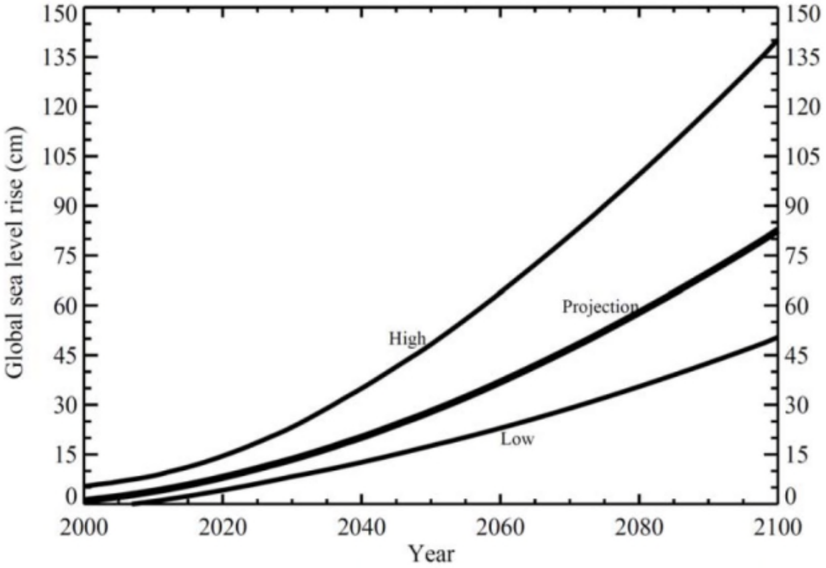


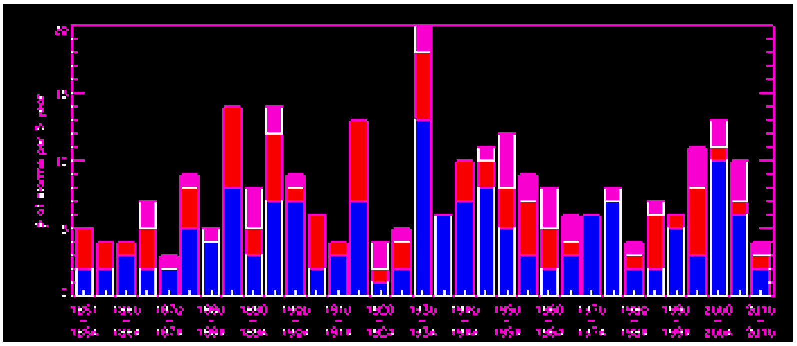
Figure 3-11. Projection of sea level rise from 2000 to 2100, along with upper and lower uncertainty bounds, based on an evaluation of the literature and alternative modeling methods (National Academy of Sciences 2012). The models employed for this composite projection are in addition to the Vermeer and Rahmstorf (2009) projections shown in Figure 3-10.

3.2.1.4 Hurricane Frequency and Intensity

Hurricanes are a climatic extreme with significant consequences over much of the Caribbean, and the changes in hurricane frequency and intensity due to climate change are a subject of considerable research. This section summarizes the best current representation of the state of science on this critical aspect of climate-related risk.

Available data on hurricane frequency and intensity shows no clear pattern over a 160-year period of historical record (data for Eastern and Western Caribbean from the Caribbean Hurricane Network [Figure 3-12]), during which there have been observable increases in global mean temperature. This is particularly true if the early years with fewer hurricanes are corrected for the fact that limited ship traffic might have caused some hurricanes or tropical storms to go unobserved (Biasutti et al. 2012; Vecchi and Knutson 2008). Note that some trends can be observed visually over more limited periods (e.g., over the last 30 years), but are not supported by the longer record in the region. These shorter trends might be related to natural climatic oscillations, but their link to anthropogenic effects has not been established.

Eastern Caribbean



Western Caribbean

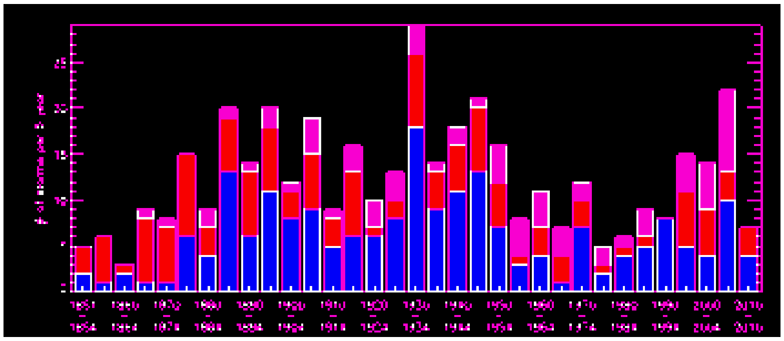


Figure 3-12. Hurricanes from 1851 to 2010, aggregated over 5 years in the Eastern and Western Caribbean. (**category 3–5: purple; category 1–2: red; tropical storms: blue**). (*Source*: http://stormcarib.com/climatology/)

Tropical cyclones and hurricanes generally form in areas with high sea surface temperatures (SST), and the intensity of these events is also related to SST (Emanuel 1987; Holland 1997). More specifically, *relative SST*, which is defined as the difference between local SST and the tropical mean SST, is found to be associated with cyclones and hurricanes. Although higher SSTs are expected in a future climate, higher relative SSTs are not necessarily expected. Other environmental factors besides SST also play a role in controlling storm activity, such as vertical wind shear, which is the difference in the winds at low and high levels in the atmosphere (http://www.gfdl.noaa.gov/global-warming-and-hurricanes; Biasutti et al. 2012). For these reasons there is no simple correlation between warmer oceans and increased occurrence of storms and hurricanes.

Storms and hurricanes are typically fine-scale events that are not well-described by global-scale models, such as the GCMs referred to in the previous section. In recent years different high-resolution modeling studies have addressed hurricane formation in the Atlantic Ocean. A downscaled climate model that reproduces past hurricane activity reasonably well (Figure 3-13) does not predict an overall increase in the frequency of Atlantic tropical storms and hurricanes. The model supports the notion of a decrease in the overall number of Atlantic hurricanes with projected 21st century climate warming.

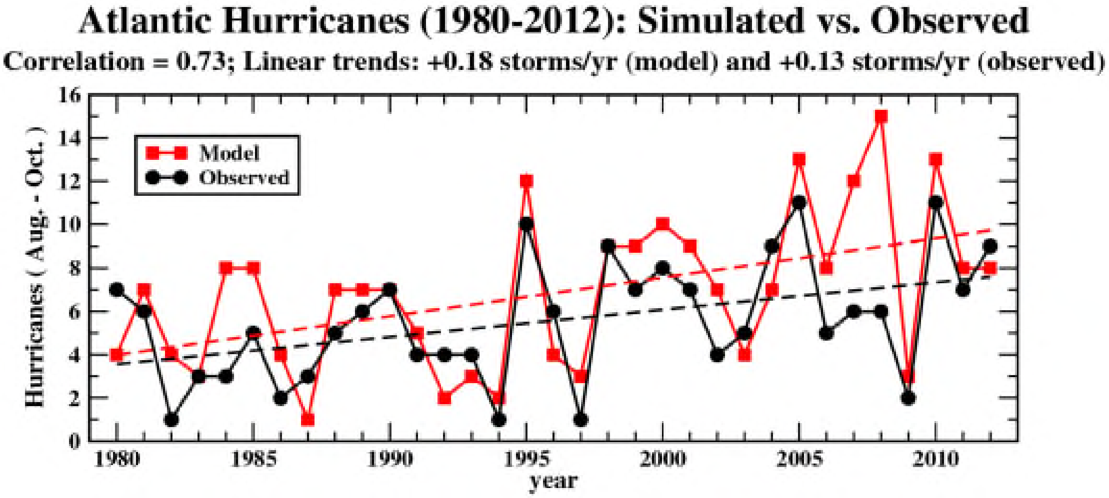


Figure 3-13. Modeled and observed hurricanes from 1980-2012.

(*Source*: http://www.gfdl.noaa.gov/global-warming-and-hurricanes)

However, other analysis projects a doubling in frequency of very intense (category 4–5) hurricanes in the Atlantic basin by the end of the 21st century. This analysis uses an 18-model average climate change projection to drive higher resolution "downscaling" models used for hurricane calculations. This finding was not consistently supported when individual models were used with the downscaling models, but the study suggests some plausible increase in hurricane frequency under future conditions.

Based on current focused research on hurricanes, the following conclusions are relevant from a climate risk assessment perspective for the Caribbean region:

- Anthropogenic warming by the end of the 21st century will likely cause hurricanes globally (not just in the Caribbean region) to be more intense on average (by 2 to 11 percent for mid-range emission scenarios). This change would imply an even larger increase in the destructive potential per storm, assuming no reduction in storm size.
- On average across the globe, assuming global climate changes within the range deemed most likely, the frequency of tropical cyclone and hurricane occurrence is expected to decrease by 6–34 percent (Knutson et al. 2010).
- Climate warming over the next century might lead to an increase in the numbers of intense hurricanes in some basins—an increase that would be substantially larger in percentage terms than the 2–11 percent increase in the average storm intensity. This increase is projected despite a likely decrease (or little change) in the global numbers of all tropical storms.
- Anthropogenic warming by the end of the 21st century will likely cause hurricanes to have substantially higher rainfall rates than present-day hurricanes, with a model-projected increase of about 20 percent for rainfall rates averaged within about 100 kilometers of the storm center.

The recent IPCC report (2013) suggests that there is low confidence in a human effect on tropical cyclones in the observations *to date*, but that in future (late 21st century) there is more likelihood of further change. From a practical standpoint, therefore, climate risk assessments in the Caribbean might justifiably consider the effects of more intense storms and hurricanes in a given location compared to storms documented in the historical record. The change in hurricane frequency and intensity in the Caribbean over the 21st century can be approximated as a small increase (~10 percent) from baseline conditions, although more uncertainty is associated with this variable as discussed above. Another approach would be to consider evaluating impacts for more extreme events than is typically done (i.e., by considering a more extreme storm with a100-year return period rather than a 25- or 50-year return period).

3.2.1.5 Integrating Sea Level Rise and Storm Surge

Storm surges result from high winds and low pressure pushing the ocean's surface up, and are associated with tropical storms and hurricanes. The previous section discussed the expectations associated with these extreme events under future climatic conditions. Storm surge elevations and return periods are useful to land use planners and emergency managers to assess the likelihood of extreme water depths associated with tropical storms or hurricanes.

Storm surge elevations are a complex function of the storm characteristics, the bathymetry of the sea water in the surrounding region, and the topography of the land where the storm is making landfall. Typically storm surges are computed through hydrodynamic models. For the Caribbean, a previous project (Caribbean Disaster Mitigation Project or CDMP) has developed storm surge estimates across the entire region. The U.S. Agency for International Development (USAID) implemented the CDMP. The storm surge estimates were developed using a numerical model called TAOS for different return periods. TAOS is a numerical model that produces estimates of maximum sustained winds at the surface, and still water surge height and wave height at the coastline, for any coastal area in the Caribbean basin. Although this work was completed in 1999, it appears to currently be the most detailed assessment available in the public domain. A non-public, commercial data resource is described below. Also, specific regions can develop more high-resolution models of storm surge, but these are typically not available off-the-shelf and might need to be performed for specific projects.

Examples of storm surge estimates from the CDMP project for two nations of interest (the Dominican Republic and Jamaica) are shown in Figure 3-14a and 3-14b for 100-year return periods. (Similar data are also available for 25- and 50-year return periods.) Typically, storm surge depth values would consist of a component of sea level rise, specific to a time period of interest, and a digital elevation model of a region, to estimate the extent of inundation.

Accurate elevation data over reasonably large areas are developed through LiDAR (Light Detection and Ranging) measurements. More accurate data are obtained through ground-based measurements. These data are not readily available in the Caribbean, at least not on a large scale. The best public domain data for the Caribbean are from the Shuttle Radar Topography Mission (SRTM), which are at 30-meter resolution. These data are also used as the elevation data source in the freely available Google Earth software.

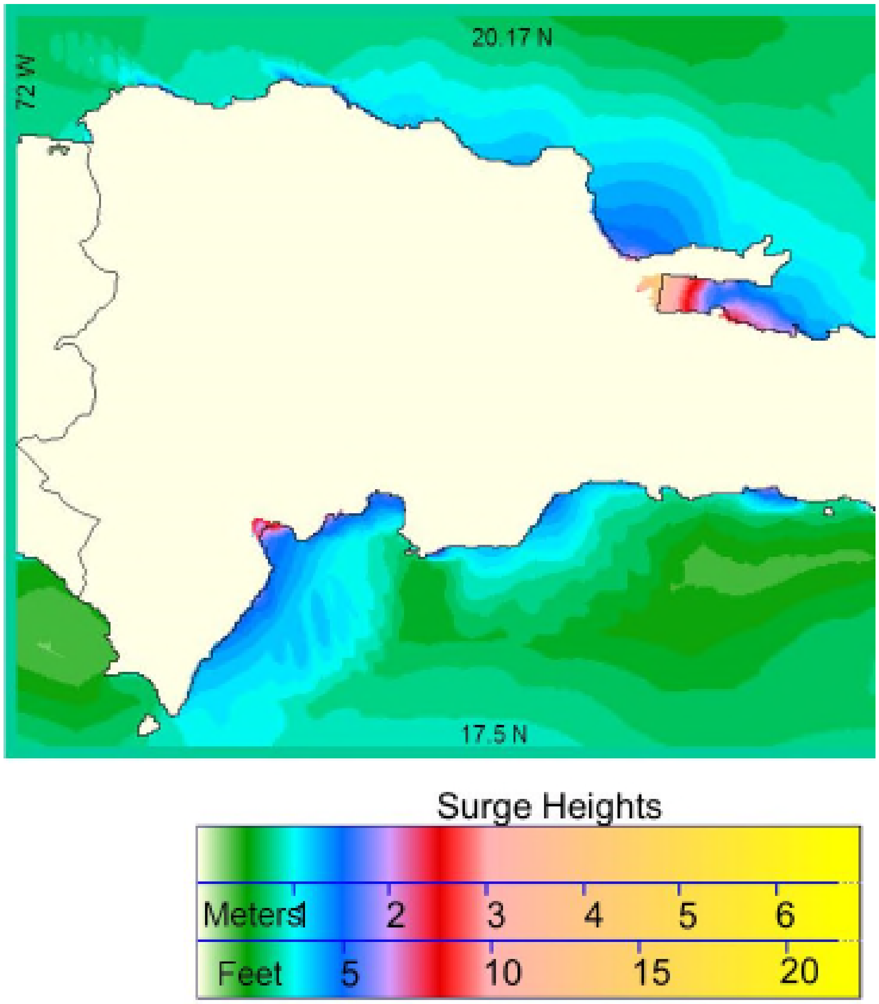


Figure 3-14a. Storm surge computed by the TAOS model for the Dominican Republic (*Source*: CDMP project).

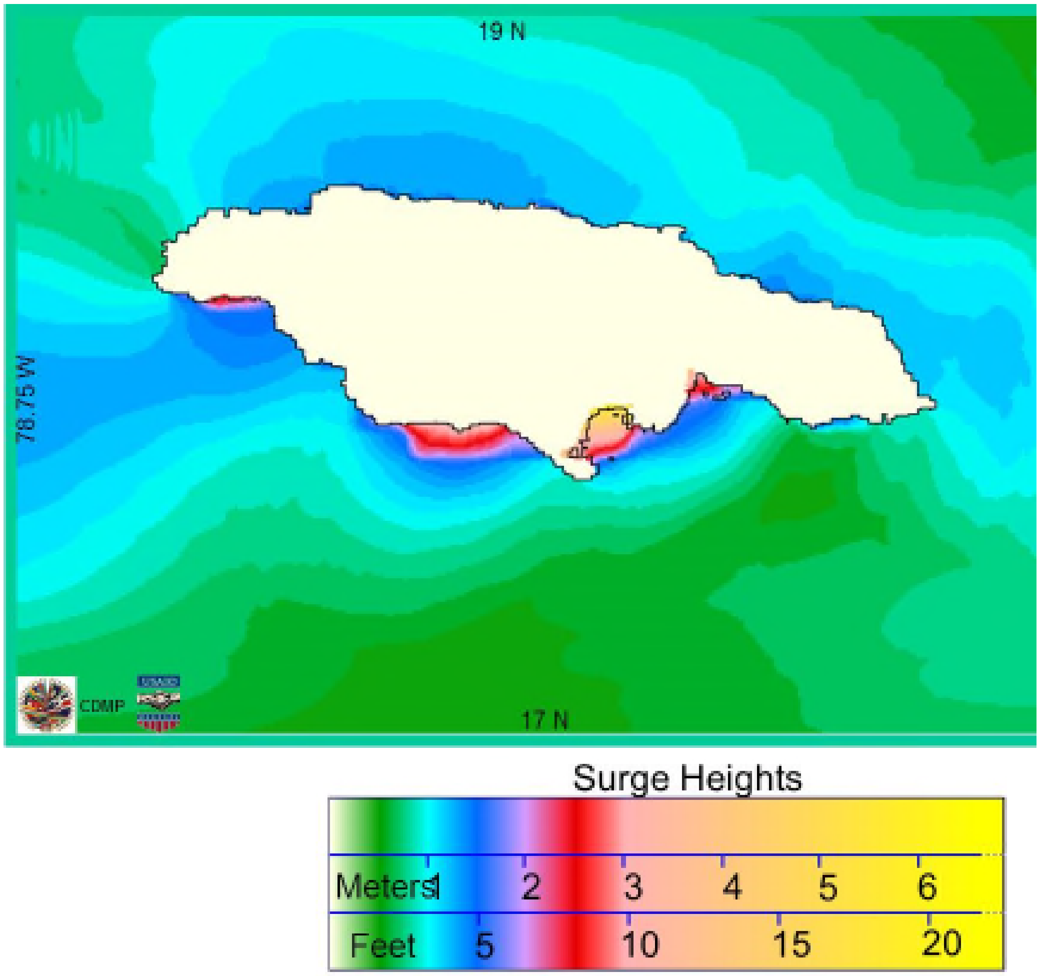
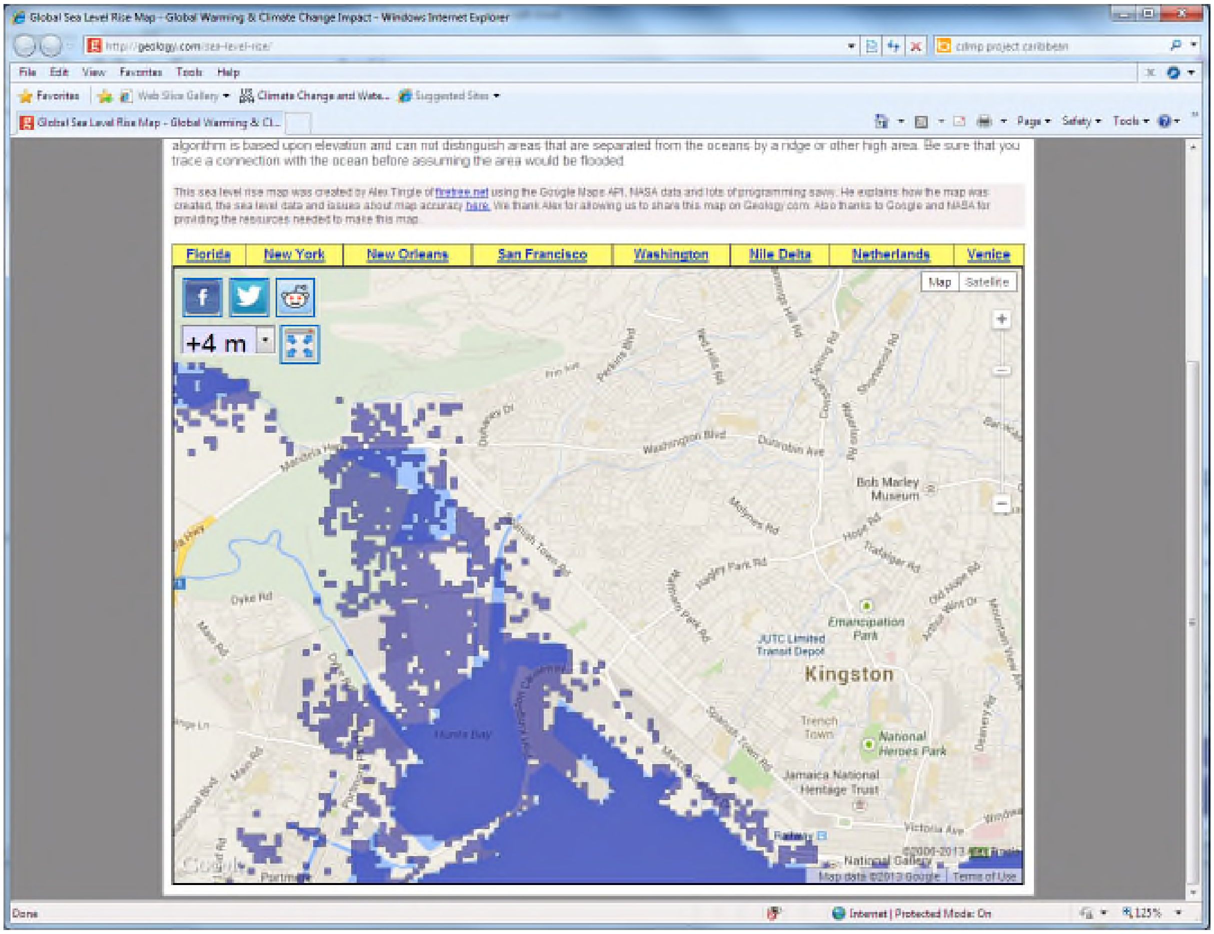


Figure 3-14b. Storm surge computed by the TAOS model for Jamaica (*Source*: CDMP project).

Using the above combination of free data sources, we show inundation examples for a city in the region (Kingston, Jamaica) (Figure 3-15). The free data appear adequate for a somewhat large-scale assessment, such as the level of an urban area or along a coastal region. However, for a more limited area, such as a project site spanning tens or hundreds of acres, more detailed, ground-based elevation measurements are strongly recommended.

In addition to the free data, there is at least one commercial tool called EQUECAT, which offers detailed data on land cover and infrastructure as well as numerical modeling of storm surges and flooding. The insurance industry uses this tool to estimate damages from storms, and the tool can be considered for specific high-value projects. The modeling approaches and results are not in the public domain, and the current assessment does not compare them against other approaches.



algorithm is based upon elevation and can not distinguish areas that are separated from the oceans by a ridge or other high area. Be sure that you trace a connection with the ocean before assuming the area would be flooded.

This sea level rise map was created by Alex Tingle of firetree.net using the Google Maps API, NASA data and lots of programming savvy. He explains how the map was created, the sea level data and issues about map accuracy here. We thank Alex for allowing us to share this map on Geology.com. Also thanks to Google and NASA for providing the resources needed to make this map.

Figure 3-15. Inundated areas for Kingston, Jamaica, for conditions representing ~4 meters higher water level than mean sea level (1.2-meter mean sea level rise due to climate change, and 2.5-meter storm surge, estimated using the TAOS model for this region).

3.2.1.6 Decision Making using Uncertain Climate Projections

Despite the quantitative nature of the data summarized above, it is important to state the uncertainties inherent in all climate projections for all variables we have described (temperature, precipitation, sea level rise, and hurricane frequency/intensity). The uncertainties associated with climate change projections have been categorized as: (1) unknown future emissions of greenhouse gases; (2) uncertain response of the global climate system to increases in greenhouse gas concentrations; and (3) incomplete understanding of regional manifestations that will result from global changes. These factors are described in greater detail below.

- Future Greenhouse Gas Emissions: We include future climate projections from three different scenarios of how greenhouse gas concentrations might appear through the 21st century. Up until year 2030, there is little uncertainty concerning greenhouse gas concentrations, and all emissions scenarios agree closely on concentrations. This is because concentrations up until 2030 depend largely on emissions that have already occurred (e.g., Trenberth 2010). Significant divergence in concentrations among different emission scenarios starts about mid-century (circa 2050).

- Climate Response to Rising Greenhouse Gas Concentrations: Because of complicated interactions between the ocean, land, and atmosphere, the chaotic nature of the climate system, and the imperfect representation of the physics of the climate in climate models, our present ability to simulate climatic responses to greenhouse gas concentrations is limited. GCMs do, however, represent our current understanding of the climate system and are useful for obtaining plausible projections of climatic responses. Because of differences in the representation of the physical processes, different GCMs can exhibit a wide range of sensitivity to changing greenhouse gas levels.
- Regional Impacts: While there is some agreement on large-scale climate processes simulated by climate models, there is significant divergence in the projections as they related to climate variables at the local scale. In particular, at a given location, the models generally agree on temperature changes, but might disagree on the nature of precipitation change. Hurricane intensity and frequency impacts are highly region specific.

To characterize this uncertainty, typically model ensembles are used for analysis, rather than any single model. Also, model output is used for several years (typically 30 years), rather than just a few years. By treating each model's projections as an equally likely possible outcome, the likelihood of any specific responses of the climate to a specific greenhouse gas concentration level can be quantified, within the realm of model results. Hurricane modeling is even more uncertain than that for temperature and precipitation, and specific projections for future impact assessment must be used with caution. Finally, even the entire realm of model results does not represent certainty, because the true climatic response of the natural system might lie outside of this realm. Thus, an analyst using these data sources must be aware of these limitations, and also of the need to update analyses as newer, and perhaps better, projection estimates become available.

3.3 Step 3: Vulnerability and Risk Assessment

The climate risk assessment process involves either conducting a basic or detailed risk assessment. The project proponent, working closely with IDB staff, will need to determine which level of analysis will best suit the specific project.

The goal of this section is to provide the reader with an understanding of the two methods for assessing the potential impacts to a proposed project. The basic assessment methodology has been developed based on the IPCC vulnerability assessment methodology, while the detailed risk assessment methodology has been developed based on methodology used by insurance companies and design firms. This section will focus on IDB member countries where many upcoming projects could take place, including Barbados, Dominican Republic, Haiti, Jamaica, and Trinidad and Tobago. Relevant data sources and tools are provided for each step.

3.3.1 Background on Climate Change Vulnerability and Risk Assessment

Climate change risk and vulnerability have been defined in different ways by different organizations with different needs. *Climate change risk* can best (or prevalently) be described as the negative consequence of hazard, exposure and vulnerability. It is assumed a hazard analysis (including a likelihood assessment) is conducted. *Vulnerability* can be described as the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change (Füssel and Klein 2006).

According to the IPCC, vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed; its sensitivity; and adaptive capacity (IPCC 2001). *Exposure* is defined as the degree of climate stress upon a particular unit analysis; it can be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC 2001). *Sensitivity* is defined as the degree to which a system will be affected by, or responsive to, climate stimuli (Smith et al. 2001). *Adaptive capacity* is defined as the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova 2001). The vulnerability assessment developed by the IPCC is considered the basic approach option.[15]

Risk assessments can be viewed in two ways: (1) top-down and bottom-up, and (2) prescriptive and diagnostic. Figure 3-16 on the right shows how different project types fit into these two axes. Top-down and bottom-up approaches relate to scale—will this assessment be at the project level or at the regional/national level? Prescriptive and diagnostic approaches describe whether the assessment looks forward or backwards in time. Combinations of these orientations favor different types of risk assessments. Adopting multiple viewpoints should be encouraged in complex situations. As discussed in Section 2, the bulk of current guidance material is consistent with top-down and prescriptive approaches, which are more generalized and not appropriate for project-level analysis.

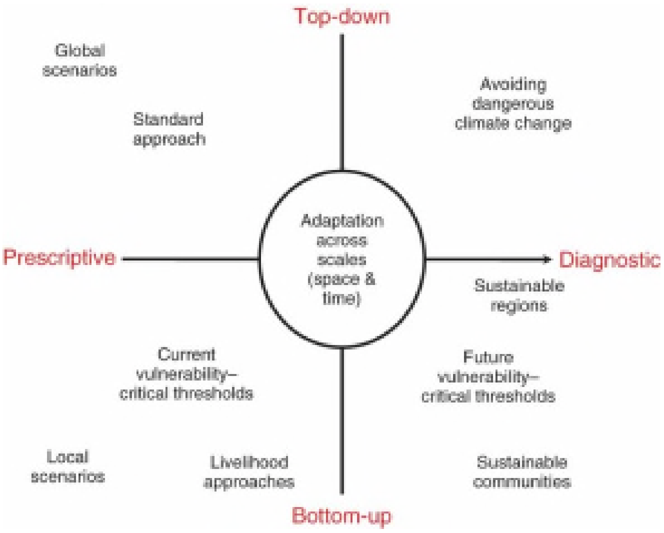


Figure 3-16. Risk assessment methodologies (*Source*: Jones and Preston 2011).

3.3.2 Determining the Type of Assessment Needed

After defining the assessment parameters, a determination should be made as to whether a basic vulnerability or more detailed risk assessment would be best suited for the proposed project. Figure 3-17 provides general guidance on which type of assessment is typically used for which project type.

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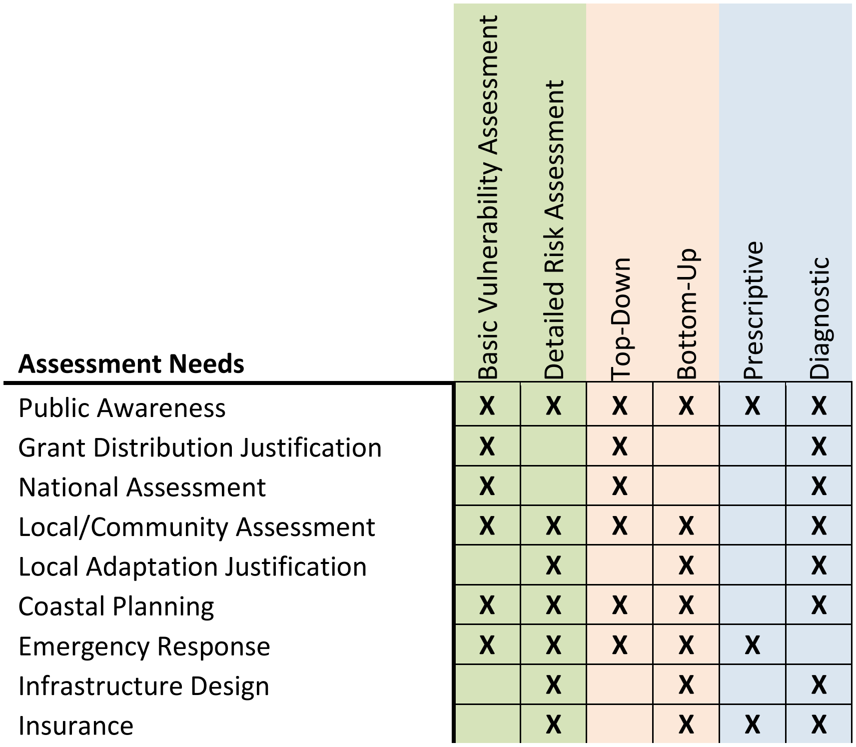
[15] For more on the IPCC vulnerability assessment methodology, refer to *Chapter 19: Assessing Key Vulnerabilities and the Risk from Climate Change* in IPCC (2007), available online at <http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch19.html>.



Assessment Needs	Basic Vulnerability Assessment	Detailed Risk Assessment	Top-Down	Bottom-Up	Prescriptive	Diagnostic
Public Awareness	X	X	X	X	X	X
Grant Distribution Justification	X		X			X
National Assessment	X		X			X
Local/Community Assessment	X	X	X	X		X
Local Adaptation Justification		X		X		X
Coastal Planning	X	X	X	X		X
Emergency Response	X	X	X	X	X	
Infrastructure Design		X		X		X
Insurance		X		X	X	X

Figure 3-17. Vulnerability and risk assessment needs compared to methodologies (*Source*: NOAA 2008).

In step 2, the project proponent will have determined the scale, scope, and available data. This information will help inform the type of assessment needed.

There are essentially two scales that have bearing on the methods selection of a vulnerability and risk assessment: (1) the regional and national (top-down) or (2) local and site-specific (bottom-up). The scale of the assessment will be based on the geographic boundaries of the project assets and projected climate risks. It is possible that both national and site-specific scales are appropriate for evaluation. For example, a hotel project might need to evaluate its infrastructure at the site level to determine whether higher building elevations could mitigate the impact of future storm surge, as well as the vulnerability of national critical infrastructure such as highways and airports. The scale of an assessment will also be informed by the availability of appropriately scaled climate projections. If climate data is not available to support a site-specific assessment, then a national-level assessment might be all that's possible.

Identifying project scope involves identifying the sector(s) that are of interest. A single-sector assessment, such as one for water or transportation, provides the ability to focus data and resources on that sector analysis. There also tends to be more quantitative decision support tools available to single-sector analysis. Qualitative assessment tends to be more applicable to multisector projects where qualitative inferences might need to be made about the relationships between sectors, or to sectors where sufficient data is not available for quantitative analysis.

For the purposes of the IDB, it is recommended that a project-specific ranking criterion be used to determine whether a project should undergo a basic vulnerability or a detailed risk assessment. Table 3-2 identifies such an illustrative ranking criteria.

Table 3.2 Proposed Ranking Criteria to Determine Type of Vulnerability Assessment Needed

Proposed Ranking Criteria		
	Proposed Ranking	
Project Attributes	Basic Vulnerability Assessment	Detailed Risk Assessment
Scale	Regional or national	Local or site-specific
Scope	Multisector	Single sector
Data Availability	Not available or limited for geographic area of interest	Data concerning project construction and siting, climate change, historical hazard events, and environment are available

3.3.3 Step 3a: Basic Vulnerability Assessment

A basic vulnerability assessment is cost effective, quick, and produces some quantitative results. However, the results are limited and uncertainty is higher. The vulnerability assessment methodology involves assessing the project's exposure, sensitivity, and adaptive capacity, which is further detailed below.

The first step is to define the project's assets. These assets could be the infrastructure itself (e.g., manufacturing facility or hydropower plant), but they could also be coral reefs or beaches for tourism-based projects. Both coral reefs and beaches are considered the basis for the crucial tourism industry in the region, which includes 40 million visitors annually (NOAA 2013). Coral reefs also serve vital functions as nurseries for marine life and as protection from storm surges. Coral reefs are affected by ocean warming or acidification as a result of higher dissolved carbon dioxide levels, and die-offs or bleaching has been extensively documented over the past decade. Because of warming temperatures, models predict significant risk to coral reefs, with substantial loss in the worst-case scenarios. Beaches in the Caribbean region have been eroding over the past two decades, with higher rates of erosion for islands hit by hurricanes. Greater erosion is expected under future sea level rise scenarios. Reduction, or even complete loss, of beach area in some regions could have a major adverse effect on tourism infrastructure and future potential.

3.3.3.1 Exposure

Exposure is defined as the degree of climate stress upon a particular unit analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC 2001). This assessment focuses on the exposure from three climate-induced hazards: (1) sea level rise, (2) flooding, and (3) hurricanes (including storm surge). To understand what could be affected, it is first necessary to identify at-risk areas. This process includes collecting data on physical environment, historical events in the area, and modeled data for potential future events.

Physical environment data include elevation models and location relative to the shoreline, river, or other water body. Several free products are available that can support this basic analysis, such as Google Earth. This Web-based product allows a user to zoom into a project site and identify an elevation using its terrain model, which is based on the SRTM data source described above. It also has a measurement tool to determine distances from the current shoreline or water body. Storm surge has been estimated for all regions of the Caribbean through the CDMP project and can provide an initial assessment of areas at risk of inundation.

To get a general idea of the current potential hazard for a country, the United Nations Environment Programme (UNEP)/Grid-Geneva developed the Global Risk Data Platform, which is supported by the United Nations Office of Disaster Reduction (UNISDR). This site provides historical and probabilistic data that can be viewed or downloaded and used in GIS. The data include:

- Hurricane wind events, tracks, frequency, risk, and probabilistic wind speeds
- Hurricane surge events and frequency
- Flood events, frequency, and risk

Representative country-specific data for five IDB member countries is summarized below.

Barbados

Barbados is home to 277,821 people and is part of the Lesser Antilles. The 432-square-kilometer island has 97 kilometers of shoreline (CIA World Factbook) and rises to the central highland region with an elevation of 340 meters above sea level. The country has wet (June through November) and dry (December through May) seasons. The annual precipitation ranges from 1,000 to 2,300 millimeters (BBC 2009).

The island does not have tide gauge data. Historical data on flood and cyclone events are available at the EM-DAT website. Historical data include:

- Flood events (1900–2013): Two events caused 3 casualties, impacted 310, and caused $500,000 in damage.
- Cyclone events (1900–2013): Seven events caused 58 casualties, impacted 10,617, and caused $106.7 million in damage.

Sources for local data and information can be found within the government website, which includes data from the Ministry of Environment and Drainage; Ministry of Agriculture, Food, Fisheries, and Water Resource Management; and Department of Emergency Management.

Dominican Republic

The Dominican Republic is a nation on the island of Hispaniola, which it shares with Haiti and part of the Greater Antilles archipelago. The 48,445-square-kilometer country is home to nearly 10 million people and has a 1,288-kilometer shoreline.

The country has two tidal gauges: (1) Puerto Plata, which has collected data between 1949 and 1969 with 73 percent coverage, and the United Nations Educational, Scientific and Cultural Organization/Intergovernmental Oceanographic Commission (UNESCO/IOC) collecting and compiling more recent data; and (2) Barahona, which has collected data between 1954 and 1969 with 64 percent coverage, and UNESCO/IOC collecting and compiling more recent data. Historical data on flood, surge, and cyclone events are available at the EM-DAT website and include:

- Flood events (1900–2013): Twenty-one events caused 832 casualties, impacted 1,473,072, and caused $55 million in damage.
- Surge events (1900–2013): One event caused 9 casualties, impacted 65,003, and caused $42.6 million in damage.
- Cyclone events (1900–2013): Twenty-seven events caused 4,485 casualties, impacted 2,863,246, and caused $2.8 billion in damage.

Sources for local data and information can be found within the government website, which includes data from the Ministry of Environment, Natural Resources, Physical Planning, and Fisheries; Ministry of Lands, Housing, Settlements, and Water Resource Management; and Office of Disaster Management. The nongovernmental organization, Asociación de Ingeniería y Consultoría Dominicana (ASICDOM) also collects local information.

Haiti

Haiti is a Caribbean country on the western, smaller portion of the island of Hispaniola, in the Greater Antillean archipelago. The 27,750-square-kilometer country is home to 9.7 million people and has a 1,771-kilometer shoreline. The World Bank's CCKP includes a country profile for Haiti that provides relevant climate change information for that country.

The country has one tidal gauge, Port Au Prince, which has collected data between 1949 and 1961 with 97 percent coverage, and the Global Sea Level Observing System (GLOSS) collecting and compiling more recent data. Historical data on flood, surge, and cyclone events are available at the EM-DAT website and include:

- Flood events (1900–2013): Forty-eight events caused 3,944 casualties, impacted 702,999, and caused $2 million in damage.
- Surge events (1900–2013): One event caused zero casualties, impacted 4,690, and caused an unknown amount in damage.
- Cyclone events (1900–2013): Thirty-five events caused 14,137 casualties, impacted 3,390,620, and caused $1.2 billion in damage.

Sources for local data and information can be found within the Direction de la Protection Civile (DPC) government website.

Jamaica

Jamaica is an island country in the Caribbean, comprising the third-largest island of the Greater Antilles and fifth-largest in the Caribbean. The 10,990-square-kilometer island is home to 2.8 million people and has a 1,022-kilometer shoreline.

The country has one tidal gauge, Port Royal, which has collected data between 1954 and 1969 with 98 percent coverage, and GLOSS collecting and compiling more recent data. Historical data on flood, surge, and cyclone events is available at the EM-DAT website and include:

- Flood events (1900–2013): Thirteen events caused 730 casualties, impacted 903,712, and caused $168 million in damage.
- Cyclone events (1900–2013): Twenty-eight events caused 604 casualties, impacted 1,579,705, and caused $2.6 billion in damage.

Sources for local data and information can be found within the government website, which includes data from the Ministry of Water, Land, Environment and Climate Change; and the Ministry of Science, Technology, Energy and Mining. Other data sources include the nongovernmental organization Abacus for Communities, and Caribbean Disaster Information Network (CARDIN) at the University of West Indies.

Trinidad and Tobago

Trinidad and Tobago is an island country to the north of South America lying off the coast of northeastern Venezuela and south of Grenada in the Lesser Antilles. It is comprised of two major islands. The 5,128-square-kilometer country is home to 1.3 million people and has a 362-kilometer shoreline.

The country has one tidal gauge, Port of Spain, which has collected data between 1983 and 1992 with 83 percent coverage, and UNESCO/IOC collecting and compiling more recent data. Historical data on flood, surge, and cyclone events are available at the EM-DAT website and include:

- Flood events (1900-2013): Two events caused 5 casualties, impacted 210, and caused an unknown amount in damage.

- Cyclone events (1900-2013): Seven events caused 40 casualties, impacted 51,560, and caused $39 million in damage.

3.3.3.2 Sensitivity

Sensitivity is the degree to which a system will be affected by, or responsive to, climate stimuli (Smith et al. 2001). This assessment focuses on the sensitivity for common IDB project types. To understand the magnitude of impact, it is first necessary to identify system susceptibility. This process includes collecting data on project characteristics and other stressors. A sensitivity assessment of eight IDB project types is provided below.

Agriculture

Agriculture in the Caribbean remains a major industry and is strongly affected by changes in precipitation patterns and droughts, as well as rising temperatures. In general, islands depend on perched fresh water aquifers of varying thicknesses for water supply. As sea level rises, there is greater potential of intrusion of sea water into aquifers, reducing the available fresh water volume. Agricultural projects could be developed to better cope with climate change including designing proper drainage, using drought-tolerant species, purchasing insurance, and using natural protective plantings.

Other stressors include water quality, disease, land use changes, increasing population, and pests.

Tourism

Tourism is a major source of foreign exchange and a key driver of several Caribbean economies. Two major risks that are unique to this sector are greater erosion and loss of beaches due to sea level rise and reduction and loss of coral reef areas. For beaches, where the inland areas are not developed, the beaches will continue moving inland as sea level rises. This is not possible where the inland areas are developed. In these cases, the effects of climate change could be addressed by greater structural protection (such as offshore breakwaters) and beach replenishment. Long-term planning needs to ensure that future development occurs at a safe distance from the active beach zone. Coral reefs are affected by temperature and ocean chemistry changes that are impossible to manage, but future planning must ensure other stressors such as pollution and overfishing are minimized.

Other stressors include overdevelopment near beaches, loss of mangroves and wetlands, water pollution, and overfishing.

Oil and Gas

Oil and gas infrastructure design characteristics can influence how a system copes with floods and hurricanes. Several Caribbean nations have significant offshore facilities for production, and associated onshore facilities for processing and transport. Offshore facilities are subject to hurricane risk, which could modestly increase under future conditions. Onshore facilities, however, are subject to greater risk as a result of sea level rise and greater potential of flooding. Forward-looking elevation, weather alerts, and disaster operations plans might reduce sensitivity to floods and hurricanes.

Other stressors include environmental concerns, security concerns, and poor construction materials or poor construction quality.

Transportation

Transportation elements of concern include ports and harbors as well as roads and bridges. Ports and harbors could be at risk of higher water elevation and flooding/erosion. Roadway infrastructure design characteristics can influence how a system copes with floods and hurricanes. Forward-looking elevation estimates; scour countermeasures; water retention ponds; and other drainage solutions, weather alerts, and disaster operations plans might reduce sensitivity to floods and hurricanes.

Other stressors (that are exacerbated by extreme climatic events), include poor construction materials or poor construction quality.

Hydropower

Hydropower design characteristics can influence how a system copes with floods and hurricanes. Climate change might also affect water availability, demand, and quality. Designing reservoir size to accommodate climate predictions, flood-proofing, elevating critical components, designing an adequate spillway, and integrating a disaster response plan into operations can all reduce sensitivity to floods. Design configuration might reduce sensitivity to high wind speeds.

Other stressors which might exacerbate climate change impacts on a hydropower project include water availability, water demand, water quality, land use changes, increasing population, and poor construction materials or poor construction quality.

Water and Sewer

Water and sewer infrastructure design characteristics can influence how a system copes with floods and hurricanes. Wastewater treatment plants are typically located near the coast and subject to flooding. Elevation, separate storm and sanitary systems, condition monitors, and properly trained personnel might reduce sensitivity to floods and hurricanes.

Other stressors include water availability, water demand, land use changes, increasing population, and poor construction materials or poor construction quality.

Manufacturing and Other Infrastructure

Other infrastructure can be designed to better cope with climate change including using wet flood-proofing, which allows floodwaters to enter a building but cause little damage; dry flood-proofing, which creates a watertight seal so floodwaters cannot enter the structure using waterproof coatings; impermeable membranes, or supplemental layers of masonry or concrete; designing the structure on piers or other elevated foundation types; implementing hurricane straps (roof-wall connections) into the building design; using a larger roof nail size and reducing nail spacing; adding shutters to a design; using a warning system; adding protective plantings; receiving building configuration design input from a wind engineer; and building redundant systems.

Other stressors include poor construction materials or poor construction quality.

3.3.3.3 Adaptive Capacity

Adaptive capacity refers to the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova 2001). To understand a project's ability to adapt to climate change, it is first necessary to determine the institutional resources and ability to absorb shocks. The preceding sections outline some of the changes that a project might be subject to, but others will become apparent with the passage of time and might not have been predicted. This process includes collecting data on the financial resources available and institutional capacity to implement changes. In many cases, the adaptation actions will be phased in over the life of the project, or will be implemented based on some trigger identified during the risk assessment process. In other circumstances there might be a need for an emergency response plan. For these projects it is necessary to ensure the organization has the capacity to carry out necessary measures at the appropriate time. The assessment should include an institutional review and plan that clearly spells out the roles, responsibilities, and budget requirements. The project management needs to ensure sufficient management support, including human and financial resources to guarantee that agreed-upon actions will be implemented on schedule.

3.3.3.4 Understanding Basic Vulnerability Assessment Results

To begin evaluating whether a project is vulnerable to climate change, the project's exposure, sensitivity, and adaptive capacity should be evaluated. As an example, if a manufacturing project was being considered in the Dominican Republic, the project location could be evaluated looking at a map and terrain model to determine exposure. Then, the facility itself could be evaluated to ensure its design takes this exposure into account.

The Central America Probabilistic Risk Assessment (CAPRA) is a tool which can be used to support a basic vulnerability assessment. CAPRA is a free modular platform for risk analysis and decision making using probabilistic for hazard and loss assessment in Latin America. This software now includes a climate change module. CCORAL could also be used to assist with a basic vulnerability assessment.

3.3.4 Step 3b: Detailed Risk Assessment

A detailed risk assessment will produce more granular information concerning project structural design, support for cost-benefit analysis, siting information, and economic loss estimates. However, these detailed risk assessments can be costly and take a longer time to complete.

Before a risk assessment can proceed, the project's assets must be defined in detail (such as design drawings, surveys, and economic data). Other quantifiable characteristics must also be compiled. Similar to the vulnerability assessment, these assets can be the infrastructure itself, such as a manufacturing facility or hydropower plant, and can also include coral reefs or beaches if the project is tourism-based.

The next two sections have been developed around the two risk components: (1) a hazard assessment and (2) a consequence assessment. Figure 3-18 provides more detail on how the risk assessment components work to generate quantifiable results.

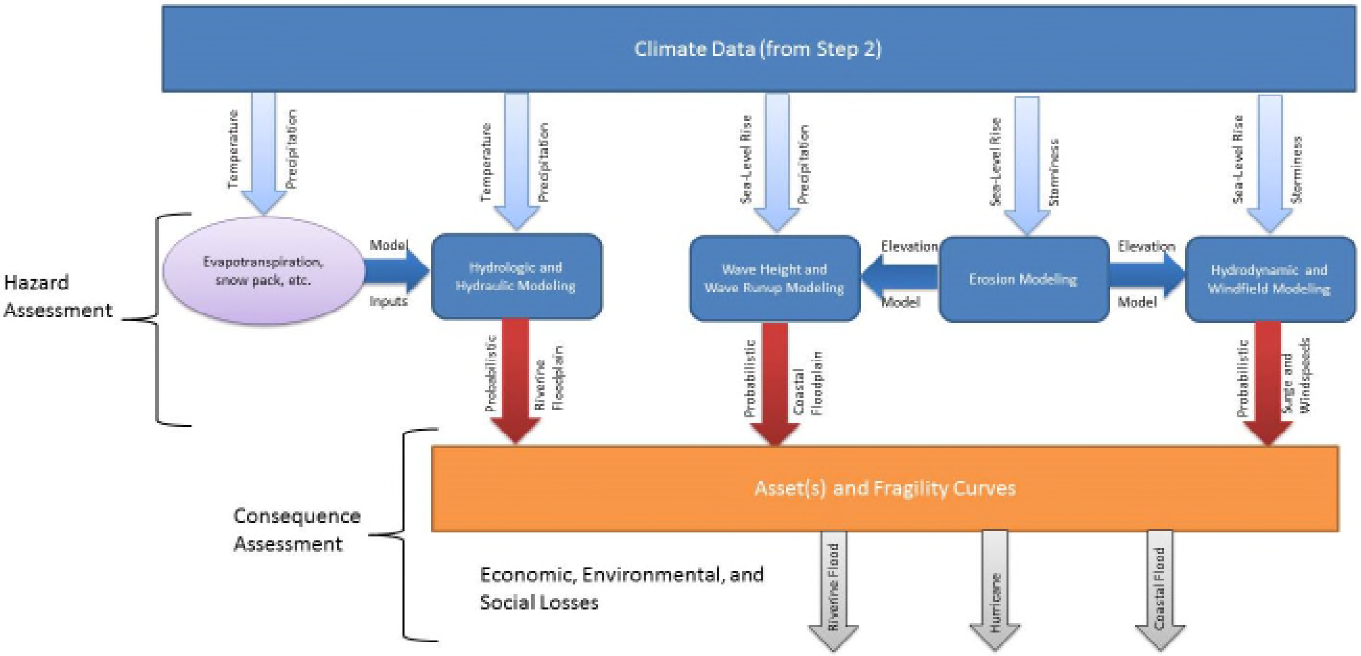


Figure 3-18. Risk assessment components.

3.3.4.1 Hazard Assessment

The hazard assessment takes the outputs from the climate assessment conducted in Section 3 and integrates that data into traditional hazard models. The hazard models are run using future conditions from the climate models. There are different types of hazard assessment approaches and tools; however, they usually involve a mapping component. The objective of the hazard assessment is to understand where the hazard could occur and identify probable characteristics. Three hazard assessment examples include:

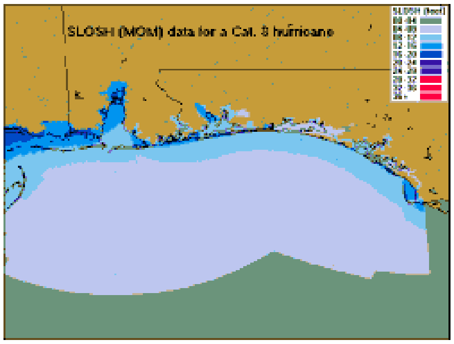


Figure 3-19. Scenario-Based (*Source*: NOAA, 2008).

- Historical: High water marks could be collected for a recent storm and used with a digital elevation model to document the extents and depths of flooding. This could be used for response and recovery and to validate modeling efforts.
- Scenario-Based: These assessments will not describe an actual event but might look at a series of potential events. The figure on the right (3-19) is an example of a scenario-based event created by the U.S. National Oceanic and Atmospheric Administration (NOAA). It is a storm surge zone map created by a Sea, Lake, and Overland Surge Hurricane (SLOSH) model. In this case, the output was derived by looking at all of the possible category 3 hurricanes and inundated the coastline with the resultant surge. No one hurricane would produce this surge, but the scenario analysis can be useful for planning purposes.
- Probabilistic: This is a risk-based map developed using a probabilistic analysis. These maps are typically developed using historical hazard information to identify an event and assign likelihood to that event occurring in the future. A common likelihood, also known as a return period, is a one percent annual chance event (commonly referred to as the 100-year event). Other methods, including Monte Carlo Simulations, assign a return period to an event of a particular magnitude.

For a detailed climate change risk assessment, the probabilistic approach is recommended. It is important to use downscaled data for input into the models since the historical events might not be indicative of future events. Also, using longer time scales produce a better estimate of the extreme events. For example, 200 years of data will provide a better indication of what a 500-year event would look like compared to 30 years of data. For this reason, a stochastic weather simulation model, also known as a weather generator, can be used to simulate longer time periods and identify those extreme events. Two basic types of stochastic weather generators are available: the “Richardson” type (Richardson 1981; Richardson and Wright 1984) and the “serial” type (Racsko et al. 1991; Semenov et al. 1998). Both weather generator types require initial calibration based on observed station data.

In a Richardson-type weather generator (e.g., WGEN) precipitation occurrence is modeled using a first-order two-state Markov procedure, which describes two precipitation classes (i.e., wet or dry) and takes into account precipitation occurrence on the previous day only. More complex models might involve more than one precipitation class as well as the occurrence of precipitation on a number of days prior to the current day, rather than on just the previous day. One of the main criticisms of Richardson-type weather generators is their inability to adequately describe the length of wet or dry series.

The serial-type weather generator was developed to attempt to overcome problems identified with the Richardson type. The first step in the process is the modeling of the sequence of dry and wet series of days. The precipitation amount and the remaining climate variables are then generated dependent on the wet or dry series. The serial-type weather generator is freely available.

Riverine Flood Assessment

In a riverine flood hazard assessment, two processes must be understood: (1) the hydrology of the watershed and (2) the channel hydraulics. Hydrologic models estimate the distribution of rainfall, with the ultimate goal of obtaining a discharge and flood hydrograph for the streams and rivers. Hydraulic models take the output from the hydrologic models, along with the stream channel morphology, to generate flood elevations. These flood elevations are used to create a flood elevation grid, which is then subtracted from the digital elevation model to produce a flood depth grid. Specialized models have also been developed for reservoir modeling for hydropower facilities.

Illustrative models appropriate for conducting a riverine flood assessment are listed below. These models require specialized expertise to run and many are focused on particular environments and geographic scales. An engineer should be consulted before selecting a model. [16]

3.3.4.2 Hydrologic Models (focused on estimated of flow volumes)

- HEC-1 and HEC-HMS – The Hydrologic Engineering Center models are produced by the U.S. Army Corps of Engineers and are provided free of charge. More information and a free download is found here.
- SWMM – The Storm Water Management Model is produced by the U.S. Environmental Protection Agency and designed for urban centers. It is also free of charge.
- MIKE11 – The Microcomputer-based Modeling System for Rivers and Channels is produced by the Danish Hydrology Institute and is provided in several different languages.
- TR – The Technical Release models were developed by the U.S. Department of Agriculture, Natural Resources Conservation Service and are provided free of charge. WinTR-55 was designed to be run with smaller watersheds.

3.3.4.3 Hydraulic Models (focused on estimation of flood elevation)

- HEC-2 and HEC-RAS – The Hydrologic Engineering Center models are produced by the U.S. Army Corps of Engineers and are provided free of charge. More information and a free download are found here.
- WSPRO – The Water-Surface PROfile computations model was produced by the U.S. Geological Survey and is free of charge. It can accommodate flow through bridges and culverts.
- MIKE11 and SWMM also contain hydraulic models.

Coastal Flood Assessment

In a coastal flood hazard assessment, three components must be understood: (1) the coastal erosion process, (2) the wave height analysis, and (3) the wave run-up analysis. Sea level rise is producing higher rates of erosion and this process needs to be understood and quantified at the beginning of a coastal flood or hurricane surge assessment. The wave height and run-up analysis will result in a coastal flood elevation.

Illustrative coastal models appropriate for conducting a coastal flood assessment are listed below. These models require specialized expertise to run and many of the models are focused on particular environments and geographic scales. An engineer should be consulted before selecting a model.[17]

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[16] When selecting a climate risk consultant, there are several types of experience which should be verified, including past performance: (1) using downscaled climate data, (2) using applicable hazard models, (3) using applicable environmental models, (4) identifying and evaluating adaptation strategies, and (5) familiarity with cost-benefit analysis.

[17] When selecting a climate risk consultant, there are several types of experience which should be verified, including past performance: (1) using downscaled climate data, (2) using applicable hazard models, (3) using

3.3.4.4 Erosion Models

- SBEACH – The Storm-induced BEAch CHange Model simulates cross-shore beach, berm, and dune erosion produced by storm waves and water levels. It is produced by the U.S. Army Corps of Engineers, Coastal & Hydraulics Laboratory and is free of charge.
- GENESIS – The GENEralized Model for SImulating Shoreline Change simulates the long-term platform evolution of the beach in response to imposed wave conditions, coastal structures, and other engineering activity. It is produced by the U.S. Army Corps of Engineers, Coastal & Hydraulics Laboratory and is free of charge.
- Bruun Rule – In 1962 Bruun proposed a basic model relating shoreline retreat to an increase in local sea level. It states that a 1-centimeter rise in sea level erodes beaches about 1 meter horizontally.

3.3.4.5 Wave Height Models

- WHAFIS – The Wave Height Analysis for Flood Insurance Studies model produced by the U.S. Federal Emergency Management Agency is provided free of charge.
- RCPWAVE – The Regional Coastal Processes Monochromatic WAVE Model is a 2-D, steady-state, monochromatic short-wave model for simulating wave propagation over arbitrary bathymetry. It is produced by the U.S. Army Corps of Engineers, Coastal & Hydraulics Laboratory and is free of charge.
- CHAMP – The Coastal Hazard Analysis Modeling Program model produced by the U.S. Federal Emergency Management Agency is provided free of charge.
- MIKE – The Microcomputer-based Modeling System for Rivers and Channels is produced by the Danish Hydrology Institute and is provided in several different languages.
- SWAN – Simulating WAves Nearshore is a third-generation wave model, developed at Delft University of Technology, which computes random, short-crested wind-generated waves in coastal regions and inland waters.

3.3.4.6 Run-up Models

- RUNUP - This program produced by the U.S. Federal Emergency Management Agency uses still-water elevation, shore profile and roughness, and incident wave condition input information to compute a wave run-up elevation.
- ACES – Automated Coastal Engineering System produced by the U.S. Army Corps of Engineers, Coastal & Hydraulics Laboratory and is free of charge.
- CHAMP – Referenced above as a wave height analysis model, CHAMP also has a run-up model.

Hurricane Assessment

Climate change is predicted to warm the oceans and increase the magnitude of hurricane events as discussed in the climate assessment section. Sea level rise should be combined with storm surge to show both extent and depth of inundation. Several hurricane surge models are available, including:

- ADCIRC – This model solves time-dependent, free-surface circulation and transport problems in two and three dimensions. The program utilizes the finite element method in space allowing the use of highly flexible, unstructured grids.
- EFDC – The Environmental Fluid Dynamics Code (EFDC Hydro) is a hydrodynamic model that can be used to simulate aquatic systems in one, two, and three dimensions. It has evolved over

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applicable environmental models, (4) identifying and evaluating adaptation strategies, and (5) familiarity with cost-benefit analysis.

the past two decades to become one of the most widely used and technically defensible hydrodynamic models in the world.

- TABS-MD – This multidimensional numerical modeling system was one of the first widely used collections of programs designed for studying multidimensional hydrodynamics in rivers, reservoirs, bays, and estuaries. The hydrodynamic engine for the system is the RMA2 engine. RMA2 and RMA4 were written by Resource Management Associates and modified by WES.

These models require specialized expertise to run and many of the models are focused on particular environments and geographic scales. An engineer should be consulted before selecting a model.[18]

3.3.4.7 Consequence Assessment

Consequence assessment focuses on the characteristics of the people, environment, and infrastructure exposed to the hazard and determines an impact. The hazard assessment in 4.3.1 produces data on riverine and coastal flood depths, surge depths, and hurricane wind speeds. These outputs can then be used to calculate losses in terms of direct and indirect economic losses, population at risk, and environmental habitat impacts. It is important to consider not only infrastructure losses, but also how other social and environmental losses could impact the financial rate of return for the proposed project.

To convert the hazard assessment information into a loss estimate, a fragility curve also known as a damage function or a damage curve is used. In this case of flood risk, the flood depths are related to a mean damage ratio (the damage sustained divided by the total value of the structure). Similar damage functions exist for different building types and different hazards. Wind hazards would apply estimated wind speed data for loss estimates (instead of flood depth data).

An example from the Flood Insurance Administration of a flood damage function is shown in Figure 3-20. The graph shows that for different levels of water, there will be different levels of damage, corresponding to different building types and foundation types. This damage percentage is then used to calculate a loss using the replacement value of a structure. Damage curves have been developed for the Caribbean region building stock in the CAPRA software described below. Other infrastructure, such as bridges, ports, and utilities also have unique damage functions. More information on the damage functions can be found in the U.S. Army Corps of Engineers Economic Guidance Memoranda.

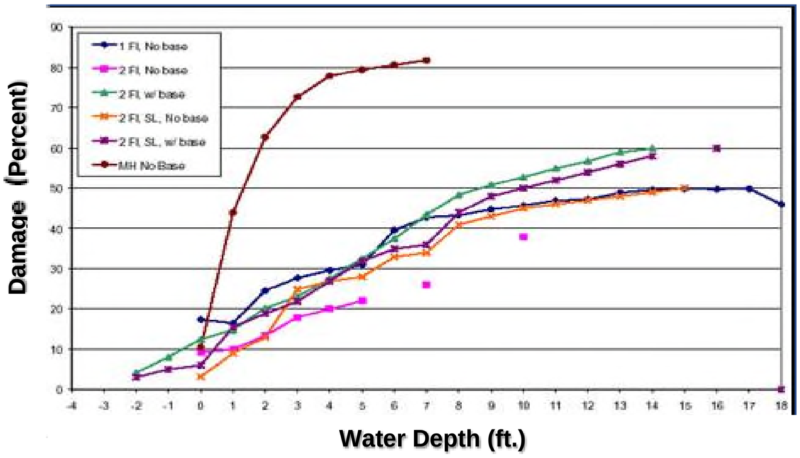

Figure 3-20. Flood damage function.

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[18] When selecting a climate risk consultant, there are several types of experience which should be verified, including past performance: (1) using downscaled climate data, (2) using applicable hazard models, (3) using applicable environmental models, (4) identifying and evaluating adaptation strategies, and (5) familiarity with cost-benefit analysis.

The IFC climate risk pilot projects provide examples of risk assessment methodologies as they apply to: hydropower (run of the river), hydropower (reservoir), port, manufacturing, and agriculture. The two tools listed below can be used to support this more detailed risk assessment:

- Central America Probabilistic Risk Assessment (CAPRA) – A free modular platform for risk analysis and decision making using probabilistic for hazard and loss assessment in Latin America. This software now includes a climate change module.
- HAZards U.S. (HAZUS) – HAZUS is risk assessment software which contains models for estimating potential losses from earthquakes, floods, and hurricanes. HAZUS uses GIS technology to estimate physical, economic, and social impacts of disasters. Although the program is US-based, some damage functions may be extracted from the model and used in a Caribbean assessment as long as the building types are similar (for example, HAZUS has been successfully used in Puerto Rico due to the similarity in building construction types).

4.0 Conclusions

This paper provides a summary of the methods and information needed to perform a climate change risk assessment, specifically tailored to the Caribbean region, and focused towards the types of projects IDB might support. A fact sheet was also developed that summarizes the disaster and climate change risk assessment approach and describes the tools that are recommended to help project proponents conduct a climate change risk assessment.

Climate projection data available for the region are in the public domain, and are often easily accessible through Web-based interfaces. Key data sources for typical climate change risk assessments are presented in this paper. It is expected that additional sources and levels of detail of data will increasingly become available. An examination of the climate projections for the Caribbean region and elsewhere shows that there is near-term climate variability, with substantial departures from current conditions beginning to occur by mid-21st century and beyond. Although certain uncertainties are associated with quantifying climate change impacts, there is a pressing need to plan for these impacts.

Insurance products are available in the commercial market to address known extreme events such as hurricanes and intense rainfall events. The Caribbean Catastrophe Risk Insurance Facility (CCRIF) provides country-level insurance for such major events, but to the best of our knowledge, these address current risks, rather than risks due to events that might occur a decade or two into the future. Although insurance provides coverage from catastrophic events in the near-term, looking over the long-term, a project's design and adaptive capacity must ensure some level of resilience from future climate change-associated events.

The climate change risk assessment for a new project, for existing infrastructure, or even for a specific sector of the economy (such as tourism or transportation) can be performed at different levels of detail depending on the project scope, resources available, and the potential risk due to the climate change impacts. At this time, it is safe to assume that the projected climate database available will be the same no matter what level of risk assessment is performed. This is because climate modeling is performed globally by multiple modeling groups, and it is not likely that any such effort will be replicated to serve local needs. Even regional climate modeling, when performed over a suite of multiple models, is unlikely to be developed at a local level. Given the same climate data, however, climate change risk assessments can vary greatly in the level of detail with which the impacts are assessed. Typically, each sector will have detailed tools for designing the pertinent infrastructure, and these detailed tools will need to consider what the response will be if climatic conditions will be different from the historical range. For example, this might include the largest storm a roadway is designed to withstand, or the level of storm surge a coastal facility such as an oil handling terminal is protected against, or the level of drought a water supply system is designed for. These analyses must focus on the location-specific design elements of the infrastructure or investment project in question. This paper is not focused on this detailed level of analysis, but provides a general roadmap that can be followed if specific investments require this level of effort.

Although climate risks to a project can be quantified within bounds of uncertainty, no effective guideline exists to help determine an acceptable level of "climate-proofing" for a specific infrastructure or a system (such as a city or a transportation network). Design for a future project can identify a range of options at different costs, such that a project proponent or lender can identify the best cost-benefit option. Adaptation of existing infrastructure can consider a variety of operational and structural modifications, again with a range of costs, such that a reasonable balance can be achieved between costs and benefits. Because of the complexity and diversity of projects with the projects with which IDB is involved, workable guidelines for different sectors cannot be established *a priori*, but are expected to evolve as different climate risk assessments are performed within a general framework such as that presented in this document. Regardless of the approach chosen, it is important to emphasize the rapidly evolving nature of climate science, particularly in the domain of extreme events. Reductions in uncertainty, or more specific projections for the Caribbean, will have a strong bearing on future risk assessment processes and the development of future guidelines for climate resilience.

5.0 Recommendations for Next Steps

The input of IDB staff (including that of the ESG, Climate Change and Sustainability Division, and Investment Officers) and other stakeholders (such as the World Bank/IFC and private sector project sponsors) would strengthen this paper and help to refine and support implementation of the proposed approach. The approach is structured as a tiered process, and provides the flexibility to conduct a low-cost project screening, a basic vulnerability assessment, or more complex risk assessment depending on the projected climate change risks to individual projects. The study team recommends that the criteria for assessing climate change risk and whether a project proponent should move to the next step in the assessment process is further defined in consultation with the IDB ESG.

Additional recommendations for next steps are provided below. It should be noted that these are considered additional measures that IDB's ESG could take to strengthen the utility of this guidance. The study team recognizes that the recommendations are subject to IDB ESG programming and institutional discretion.

Intersection of climate change planning and IDB standards and processes. Additional guidance on where/how climate change risk assessment intersects with IDB's environmental and social safeguard requirements, as well as with the project cycle for non-sovereign guaranteed operations, would better assist private sector project sponsors in understanding and meeting IDB borrowing requirements.

Internal capacity-building on climate change risk. It will be important that IDB staff and independent reviewers are knowledgeable of climate risks and mitigation to ensure that the climate change risk process is effectively carried out (risk realized, mitigation options identified and implemented). Developing training programs on climate change and risk assessment, creating platforms for collaboration, and sharing lessons learned and common problems could be useful in building internal capacity.

Conducting one or more pilot projects to refine the proposed approach. It is recommended that the climate change risk assessment approach is tested on a pilot project basis to ensure effectiveness and utility. A pilot project could evaluate the strengths and limitations of the data and methodologies applied and uncertainties associated with the modeling and data inputs/outputs. Pilot projects can be designed several different ways; two are suggested below (which could also be combined):

— Evaluate effectiveness of project screening, basic, and in-depth vulnerability assessment results. Compare the results of each type of assessment within the context of a specific project and project site.

— Assess the approach and tools across multiple sectors and geographic locations. Compare the modeling and data inputs/outputs across different sectors (such as coastal oil and gas infrastructure versus inland infrastructure project).

External capacity-building on climate change risk assessment process and tools. Raising the awareness of climate change risks and providing further guidance on how to conduct a climate change risk assessment could strengthen the results of individual project assessments and also assist the private sector with better conceptualizing projects. Identifying lessons learned from other institutions and exchanging experiences with them would facilitate the integration of best practices.

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Annex 1: Tools and Resources

Tools and Resources for Conducting a Climate Change Risk Assessment in the Caribbean

Tool/Resource	**General Resource**	**Relevant Step**			
		Step 1: Screening	**Step 2: Data Collection**	**Step 3a: Basic Vulnerability Assessment**	**Step 3b: Complex Risk Assessment**
ADCIRC - hurricane model					●
Automated Coastal Engineering System (ACES) - run-up model					●
Caribbean Climate Online Risk and Adaptation TooL (CCORAL) - Guidance and regional climate data		●	●	●	
Caribbean Community Climate Change Centre - Guidance documents and regional climate data	●	●	●	●	
Caribbean Disaster Information Network – for historical data on hazard events				●	●
Caribbean Disaster Mitigation Project (CDMP) – for storm surge data			●	●	●
Caribbean Hurricane Network – for hurricane data			●	●	●
Caribbean Institute for Meteorology and Hydrology (CIMH)			●		●
Central America Probabilistic Risk Assessment – for risk assessment/decision support				●	●
Coastal Hazard Analysis Modeling Program model (CHAMP) - wave height and run-up model					●
Economic Guidance Memoranda – for consequence assessment					●
Effects of climate change on the coast of Latin America and the Caribbean – Guidance documents	●				
Effects of climate change on the coast of Latin America and the Caribbean – Database		●	●	●	
Environmental Fluid Dynamics Code (EFDC Hydro) - hurricane model					●
EQUECAT - for storm surge and flooding			●		●
GENEralized Model for Simulating Shoreline Change model (GENESIS)– erosion model					●
Global Risk Data Platform - for hurricane and flood data			●	●	●
Global Sea Level Observing System – for tidal gauges			●	●	●
Google Earth software		●	●	●	
HAZards US (HAZUS) – for complex risk assessment					●
HEC-1 and HEC-HMS - hydrologic model					●
HEC-2 and HEC-RAS models - hydraulic model					●
IDB-World Bank Pilot Program for Climate Resilience in the Caribbean – Guidance documents	●				
Intergovernmental Panel on Climate Change - Guidance documents	●				
International Finance Corporation Climate Risk Pilot Projects – for guidance on complex risk assessment	●				●

Tools and Resources for Conducting a Climate Change Risk Assessment in the Caribbean

Tool/Resource	General Resource	Relevant Step			
		Step 1: Screening	Step 2: Data Collection	Step 3a: Basic Vulnerability Assessment	Step 3b: Complex Risk Assessment
LARS- Weather Generator (LARS-WG) – serial weather generator					●
Microcomputer-based Modeling System for Rivers and Channels (MIKE) - wave height model					●
Microcomputer-based Modeling System for Rivers and Channels-11 (MIKE 11) - hydrologic and hydraulic model					●
National Communications for the United Nations Framework Convention on Climate Change (UNFCCC) - Guidance documents on country vulnerability and adaptation priorities	●			●	
North American Regional Climate Change Assessment Program (NARCCAP) - for dynamically downscaled projections			●		●
Permanent Service for Mean Sea Level (PSMSL) – for tidal gauge data			●	●	●
Providing Regional Climates for Impacts Studies (PRECIS) - for regional downscaled projection for the Caribbean			●		●
Regional Coastal Processes Monochromatic WAVE Model (RCWAVE) - wave height model					●
RUNUP- run-up model					●
Sea Level Station Monitoring Facility – for tidal gauges			●	●	●
Shuttle Radar Topography Mission (SRTM) - for LIDAR data			●		●
Simulating WAves Nearshore (SWAN) - wave height model					●
Storm-induced BEAch CHange Model (SBEACH) – erosion model					●
TABS-MD- hurricane model					●
Technical Release models (TR) - hydrologic model					●
The International Disaster Database, also referred to as the Emergency Events Database (EM-DAT) – for historical data on hazard events			●	●	●
The Storm Water Management Model (SWMM) - hydrologic and hydraulic model					●
Tsunami Alert System - for tidal gauge data			●		●
Water-Surface PROfile computations model (WSPRO) - hydraulic model					●
Wave Height Analysis for Flood Insurance Studies model (WHAFLS) – wave height model					●
World Bank's Climate Change Knowledge Portal - Guidance documents and regional climate data		●	●	●	●
WorldClim – for CMIP5 projections			●		●