THE CARIBBEAN AND CLIMATE CHANGE

THE COSTS OF INACTION

RAMÓN BUENO
CORNELIA HERZFELD
ELIZABETH A. STANTON
FRANK ACKERMAN

Tufts University

May 2008

Gulf of Mexico
North Atlantic Ocean
Caribbean Sea
North Pacific Ocean
UNITED STATES
Tampa
St. Petersburg
Miami
Key West
Straits of Florida
Tropic of Cancer
THE BAHAMAS
Grand Bahama
Freeport
Great Abaco
BIMINI ISLANDS
New Providence
Nassau
Eleuthera
Andros Island
Great Bahama Bank
Cat Island
San Salvador
Rum Cay
Long Island
Samana Cay
Great Exuma
Cay Sal Bank (THE BAHAMAS)
Guinchos Cay (THE BAHAMAS)
Cay Lobos (THE BAHAMAS)
RAGGED ISLAND RANGE (THE BAHAMAS)
Crooked Island
Acklins Island
Mayaguana
Great Inagua
Turks and Caicos Islands (U.K.)
Grand Turk
Havana
Matanzas
Pinar del Río
Santa Clara
Cienfuegos
CUBA
Nuevitas
Camagüey
Holguín
Manzanillo
Santiago de Cuba
Guantánamo
U.S. Naval Base Guantanamo Bay
Windward Passage
Isla de la Juventud
Yucatan Channel
Campeche Bank
Mérida
Cancún
Isla Cozumel
Campeche
MEXICO
Chetumal
Belize City
Belmopan
BELIZE
Flores
GUATEMALA
Guatemala
Puerto Barrios
San Pedro Sula
La Ceiba
HONDURAS
Tegucigalpa
Puerto Lempira
ISLAS DE LA BAHÍA
SWAN ISLANDS (HONDURAS)
Santa Ana
San Salvador
San Miguel
EL SALVADOR
Choluteca
Mosquito Coast
Cayos Miskitos
Puerto Cabezas
Matagalpa
León
NICARAGUA
Managua
Granada
Bluefields
Lago de Nicaragua
ISLAS DEL MAIZ
Isla de la Providencia (COLOMBIA)
Isla de San Andrés (COLOMBIA)
Middle America Trench
Puntarenas
San José
Puerto Limón
COSTA RICA
Bocas del Toro
Colón
Panama
Balboa
Panama Canal
Golfito
David
PANAMA
Santiago
La Palma
George Town
Cayman Islands (U.K.)
Cayman Trench
Montego Bay
Kingston
JAMAICA
Navassa Island (U.S.)
Cap-Haïtien
HAITI
Port-au-Prince
Les Cayes
Santiago
DOMINICAN REPUBLIC
Santo Domingo
Isla Mona
Mona Passage
Milwaukee Deep
Puerto Rico Trench
San Juan
Puerto Rico (U.S.)
British Virgin Is. (U.K.)
Virgin Is. (U.S.)
St. Croix
Anegada Passage
Anguilla (U.K.)
St. Martin (Guad. and Neth. Antilles)
St. Barthelemy (Guad.)
Neth. Antilles (NETH.)
Basseterre
ST. KITTS AND NEVIS
ANTIGUA AND BARBUDA
St. John's
Plymouth
Montserrat (U.K.)
Guadeloupe (FRANCE)
Basse-Terre
Marie-Galante
DOMINICA
Roseau
Isla Aves (VENEZUELA)
Aves Ridge
Beata Ridge
Martinique (FRANCE)
Fort-de-France
Castries
ST. LUCIA
BARBADOS
Bridgetown
Kingstown
ST. VINCENT AND THE GRENADINES
GRENADA
St. George's
Tobago
TRINIDAD AND TOBAGO
Port-of-Spain
Trinidad
Aruba (NETH.)
Oranjestad
Netherlands Antilles (NETH.)
Curaçao
Willemstad
Bonaire
Golfo de Venezuela
Isla la Tortuga
Isla de Margarita
Santa Marta
Barranquilla
Cartagena
Maracaibo
Lago de Maracaibo
Barquisimeto
Valencia
Puerto Cabello
Caracas
Maracay
Cumaná
Barcelona
Maturín
Ciudad Bolívar
Ciudad Guayana
San Fernando
Mérida
Cúcuta
San Cristóbal
Bucaramanga
Arauca
Monteria
Medellín
Pereira
Ibagué
Bogotá
Buenaventura
Cali
CORDILLERA ORIENTAL
ANDES
COLOMBIA
VENEZUELA
Puerto Ayacucho
GUIANA HIGHLANDS
GUYANA
Georgetown
BRAZIL
Peru - Chile Trench
Isla del Coco (COSTA RICA)
Scale 1:12,500,000
Lambert Conformal Conic Projection, standard parallels 9°N and 17°N
100 200 300 Kilometers
100 200 300 Miles
Boundary representation is not necessarily authoritative.

THE CARIBBEAN AND CLIMATE CHANGE

THE COSTS OF INACTION

RAMÓN BUENO
CORNELIA HERZFELD
ELIZABETH A. STANTON
FRANK ACKERMAN

Stockholm Environment Institute—US Center
Global Development and Environment Institute, Tufts University

May 2008

The full report is available online at
http://www.sei-us.org/climate-and-energy/Caribbean_Inaction_Cost.htm
http://www.gdae.org/CaribbeanClimate.html

EXECUTIVE SUMMARY

The two dozen island nations of the Caribbean, and the 40 million people who live there, are in the front lines of vulnerability to climate change. Hotter temperatures, sea-level rise and increased hurricane intensity threaten lives, property and livelihoods throughout the Caribbean. As ocean levels rise, the smallest, low-lying islands may disappear under the waves. As temperatures rise and storms become more severe, tourism—the life-blood of many Caribbean economies—will shrink and with it both private incomes and the public tax revenues that support education, social services, and infrastructure. And these devastating impacts will occur regardless of the fact that Caribbean nations have contributed little to the release of the greenhouse gases that drive climate change.

This report offers a preliminary examination of the potential costs to the island nations of the Caribbean if greenhouse gas emissions continue unchecked. In many respects, this study uses a methodology similar to our 2007 report on the costs of inaction for the state of Florida. As in that report, we compare an optimistic scenario and a pessimistic one. Under the optimistic scenario—called "rapid stabilization" or "low-impact"—the world begins taking action in the very near future and greatly reduces emissions by mid-century with additional decreases through the end of the century. Under the pessimistic scenario—called "business-as-usual" or "high-impact"—greenhouse gas emissions continue to skyrocket throughout the 21st century. Both scenarios are based largely on the 2007 report of the Intergovernmental Panel on Climate Change (IPCC), a panel of more than 2,000 scientists, whose consensus findings are approved by all participating governments, including the United States. The cost of inaction, or the difference between these two scenarios, may be seen as the potential savings from acting in time to prevent the worst economic consequences of climate change.

The projections presented here are by no means a comprehensive picture of all climate damages. Indeed, they are based on just three categories of effects:

- Hurricane damages, extrapolated from average annual hurricane damages in the recent past;
- Tourism losses, assumed to be proportional to the current share of tourism in each economy; and
- Infrastructure damages, due to sea-level rise (exclusive of hurricane damage), which are projected as a constant cost per affected household.

For just these three categories—increased hurricane damages, loss of tourism revenue, and infrastructure damages—the Caribbean's annual cost of inaction is projected to total $22 billion annually by 2050 and $46 billion by 2100. These costs represent 10 percent and 22 percent, respectively, of the current Caribbean economy.*

Table ES-1. Caribbean Region—Cost of Inaction

(High-Impact minus Low-Impact Scenarios)

Total Caribbean	Cost of Inaction ($US Billions)			
	2025	2050	2075	2100
Storms	$ 1.1	$ 2.8	$ 4.9	$ 7.9
Tourism	1.6	3.2	4.8	6.4
Infrastructure	8.0	15.9	23.9	31.9
Total	$10.7	$21.9	$33.7	$46.2
% Current GDP	**5.0%**	**10.3%**	**15.9%**	**21.7%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table ES-2 presents the cost of inaction for each country included in the study. While the regional average is large, rising from five percent of GDP in 2025 to 22 percent in 2100, there is also considerable variation around this average; some countries have much higher projected impacts. The projected cost of inaction reaches an appalling 75 percent of GDP or more by 2100 in Dominica, Grenada, Haiti, St. Kitts & Nevis, and Turks & Caicos, and smaller, but still impressively high levels for a number of others islands.

In addition to providing preliminary estimates of the costs of climate inaction for the Caribbean, this report also looks more closely at the implications for two larger islands, Puerto Rico and Cuba, and considers the parallels and contrasts for one of the mainland countries facing the Caribbean—Colombia.

* Note that in one key respect, the methodology used here departs from our Florida analysis and instead is based on the World Bank's 2002 projection of climate impacts on selected Caribbean nations. In particular, we compare projected future climate damages to the current (2004) population and GDP (gross domestic product, or national income) for each country. This allows us to isolate the impacts of climate change, separated from the impacts of population and economic growth. In the later years of this century, GDP will likely be larger than it is today for most or all of the region. (Projection of future GDP for the numerous Caribbean nations and territories is beyond the scope of this preliminary study.) However, some of our damage estimates are projected as percentages of GDP. So as the island economies grow, the damages will grow as well.

Table ES-2. Caribbean Region Summary—Cost of Global Inaction on Climate Change

	Cost of Inaction: % of current GDP			
	2025	2050	2075	2100
Anguilla	10.4	20.7	31.1	41.4
Antigua & Barbuda	12.2	25.8	41.0	58.4
Aruba	5.0	10.1	15.1	20.1
Bahamas	6.6	13.9	22.2	31.7
Barbados	6.9	13.9	20.8	27.7
British Virgin Islands	4.5	9.0	13.5	18.1
Cayman Islands	8.8	20.1	34.7	53.4
Cuba	6.1	12.5	19.4	26.8
Dominica	16.3	34.3	54.4	77.3
Dominican Republic	9.7	19.6	29.8	40.3
Grenada	21.3	46.2	75.8	111.5
Guadeloupe	2.3	4.6	7.0	9.5
Haiti	30.5	61.2	92.1	123.2
Jamaica	13.9	27.9	42.3	56.9
Martinique	1.9	3.8	5.9	8.1
Montserrat	10.2	21.7	34.6	49.5
Netherlands Antilles	7.7	16.1	25.5	36.0
Puerto Rico	1.4	2.8	4.4	6.0
Saint Kitts & Nevis	16.0	35.5	59.5	89.3
Saint Lucia	12.1	24.3	36.6	49.1
Saint Vincent & the Grenadines	11.8	23.6	35.4	47.2
Trinidad & Tobago	4.0	8.0	12.0	16.0
Turks & Caicos	19.0	37.9	56.9	75.9
U.S. Virgin Islands	6.7	14.2	22.6	32.4
TOTAL CARIBBEAN	**5.0%**	**10.3%**	**15.9%**	**21.7%**

Sources: Authors' calculations. Percentages based on 2004 GDP.

CASE STUDY: PUERTO RICO

Puerto Rican rainforests, mangroves, and beaches, important to tourists and residents alike, are extremely vulnerable to climate change. Most of the population lives in or near coastal zones, and most economic activity is located there as well, including most hotels, hospitals, and electric power plants. More than half of the population lives in the San Juan metropolitan area, a coastal city that is very close to sea level. A rise of three feet in sea level would flood large parts of the city.

The cost of global climate inaction for Puerto Rico is projected to reach $2.5 billion annually by 2050 and exceeds $5 billion by 2100. These costs represent nearly three percent and six percent, respectively, of Puerto Rico's current GDP (see Table ES-3). As with all other projections in this report, these figures reflect impacts from only three categories, namely from decreased tourism, hurricane damages, and infrastructure damage due to sea-level rise.

Although the projected damages are higher, in dollars, than for most other islands, they represent a smaller fraction of Puerto Rico's larger GDP.

Table ES-3. Puerto Rico—Cost of Inaction

(High-Impact minus Low-Impact Scenarios)

Puerto Rico	Cost of Inaction ($US Billions)			
	2025	**2050**	**2075**	**2100**
Storms	0.2	0.4	0.7	1.1
Tourism	0.2	0.5	0.7	1.0
Infrastructure	0.8	1.6	2.4	3.2
Total	**$1.2**	**$2.5**	**$3.8**	**$5.2**
% Current GDP	**1.4%**	**2.8%**	**4.4%**	**6.0%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

CASE STUDY: CUBA

Cuba, the largest island in the Caribbean, faces unique challenges that make it particularly vulnerable to the effects of climate change. Over 10 percent of Cubans live less than a mile from the shoreline, a lower share than on many smaller Caribbean islands, but a large number of people nonetheless. Cuba has the longest coastline among Caribbean islands, and a land mass big enough to be hit by hurricanes moving along several different storm paths. Its 11 million people have limited income levels and modest living conditions.

The cost of global climate inaction for Cuba is estimated at nearly $5 billion annually by 2050, growing to over $10 billion by 2100, from impacts on tourism, hurricane damage, and infrastructure impacts due to sea-level rise. These losses amount to almost 13 percent and 27 percent, respectively, of Cuba's current GDP (see Table ES-4).

Table ES-4. Cuba—Cost of Inaction

(High-Impact minus Low-Impact Scenarios)

Cuba	Cost of Inaction ($US Billions)			
	2025	**2050**	**2075**	**2100**
Storms	0.3	0.8	1.4	2.2
Tourism	0.2	0.4	0.6	0.8
Infrastructure	1.8	3.6	5.4	7.3
Total	**$2.3**	**$4.8**	**$7.4**	**$10.2**
% Current GDP	**6.1%**	**12.5%**	**19.4%**	**26.8%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Twenty-two percent of the Caribbean's total costs of global climate inaction falls on Cuba, reflecting its status as the region's largest island. The cost of inaction as a percentage of GDP is slightly above average, although debates over the interpretation of Cuban GDP data make these percentages uncertain. Cuba's projected losses are, however, minimized both by lower-than-average hurricane damages, and by the relatively small size of the tourism industry. As tourism expands, so too will Cuba's exposure to climate damages.

CASE STUDY: COLOMBIA

This report focuses principally on the islands of the Caribbean, but the term "Caribbean" is sometimes used more broadly to also include the countries of Central America and the northern coast of South America. While analysis of the costs of climate inaction for all countries surrounding the Caribbean is beyond the scope of this report, we look briefly at the impacts on one of the coastal countries, Colombia. Unlike our examination of the Caribbean island nations, however, our discussion of Colombia is solely qualitative and does not include quantitative projections of economic impacts.

Colombia's Caribbean coastline is over 1,000 miles long and includes several of the country's largest cities and much of its economic infrastructure, generating 16 percent of Colombia's GDP. Agriculture and cattle ranching are important economic activities of the region. Tourism is also important all along the coast, especially in the colonial city of Cartagena and the Caribbean islands of San Andrés and Providencia, although tourism's contribution to GDP is only 2.3 percent.

Colombian studies examining the consequences of a one meter (39 inches) sea-level rise over the next 100 years conclude that in addition to the erosion of beaches, marshes, and mangroves, there could be permanent flooding of 1,900 square miles in low-lying coastal areas, affecting 1.4 million people, 85 percent of them in urban areas. For the Caribbean coastal area, about five percent of crop and pasture land would be exposed to various degrees of flooding; nearly half of that area is classified as highly vulnerable. At the same time, the intensification of droughts, desertification, and soil degradation could nearly double the size of Colombia's northeastern desert. Another anticipated consequence of climate change is the total loss of glacial ice within 100 years, with perhaps three-fourths lost by 2050. The retreat and disappearance of glaciers will affect water availability, hydropower generation and ecosystems.

Colombia faces some of the same consequences as Caribbean islands from sea-level rise and warming, as well as a unique set of challenges from impacts like the ecological and economic consequences of melting glaciers at high altitudes. Given Colombia's economic, social and political challenges, adaptation measures to lessen the impacts of climate change may be difficult to afford.

The bottom line remains the same in Colombia as in the Caribbean islands: equitable and sustainable development will face new challenges, as sorely needed resources will be diverted to meet the rising costs of global inaction, in countries that make only the smallest contributions to the emissions that cause climate change.

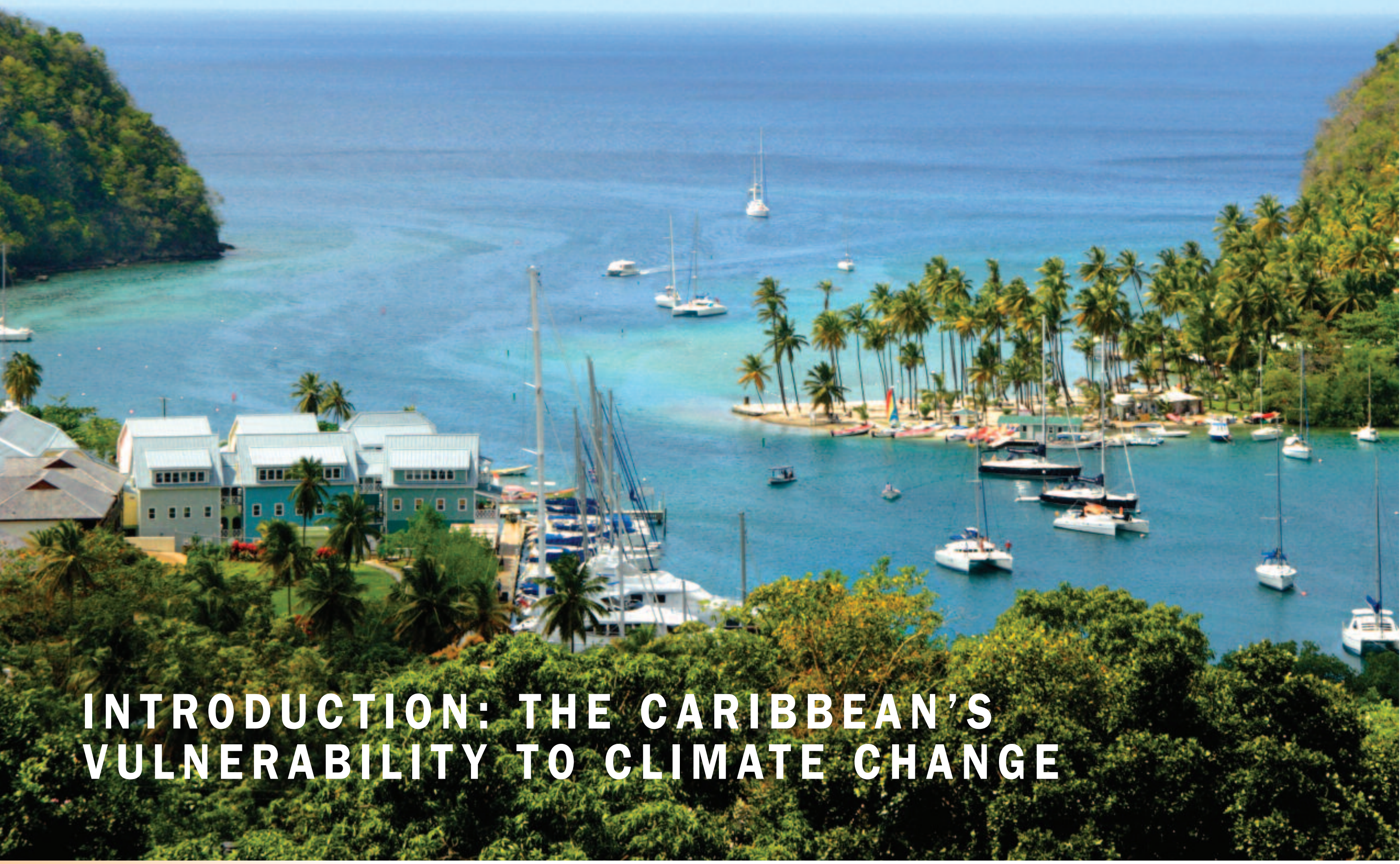
ACKNOWLEDGMENTS

We would like to thank Marisa Escobar from the Stockholm Environment Institute for her assistance. Thanks also to Karen Florini at Environmental Defense Fund for proposing and supporting the project, and to Jane Tenenbaum and Clare Kazanski for the design and production of the final report.

This study was supported by a grant from Environmental Defense Fund. The opinions and conclusions, as well as any errors, are solely the responsibility of the authors.

CONTENTS

List of Tables



INTRODUCTION: THE CARIBBEAN'S VULNERABILITY TO CLIMATE CHANGE

The work of the Intergovernmental Panel on Climate Change (IPCC)—a panel of more than 2,000 scientists whose consensus findings are approved by all participating governments, including the United States—makes it ever clearer that "warming of the climate system is unequivocal…", that "[m]ost of the observed increase…is very likely due to the observed increase in anthropogenic greenhouse gas concentrations,"[1] and that the growing accumulation of greenhouse gases in the atmosphere resulting from human activities is exceeding the historical levels that keep the Earth habitable.

As temperatures increase, ocean water warms and expands, glaciers and ice sheets melt, and sea levels rise. Rising sea levels lead to more salt water intrusions into aquifers that supply fresh water, a resource that is already in short supply on some islands, especially in the Eastern Caribbean. Warmer waters also fuel stronger hurricanes—ample cause for concern in a region already pummeled by hurricanes that cause widespread physical and economic damage, including many deaths, on an almost annual basis.

Indeed, coping with recurring natural disasters is already a fact of life for much of the Caribbean region. Small islands with low elevations can suffer terrible effects from wind and waves in storms; these impacts are amplified by local social and economic conditions. It can take years for island economies to recover from the impact of a hurricane. Many Caribbean residents are very poor by world standards,[2] and many Caribbean nations have significant international debts.[3] For developing nations around the world, paying the price of protective measures like dikes and sea walls is simply out of the question. Insulating shorelines against storms, elevating structures as sea levels rise, and even installing air conditioning in homes and businesses is a luxury that will be widely affordable only in richer countries.

If climate change continues unchecked, money that could be used for poverty alleviation and other social services, or for economic development, will instead be diverted to efforts to recover from the impacts of climate change. The unwelcome costs of climate change, imposed by the actions of higher income nations, may make development unaffordable to the people of the Caribbean.

The Caribbean population is largely concentrated in coastal areas where much of the infrastructure may not be able to withstand significantly stronger winds, deeper incursions from more forceful ocean surges, and heavier rains. The anticipated climate changes will accelerate the erosion of coastal beaches, land and protective mangroves. Coastal houses, hotels and other buildings, along with roads and other infrastructure are vulnerable, as are those who live and work there. (Even mainland U.S. infrastructure in coastal regions is highly vulnerable to such effects, as demonstrated by the aftermath of Hurricane Katrina in 2005.)

Still greater vulnerability and higher economic damages will result if new construction and development along the coast is not built to withstand the impacts of rising sea levels and increasing occurrences of floods, and land and mud slides. Conversely, conditions of poverty and inadequate development in some communities and islands may continue to lead to substandard construction of buildings and infrastructure, accentuating their vulnerability.

Despite greater precipitation during storms and other peak periods, more frequent and longer droughts are expected in parts of the Caribbean this century. Negative health impacts will include greater heat stress for vulnerable populations (such as the elderly), worse sanitation conditions from limited water supplies or contaminated water from floods, and conditions that can favor the spread of water and vector-borne diseases, such as dengue fever, malaria, and diarrhea. Public health systems may not be adequate to face greater demands on their services, many of which already are strained by insufficient resources as they face high incidence of HIV and AIDS.[4]

Higher temperatures also will have serious consequences for agriculture and ecosystems. Important commercial fisheries are at risk as their coral reef habitats are stressed by warmer waters, as was the case during the summer of 2005, which caused record bleaching in coral reefs.[5] Coral reefs in the area have already been under stress from other human impacts; climate change now emerges as a major new threat. Coral reefs are vital to many island economies, providing fishing grounds, coastal protection, and tourism opportunities.

The Caribbean is one of the world's most tourism-dependent regions. The industry contributes 15 percent of the region's national income, or gross domestic product (GDP), and much higher fractions for some islands—more than two-thirds in several of the smaller countries. In 2004, tourism in the Caribbean was a $28 billion industry and employed 2.4 million people. The tourist industry, of course, is entirely dependent on the existence of attractive beaches and other natural areas, and on comfortable weather. Cruise ship voyages, a market in which the Caribbean accounts for half of the global total, are less susceptible (although not entirely invulnerable) to climate impacts. Despite rapid growth in recent years, cruise ships still account for no more than 10 percent of international tourist receipts in the region.[6]

Most tourists come from colder climates—over 80 percent come from the United States, Canada and Europe—and more of them might vacation closer to home if northern winters become milder in future decades.[7] Researchers have examined how climate-related changes in temperature, health risks, and in other environmental features (e.g., beaches and ecosystems) may have a significant impact on tourists' destination choices within the islands. One survey of visitors to two tourism-dependent islands found that 80 percent of the respondents would be unwilling to revisit the island for the same price if the environmental attractions (coral reefs and beaches, respectively) were negatively affected by climate change.[8]

Finally, energy and food security are pressing concerns for a region that is highly susceptible to rising world prices for fuel and food. About 90 percent of energy used in the Caribbean is derived from crude oil, which must be imported (except in oil-rich Trinidad and Tobago).[9] As temperatures gradually increase in a region that is already often hot for much of the year, those who can afford to consume more electricity for air conditioning will do so, causing greater carbon emissions and raising the demand for energy even higher.

Food security is also of concern due to the vulnerability and limited scale of Caribbean agriculture, already facing uncertain impacts from temperature and precipitation changes. Many islands, including Barbados, Jamaica, and Puerto Rico, are highly dependent on imported food and agricultural products, and very susceptible to changes in world food prices. Such prices may spike upwards as climate change exacerbates droughts and floods in the world's major agricultural producing regions.

This roster of vulnerabilities is indifferent to the fact that Caribbean nations' emissions of the greenhouse gases responsible for climate change are very small. Greenhouse pollutants like carbon dioxide affect our shared atmosphere regardless of where in the world they are emitted.[10] But the effects of climate change will hit some regions harder and sooner than others, because some nations are better situated than others—in terms of both geography and infrastructure—to weather the worst effects. The combination of strong local climate effects, low-lying island geography, and limited economic resources with which to create buffers against the worst climatic effects, makes the Caribbean especially vulnerable.[11]

While local social, economic, and political systems shape the Caribbean islands' vulnerability and ability to cope, the climate-related challenges they face are global in origin. Ultimately, global equity is at the core of the problem. It is also the solution to the area's twin challenges of developing in a sustainable way to meet the needs of its citizens while preparing for the potentially daunting consequences of climate change in the region.

METHODOLOGY

We constructed a model to project key categories of the potential costs of climate change in the Caribbean over the next century. Our analysis builds on and extends some of the findings from the World Bank's 2002 study of climate costs in the CARICOM (Caribbean Community and Common Market) countries, and the more recent (2007) study of Florida by our research group.[12] Our analysis extends beyond CARICOM to encompass 24 island entities in the Caribbean, including dependencies of France, the Netherlands, the United Kingdom, and the United States.[13]

We present estimates only for three major categories of damages—damages from increased hurricane intensity, loss of infrastructure due to sea-level rise, and loss of tourism revenue. This is not to imply that damages in other areas mentioned earlier, such as agriculture, public health, energy and water resources, will be insignificant; rather, our choice of categories is based largely on availability of easily comparable data.[14]

As in our Florida study, we estimate the difference between a "low-impact" (rapid stabilization) scenario assuming ambitious emission reductions, and a "high-impact" (business as usual) scenario assuming little or no mitigation and adaptation. In the treatment of population and economic growth, however, we follow the method used in the World Bank study, rather than our Florida analysis: we project climate impacts throughout this century under the assumption that population and GDP remain fixed at recent (2004) levels. This approach avoids the substantial difficulty in predicting future GDP and population growth in this somewhat disparate group of nations. It also allows us to isolate the effects of climate change from the effects of economic and demographic growth. Nevertheless, while the Caribbean is not projected to have the same high-growth rates as Florida, it is likely to experience some appreciable GDP growth over the course of the 21st century. As a result, the impacts on actual future GDP would be correspondingly smaller than described here in terms of current GDP.

The two scenarios used in our Caribbean model are generally consistent with the IPCC's "B1" and "A2" scenarios. The IPCC does not make a single projection of future climate change, but instead calculates a set of six possible futures. Of these, B1 has the slowest growth of emissions, and consequently the lowest impacts. A2 has the second fastest growth of the six scenarios, and has been widely used to represent the impacts from business-as-usual emissions.

As small island nations, the Caribbean countries share many characteristics. Nonetheless, there are significant differences between the islands in terms of size, population, social and economic conditions, infrastructure, standard of living, etc. Their geographical location within the Caribbean is crucial in relation to hurricane paths, with some islands suffering frequent damages (e.g., The Bahamas, Cayman Islands or Cuba) and others infrequently or not at all (e.g., Aruba, Trinidad and Tobago). Temperature increases and sea-level rise interact with island topography (coastal low-lying lands, versus steeper inclines) and with the other physical, social, and economic conditions in determining the consequences of extreme climate changes and the islands' vulnerability to them. The importance of tourism to the local island economies varies as well. These factors explain the very different impacts seen in our model results for different countries.

In order to apply the model across the range of islands, the following simplifying assumptions were made (see the Appendix II for further details):

Hurricane damages

For hurricane damages from increased storm intensity we used historical information on hurricane and flood damages, and calculated an average annual cost per island based on the costs between 1990 and 2007.[15] From these historical average annual storm damages, projections were made for damages in 2025, 2050, 2075 and 2100 for both the low- and high-impact scenarios using the formulas described in our Florida study:

- In both the low- and high-impact scenarios, doubling of hurricane damages for every meter (39 inches) of sea-level rise (as discussed in Appendix II, we use a higher sea-level rise value than does the IPCC to account for recent observed trends).
- In the high-impact scenario only, losses are compounded by an additional doubling of damages for each doubling of atmospheric carbon dioxide concentrations in the atmosphere, which accounts for greater storm intensity.

Tourism

The World Bank study estimated the loss of tourist revenue that could be attributed to increased temperature, loss of beaches, and environmental degradation. We used their estimate of the ratio of lost tourist revenue to total tourist expenditures for the CARICOM island countries as a whole, and applied this ratio to the tourist expenditures, as reported by the World Travel & Tourism Council, on each island for the year 2007.[16]

Infrastructure

The World Bank study estimated the cost per affected household of reconstructing housing, other buildings, roads, and infrastructure lost to sea-level rise, and estimated that 19 percent of the population would be affected in the low-impact case, and 66 percent in the high-impact case. For the islands not in the original World Bank study, we applied the same hypotheses for all except the three largest (Cuba, Dominican Republic/Haiti and Puerto Rico) where it seems likely that smaller fractions of the population live in the coastal areas which are at risk from sea-level rise.[17] To be conservative, we used half the World Bank estimates of the affected population for the largest islands.

RESULTS: PROJECTED COSTS OF INACTION IN THE CARIBBEAN

What price will the Caribbean be forced to pay for the impacts of climate change in the 21st century? What are the likely costs of inaction—of insufficient efforts world-wide to prevent worsening climate change?

Our model projects significant costs for Caribbean island nations as a result of global climate inaction. As shown in Table 1, the difference between the high- and low-impact scenarios in the three modeled categories—damages from increased hurricane intensity, loss of tourism from rising temperatures and sea-level rise, and infrastructure damages from sea-level rise—comes to $22 billion annually by 2050 and $46 billion by 2100. To place these numbers in context, these costs represent 10 percent and 22 percent, respectively, of the Caribbean economy as of 2004 (although even a relatively low-growth region would be expected to experience some increase in GDP over the course of this century). Losses in infrastructure from the effects of sea-level rise are the largest contributor to these costs. These figures provide one indication of the magnitude of potential consequences of unconstrained climate change in the region in the absence of adaptation efforts.

Table 1. Caribbean Region—Cost of Inaction

(High-Impact minus Low-Impact Scenarios)

Total Caribbean	**Cost of Inaction ($US Billions)**			
	2025	**2050**	**2075**	**2100**
Storms	1.1	2.8	4.9	7.9
Tourism	1.6	3.2	4.8	6.4
Infrastructure	8.0	15.9	23.9	31.9
Total	**$10.7**	**$21.9**	**$33.7**	**$46.2**
% Current GDP	**5.0%**	**10.3%**	**15.9%**	**21.7%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table 2 presents the projected costs for the low- and high-impact scenarios from which we calculated the costs of inaction. Note that while the costs of inaction could be avoided with prompt and vigorous actions to reduce the greenhouse gases that are driving sea-level rise and temperature increases, the costs in the low-impact scenario are now all but inescapable—although swift investment in adaptation measures could assure that, for some categories of damages, money is spend to avoid damage, not to rebuild after damage has occurred. Even under the low-impact scenario, the annual costs of climate change for the Caribbean are projected to be nearly $6 billion by 2050 and $10 billion by 2100—a substantial depletion of resources, nearly three percent of current GDP in 2050 and approaching five percent by the end of the century. By 2050 the costs in the high-impact scenario are roughly four times higher than in the low-impact scenario and five times higher by 2100, imposing a vastly greater burden.

Table 2. Caribbean Region—Low- and High-Impact Scenarios

Total Caribbean	Climate Change Scenarios: $US Billions			
LOW-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	1.9	2.0	2.0	2.1
Tourism	0.4	0.8	1.2	1.6
Infrastructure	1.5	2.9	4.4	5.9
Total	**$3.8**	**$5.7**	**$7.7**	**$9.6**
% Current GDP	**1.8%**	**2.7%**	**3.6%**	**4.5%**
HIGH-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	3.1	4.7	7.0	10.0
Tourism	2.0	4.0	6.0	8.0
Infrastructure	9.4	18.9	28.3	37.8
Total	**$14.5**	**$27.6**	**$41.3**	**$55.8**
% Current GDP	**6.8%**	**13.0%**	**19.5%**	**26.3%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table 3 presents the cost of inaction for each country included in the study. While the regional average is large, rising from five percent of current GDP in 2025 to 22 percent in 2100, there is also considerable variation around this average; some countries have much higher projected impacts. The projected cost of inaction reaches an astonishing 75 percent of current GDP or more by 2100 in Dominica, Grenada, Haiti, St. Kitts & Nevis, and Turks & Caicos, and smaller, but still impressively high levels for a number of others islands.

Some of the projected costs of inaction, in fact, exceed 100 percent of GDP. How can this be the case? Recall that the percentages in the tables are comparing projected future damages to current GDP; it is likely that GDP will be larger, and hence the true percentages somewhat smaller, by later in this century. Damages actually can exceed 100 percent of GDP, if a particularly violent storm destroys buildings and infrastructure that took many years to build. In 2004, damages in Grenada from Hurricane Ivan were estimated at twice the island's GDP.[18] The real message of our model, however, is not the precise projection, but the overall seriousness of impacts that will result from a worsening climate. As damages mount up, climate change will cause a breakdown in Caribbean economic life; at some point—likely well before the projected annual damages reach 100 percent of GDP—it will become impossible to keep restoring damaged property, and tourism and other weather-sensitive industries will move elsewhere. Indeed, as sea levels rise, residents of small low-lying islands, like Turks & Caicos, may be unable to continue inhabiting them.

Table 3. Caribbean Region Summary—Cost of Global Inaction on Climate Change

	Cost of Inaction: % of current GDP			
	2025	**2050**	**2075**	**2100**
Anguilla	10.4	20.7	31.1	41.4
Antigua & Barbuda	12.2	25.8	41.0	58.4
Aruba	5.0	10.1	15.1	20.1
Bahamas	6.6	13.9	22.2	31.7
Barbados	6.9	13.9	20.8	27.7
British Virgin Islands	4.5	9.0	13.5	18.1
Cayman Islands	8.8	20.1	34.7	53.4
Cuba	6.1	12.5	19.4	26.8
Dominica	16.3	34.3	54.4	77.3
Dominican Republic	9.7	19.6	29.8	40.3
Grenada	21.3	46.2	75.8	111.5
Guadeloupe	2.3	4.6	7.0	9.5
Haiti	30.5	61.2	92.1	123.2
Jamaica	13.9	27.9	42.3	56.9
Martinique	1.9	3.8	5.9	8.1
Montserrat	10.2	21.7	34.6	49.5
Netherlands Antilles	7.7	16.1	25.5	36.0
Puerto Rico	1.4	2.8	4.4	6.0
Saint Kitts & Nevis	16.0	35.5	59.5	89.3
Saint Lucia	12.1	24.3	36.6	49.1
Saint Vincent & the Grenadines	11.8	23.6	35.4	47.2
Trinidad & Tobago	4.0	8.0	12.0	16.0
Turks & Caicos	19.0	37.9	56.9	75.9
U.S. Virgin Islands	6.7	14.2	22.6	32.4
TOTAL CARIBBEAN	**5.0%**	**10.3%**	**15.9%**	**21.7%**

Sources: Authors' calculations. Percentages based on 2004 GDP.

Looking inside our model, there are cases in which countries stand out because of high impacts in each of our three cost categories. Average annual hurricane damages in the recent past, used as the basis for our projection of future **hurricane damages**, vary widely throughout the region. The regional average is one percent of current GDP, but three countries, the Cayman Islands, Grenada, and St. Kitts & Nevis, have had hurricane damages averaging 10–15 percent of GDP since 1990. In three others, Antigua & Barbuda, Dominica, and Montserrat, hurricane losses have been roughly five to seven percent of GDP. Our projection of future hurricane damages is proportional to recent past damages, so it is particularly large for these six countries.

Tourism is important to economies throughout the region, but some are much more tourist-dependent than others. The economies of Anguilla and Turks & Caicos appear to be dominated by tourism; tourism also accounts for a very large share of economic activity in many of the other small countries. In contrast, tourism is a smaller than average proportion of GDP in several of the larger economies, including Cuba, Haiti, Puerto Rico, and Trinidad & Tobago. Our projection of climate-related tourism losses is proportional to the current share of tourism in the economy, so the more heavily tourist-based economies suffer greater losses in this category.

Infrastructure damages, our largest cost category, is projected as a constant cost per affected household (as noted above, this approach is modified from the World Bank analysis with regard to the large islands); this category is based on sea-level rise, and excludes hurricane damages. Thus it is largest, as a percentage of GDP, in the lowest income countries. Haiti stands out in this respect, as by far the lowest-income country of the region, and it is therefore hardest hit, in percentage terms, by the projected infrastructure costs. Haiti's poverty creates unique challenges and levels of vulnerability, accentuating the problems faced throughout the region. For example, most forests in Haiti have already been cut down for fuel wood, the affordable fuel for the majority of Haitians. The loss of forests makes Haiti more vulnerable to greater damages, with less protection against strong winds, floods and mud slides. Hurricane Jeanne in 2004 had devastating impacts, leaving over 200,000 people homeless and 3,000 dead, though it was only of tropical storm intensity (technically speaking, not quite a hurricane) when it struck the country.[19]

CLIMATE IMPACTS ON PUERTO RICO

During the latter half of the 20th century the Commonwealth of Puerto Rico, a "non -incorporated territory" of the United States with a population of nearly four million, underwent rapid industrial transformation and commercial development. In nighttime satellite images of the Earth, Puerto Rico stands out in the Caribbean—it is about as bright as the Eastern United States, Western Europe, or Japan.[20]

In 2006, Puerto Rico's GDP was $86.5 billion while per capita GDP (or average income) was just over $22,000. In that year, manufacturing accounted for 42 percent of output and 11 percent of employment, while agriculture accounted for only 0.4 percent of GDP but almost two percent of the labor force. Annual tourism expenditures exceed $2 billion and create over 50,000 direct and indirect jobs—large absolute numbers, but a much smaller percentage of the economy than many smaller islands.[21] Average life expectancy is 78 years and 94 percent of the population is literate; Puerto Rico would rank high in terms of the United Nation's Human Development Index.[22]

The main island accounts for 99 percent of Puerto Rico's 3,435 square miles; the interior of the main island is mountainous with a peak elevation of 4,390 feet above sea level. Vieques and Culebra islands to the east are populated year-round, while Mona to the west is an ecological reserve. Temperatures vary between the warmer coast and inland mountains, with average annual temperatures around 84 degrees Fahrenheit (29 degrees Celsius), although temperatures in the 90s (32–37 degrees Celsius) are common in the summer months. Puerto Rico is one of the richest islands in the region in terms of biodiversity and wildlife species.

Puerto Rican rainforests, mangroves, and many miles of coast, providing beach, sand, and sun to tourists and residents alike, are extremely vulnerable to climate change.[23] Hotter local temperatures, along with warmer winters in northern latitudes, may eventually reduce the number of tourist visits, especially when combined with the threat of beach erosion from sea-level rise and the destructive forces of stronger hurricanes, ocean surges and heavy rains.

Most of the population lives in or near coastal zones, and most economic activity is located there as well, including most hotels, hospitals, and electric power plants; some power plants are less than 160 feet from the waterline and less than six feet above sea level. More than half of the population lives in the San Juan metropolitan area, a coastal city that is very close to sea level. A rise of three feet (almost a meter) in sea level would flood large parts of the city.[24]

Puerto Rico was largely spared by major hurricanes during its decades of industrialization after World War II. In the last two decades, however, the island has faced damaging storms. For example, in 1989 Hurricane Hugo (a Category 3 storm) passed over the northeast corner of Puerto Rico and caused an estimated $1 billion in damages; Hurricane Georges (Category 2) crossed the island in 1998, leaving behind 12 dead and total damages amounting to $2.3 billion.[25]

Landslide hazards are a growing concern in Puerto Rico. Bursts of heavy rainfall from intense storms trigger numerous landslides in the mountain areas of the island, causing substantial property damage and sometimes loss of life.[26] With a high and growing population density (higher than in Japan or in the Netherlands), there is increased construction on vulnerable slopes exposing more of the population to these hazards.

High urban population density, growing numbers of older people, and other at-risk groups, and a relatively high poverty rate (by U.S. if not Caribbean standards) increase the island's social vulnerability to climate change damages. At the same time, Puerto Rico's relatively high per capita fuel and energy consumption—in electricity and transportation (one automobile per 1.3 Puerto Ricans)—contributes to atmospheric warming and to accelerating import bills for energy.

PUERTO RICO'S COST OF CLIMATE INACTION

Our model's cost of global climate inaction for Puerto Rico, the difference between the high and low-impact scenarios in our three categories of damages and losses, comes to $2.5 billion annually by 2050 and exceeds $5 billion by 2100. These costs represent nearly 3 percent and 6 percent, respectively, of Puerto Rico's economy.

Table 4. Puerto Rico—Cost of Inaction

(High-Impact minus Low-Impact Scenarios)

Puerto Rico	Cost of Inaction ($US Billions)			
	2025	2050	2075	2100
Storms	0.2	0.4	0.7	1.1
Tourism	0.2	0.5	0.7	1.0
Infrastructure	0.8	1.6	2.4	3.2
Total	**$1.2**	**$2.5**	**$3.8**	**$5.2**
% Current GDP	**1.4%**	**2.8%**	**4.4%**	**6.0%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table 5 reports the projected costs for the low- and high-impact scenarios from which we calculated the above costs of inaction. By 2050 Puerto Rico would experience annual losses of nearly $1 billion (just under one percent of its current GDP) in the low-impact scenario or just over $3 billion (3.6 percent of current GDP) in the high-impact case. By the end of the century, the costs exceed $1 billion (1.3 percent of Puerto Rico's current GDP) in the low-impact scenario and are more than $6 billion (over seven percent of the island's current GDP) in the high-impact scenario.

Table 5. Puerto Rico—Low- and High-Impact Scenarios

Puerto Rico	Climate Change Scenarios: $US Billions			
LOW-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.3	0.3	0.3	0.3
Tourism	0.1	0.1	0.2	0.2
Infrastructure	0.1	0.3	0.4	0.6
Total	**$0.5**	**$0.7**	**$0.9**	**$1.1**
% Current GDP	**0.5%**	**0.8%**	**1.0%**	**1.3%**
HIGH-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.4	0.6	0.9	1.3
Tourism	0.3	0.6	0.9	1.2
Infrastructure	0.9	1.9	2.8	3.8
Total	**$1.7**	**$3.1**	**$4.7**	**$6.3**
% Current GDP	**1.9%**	**3.6%**	**5.4%**	**7.3%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Although the dollar amounts of projected damages in Puerto Rico are among the highest in the region, they represent a smaller fraction of the island's higher GDP. As was the case throughout the Caribbean region, infrastructure damages are the largest of our three categories.

CLIMATE IMPACTS ON CUBA

Cuba, the largest island in the Caribbean, is twelve times the size of Puerto Rico, with an area of 42,803 square miles. The main island accounts for 95 percent of the land area, and is home to 99 percent of the population; Isla de la Juventud in the southwest contains just under three percent and less than one percent of the population, while the rest consists of literally thousands of smaller keys around the coast.[27] While most of the island is relatively flat or has

rolling plains, there are three mountain ranges; the steepest is the Sierra Maestra in the southeastern end, where the highest point is the Pico Turquino, at 6,480 feet.

Hurricanes have caused extensive weather-related damages and deaths in Cuba, although the 20 year period from 1975 through 1995 was unusually free of tropical cyclones.[28] Since then the island has been visited by stronger storms like Lili in 1996, George in 1998, Irene in 1999, Michelle in 2001 (a Category 4 hurricane that caused almost $2 billion in reported damages to property and agriculture, as well as five deaths) and Dennis in 2005 (causing a reported $1.4 billion in damages).[29] Hurricane Noel in 2007 produced extreme flooding and agricultural losses.[30] During the second half of the 20th century mean annual air temperature rose 0.9 degree Fahrenheit (0.5 degree Celsius) and there were more frequent heavy rains, severe local storms and droughts.[31]

From a climate change perspective, Cuba faces unique challenges that make it particularly vulnerable. Over 10 percent of Cubans live less than a mile from the shoreline, a lower share than on many smaller Caribbean islands, but a large number of people nonetheless.[32] Cuba has the longest coastline among Caribbean islands, and a land mass big enough to be hit by hurricanes moving along several different storm paths. Its 11 million people have limited income levels and modest living conditions, which will make them especially vulnerable to worsening climate impacts over the course of the 21st century.

CHANGING ECONOMIC OUTLOOK?

Since the economic collapse of the early 1990s, Cuba's economy has changed significantly. Sugar production, once the dominant industry, has declined sharply, dropping to less than 15 percent of the eight million tons reached in 1989, with half of all mills closed by 2002. Mining has expanded, and nickel is now by far the country's leading export.[33]

Tourism, along with mining, has become a leading engine of the Cuban economy, with the number of tourist visitors growing to over two million per year. The share of tourism in the Cuban economy is still quite low by Caribbean standards, but with all indications that the government plans an accelerated expansion of tourism, it is likely to grow.[34] Any future turn toward greater openness and normalization of relations with the United States, when and if it occurs, would probably expand Cuba's tourism sector even more. Since tourism is one of the most climate-dependent economic sectors, Cuba will be at risk for greater economic damages from climate change as its tourism industry takes off.

The capital city of Havana, which faces north to the sea, is vulnerable to rising sea levels and future hurricanes of greater intensity. Many buildings suffer from gradually deteriorating physical condition, the result of inadequate maintenance over the decades. In some of the extreme weather events of recent years, surging storm waves flowed over the Malecón boardwalk to flood many city blocks, further deteriorating the physical infrastructure.

CUBA'S COST OF CLIMATE INACTION

Our model's calculated cost of global climate inaction for Cuba—the difference between the high- and low-impact scenarios—is nearly $5 billion annually by 2050, growing to over $10 billion by 2100. These losses amount to almost 13 percent and 27 percent, respectively, of the Cuban economy.

Table 6. Cuba—Cost of Inaction

(High-Impact minus Low-Impact Scenarios)

Cuba	Cost of Inaction ($US Billions)			
	2025	**2050**	**2075**	**2100**
Storms	0.3	0.8	1.4	2.2
Tourism	0.2	0.4	0.6	0.8
Infrastructure	1.8	3.6	5.4	7.3
Total	**$2.3**	**$4.8**	**$7.4**	**$10.2**
% Current GDP	**6.1%**	**12.5%**	**19.4%**	**26.8%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

As the largest Caribbean island, Cuba incurs a 22 percent share of the region's total costs of global inaction. The cost of inaction as a percentage of GDP is slightly above average, although debates over the interpretation of Cuban national income data make these percentages uncertain.[35] Cuba's projected losses, however, are minimized both by lower-than-average hurricane damages, and by the relatively small size of the tourism industry. As tourism expands, so too will Cuba's exposure to climate damages. (As noted above, our model extrapolates future hurricane impacts from past trends, and assumes that tourism rates remain constant.)

Cuba's economic costs under the low- and high-impact scenarios, from which we calculated the above costs of inaction, are listed in Table 7. By the year 2050 the annual losses in Cuba in the low-impact scenario are over $1 billion (or 3.5 percent of Cuba's current GDP) and exceed $6 billion (16 percent) in the high-impact case. These annual losses grow by the end of the century to over $2 billion (almost 6 percent of Cuba's current GDP) in the low-impact scenario and to over $12 billion (32 percent) in the high-impact scenario.

Table 7. Cuba—Low- and High-Impact Scenarios

Cuba	Climate Change Scenarios: $US Billions			
LOW-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.5	0.5	0.6	0.6
Tourism	0.0	0.1	0.1	0.2
Infrastructure	0.3	0.7	1.0	1.3
Total	**$0.9**	**$1.3**	**$1.7**	**$2.1**
% Current GDP	**2.4%**	**3.5%**	**4.5%**	**5.6%**
HIGH-IMPACT	**2025**	**2050**	**2075**	**2100**
Storms	0.9	1.3	1.9	2.8
Tourism	0.2	0.5	0.7	0.9
Infrastructure	2.1	4.3	6.4	8.6
Total	**$3.2**	**$6.1**	**$9.1**	**$12.3**
% Current GDP	**8.5%**	**16.0%**	**23.9%**	**32.4%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

CLIMATE IMPACTS ON COLOMBIA

To this point, this report has focused solely on the islands of the Caribbean. The term "Caribbean," however, is often interpreted as including the countries of Central America and South America that border the Caribbean Sea. While analysis of the costs of climate inaction for all countries surrounding the Caribbean is beyond the scope of this report, here we provide a qualitative look at the impacts on Colombia, which lies on the mainland but has a 1,000 mile Caribbean coast. Unlike our examination of the Caribbean island nations, this discussion of Colombia does not include quantitative projections of economic impacts.

With 45 million people, Colombia is the third most populous Latin American nation, after Brazil and Mexico. Colombia's geography is remarkably varied, with lengthy coastlines along both the Caribbean and the Pacific Ocean, giving way to high-altitude areas further inland. Relatively moderate year-round temperatures characterize the country. The countryside ranges from coastal lowlands and northeastern deserts to Andean mountains and tropical rainforests in the interior. Colombia also includes a series of small islands, such as San Andrés and Providencia in the western Caribbean. About 20 percent of Colombia's population lives in the Caribbean coastal zone, and another 10 percent along the Pacific coast.

The Caribbean region of Colombia has many beaches, mangroves, rolling hills, and low-lying coastal plains, all near sea level. It encompasses tropical humid floodplains, the deltas of several large rivers including the Sinu River and Magdalena River, and the striking Sierra Nevada de Santa Marta, a glacier-capped mountain range detached from the Andes that reaches an altitude of almost 19,000 feet. In contrast with the humid conditions of the floodplains further south, the country's northernmost area, the Guajira peninsula, is dry, including deserts where coal and natural gas mining are the main economic activities.[36]

West of the Andes and along the Pacific coast is the Chocó Biogeográfico, a tropical rain forest whose varied ecological, climatic, and geologic conditions are said to contain the highest biodiversity concentration in the world. Deforestation and industrial development are the major threats to these forests, with the loss of these rich forests leading to greater erosion of coastal areas. Deforestation from lumbering is also significant in the jungles of Colombia's Amazon region.[37]

Colombia's GDP in 2006 was $153 billion, with industry accounting for one-third of output and 18 percent of employment; the main industrial products are textiles, food processing, oil, and beverages. Commerce and services amount to more than half of the economy. Agriculture's share of the country's economic activity is declining, and is now only 12 percent of GDP (the main products are coffee, cut flowers, bananas, and rice), while mining accounts for 7 percent of GDP.[38] The United States, Colombia's main trading partner, receives 37 percent of the country's exports and provides 28 percent of its imports.[39]

Widespread social inequality and conflict have long been a reality in Colombia. Sixty percent of the population lives in poverty, with unemployment in the high double digits. As periodically reported in the world media, Colombia's socio-political conflicts include the Americas' longest lasting insurgency. Amidst these conditions, Colombia became the world's leading grower of coca and supplier of cocaine. Challenging living conditions for a large part of the population have led to dense settlement in areas with higher vulnerability to natural disasters. These same areas will be particularly vulnerable to climate change.

The Caribbean coast includes several of the country's largest cities and much of its economic infrastructure, and generates 16 percent of Colombia's GDP. Agriculture and cattle ranching are important economic activities of the region. Tourism is also important all along the coast, especially in the colonial city of Cartagena and the Caribbean islands of San Andrés and Providencia, although tourism's contribution to national GDP is only 2.3 percent.

Colombian studies examining the consequences of a one-meter (39 inches) sea-level rise over the next 100 years conclude that in addition to the erosion of beaches, marshes, and mangroves, there could be permanent flooding of 1,900 square miles in low-lying coastal areas, affecting 1.4 million people, 85 percent in urban areas.[40] For the Caribbean coastal area, about five percent of crop and pasture land would be exposed to various degrees of flooding; nearly half of that area is classified as highly vulnerable. The Pacific coastal areas, on the other hand, are more susceptible to erosion from sea-level rise than to flooding.

In two major cities on the Caribbean coast, Barranquilla and Cartagena, most manufacturing facilities are in highly vulnerable areas, as are 45 percent of roads in the area (with another 23 percent slightly vulnerable). In the tourist-oriented island of San Andrés, 17 percent of the land would be flooded by a meter (39 inches) of sea-level rise, especially along the northern and eastern shores where most economic activity and richest natural resources are concentrated.

In general, the Caribbean region of Colombia is projected to become drier while the southern region of the country becomes wetter.[41] Since, however, some of the major rivers' headwaters are in the southern region of the country, heavier precipitation in the south may result in increased flooding in northern river deltas. River deltas also will be at risk of increased flooding from rising sea levels.[42]

Much of Colombia's land suitable for intensive agriculture is located in the páramo, a high elevation ecosystem of valleys, plains and lakes between the forest and snow lines, where the vegetation is mostly treeless grasslands and shrub lands. While vegetation cover and forests at different altitude levels vary greatly in their ability to adapt to changing climatic conditions, the agricultural soils in the most humid areas of the páramo are particularly vulnerable.[43] This highland ecosystem, already under pressure from population growth, farming and cattle-raising, would shrink with rising temperatures and a doubling of CO_2 concentrations, potentially losing over half its current area by 2050.[44]

The intensification of droughts, desertification and soil degradation in Colombia's Caribbean region could nearly double the size of the country's northeastern desert. Another anticipated consequence of climate changes is the total loss of glacial ice within 100 years, with perhaps three-fourths lost by 2050.[45] The retreat and disappearance of glaciers will affect water availability, hydropower generation, and ecosystems, especially in the páramo.[46]

Tens of thousands of Colombians live in areas regularly affected by floods, one of the nation's

main causes of damages from natural disasters in the country. Mudslides also lead to serious loss of property and lives from time to time. For example, mudslides in 1983 left 22,000 dead and affected 200,000 people.[47] The spread and greater incidence of dengue fever, malaria and other diseases, which increase after periods of heavy rain and with diminished sanitation from contaminated waters, is a likely and serious health concern.[48] Overall, the existing ratio of damages due to natural disasters (including earthquakes as well as floods, storms, and related phenomena) to GDP in Colombia has been estimated to be greater than 10 percent.[49]

In summary, Colombia faces some of the same consequences as Caribbean islands from sea-level rise and warming, as well as its own unique set of challenges from impacts such as the ecological and economic consequences of melting glaciers at high altitudes. Given Colombia's economic, social and political challenges, most of which will be seriously exacerbated by climate change, adaptation measures to lessen the impacts of climate change may be difficult to afford.

The bottom line remains the same in Colombia as in the Caribbean islands: equitable and sustainable development will face new challenges, as sorely needed resources will be diverted to meet the rising costs of global inaction—in countries that made only the smallest contributions to the emissions that cause climate change.

APPENDIX I
MODEL RESULTS—ISLAND DETAIL

Table I-1a. Caribbean Region—Low-Impact Scenario—Island Detail—2025, 2050

		LOW IMPACT – 2025 ($US Billions)					LOW IMPACT - 2050 ($US Billions)				
	GDP ($US Billions)	Storms	Tourism	Infrastructure	TOTAL	% of Current GDP	Storms	Tourism	Infrastructure	TOTAL	% of Current GDP
Anguilla	0.12	0.00	0.00	0.00	0.00	2.3%	0.00	0.00	0.00	0.01	4.6%
Antigua & Barbuda	0.75	0.04	0.01	0.01	0.06	7.4%	0.04	0.02	0.01	0.07	9.5%
Aruba	2.35	0.00	0.02	0.01	0.03	1.1%	0.00	0.04	0.01	0.05	2.3%
Bahamas	5.79	0.18	0.04	0.02	0.24	4.2%	0.19	0.08	0.04	0.31	5.3%
Barbados	2.54	0.00	0.02	0.02	0.04	1.5%	0.00	0.03	0.04	0.07	2.9%
British Virgin Islands	0.97	0.00	0.01	0.00	0.01	1.1%	0.00	0.02	0.00	0.02	2.2%
Cayman Islands	2.20	0.23	0.01	0.00	0.25	11.1%	0.24	0.02	0.01	0.27	12.0%
Cuba	38.06	0.53	0.05	0.34	0.92	2.4%	0.55	0.09	0.67	1.31	3.5%
Dominica	0.25	0.02	0.00	0.01	0.02	9.3%	0.02	0.00	0.01	0.03	11.8%
Dominican Republic	20.52	0.20	0.07	0.29	0.56	2.7%	0.20	0.14	0.58	0.93	4.5%
Grenada	0.39	0.06	0.00	0.01	0.07	17.6%	0.06	0.00	0.01	0.08	20.5%
Guadeloupe	8.62	0.02	0.00	0.03	0.06	0.7%	0.03	0.01	0.06	0.09	1.1%
Haiti	4.38	0.03	0.00	0.24	0.27	6.2%	0.03	0.00	0.49	0.52	11.8%
Jamaica	8.77	0.07	0.04	0.19	0.30	3.4%	0.07	0.07	0.38	0.53	6.0%
Martinique	9.90	0.03	0.00	0.03	0.06	0.7%	0.03	0.01	0.06	0.10	1.0%
Montserrat	0.03	0.00	0.00	0.00	0.00	6.4%	0.00	0.00	0.00	0.00	8.0%
Netherlands Antilles	2.70	0.08	0.02	0.02	0.12	4.3%	0.09	0.04	0.03	0.15	5.7%
Puerto Rico	86.73	0.26	0.06	0.15	0.46	0.5%	0.26	0.12	0.30	0.68	0.8%
Saint Kitts & Nevis	0.36	0.05	0.00	0.00	0.06	16.1%	0.05	0.00	0.01	0.06	18.1%
Saint Lucia	0.70	0.00	0.01	0.01	0.02	2.8%	0.00	0.01	0.02	0.04	5.2%
Saint Vincent & the Grenadines	0.37	0.00	0.00	0.01	0.01	2.3%	0.00	0.00	0.01	0.02	4.7%
Trinidad & Tobago	12.61	0.00	0.01	0.09	0.10	0.8%	0.00	0.02	0.18	0.19	1.5%
Turks & Caicos	0.18	0.00	0.01	0.00	0.01	4.3%	0.00	0.01	0.00	0.02	8.7%
U.S. Virgin Islands	3.10	0.10	0.03	0.01	0.13	4.3%	0.10	0.05	0.02	0.17	5.5%
TOTAL CARIBBEAN	**$212.40**	**$1.91**	**$0.40**	**$1.47**	**$3.79**	**1.8%**	**$1.98**	**$0.80**	**$2.95**	**$5.72**	**2.7%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.
***GDP**: CTO 2004, except as noted; Cuba & Haiti, CEPAL 2007; Guadeloupe & Martinique, INSEE (National Institute for Statistics and Economic Studies, France).*
***Storms**: 17 year average (1990–2007), data from Emergency Events Database EM-DAT, using Advanced Search.*
***Tourist Expenditures**: Visitor Exports from WTTC 2007, except as noted; Dominica & Trinidad WTTC 2004; Montserrat and Turks & Caicos CTO 2004.*
***Infrastructure**: Haites et al. 2002.*

Table I-1b. Caribbean Region—Low-Impact Scenario—Island Detail—2075, 2100

		LOW IMPACT – 2075 ($US Billions)					LOW IMPACT – 2100 ($US Billions)				
	GDP ($US Billions)	Storms	Tourism	Infrastructure	TOTAL	% of Current GDP	Storms	Tourism	Infrastructure	TOTAL	% of Current GDP
Anguilla	0.12	0.00	0.01	0.00	0.01	7.0%	0.00	0.01	0.00	0.01	9.3%
Antigua & Barbuda	0.75	0.04	0.02	0.02	0.09	11.6%	0.05	0.03	0.03	0.10	13.7%
Aruba	2.35	0.00	0.06	0.02	0.08	3.4%	0.00	0.08	0.03	0.11	4.6%
Bahamas	5.79	0.19	0.12	0.06	0.37	6.4%	0.20	0.16	0.08	0.44	7.6%
Barbados	2.54	0.00	0.05	0.06	0.11	4.4%	0.00	0.07	0.08	0.15	5.8%
British Virgin Islands	0.97	0.00	0.03	0.00	0.03	3.2%	0.00	0.03	0.01	0.04	4.3%
Cayman Islands	2.20	0.25	0.03	0.01	0.28	12.9%	0.26	0.03	0.01	0.30	13.8%
Cuba	38.06	0.57	0.14	1.01	1.72	4.5%	0.58	0.19	1.34	2.12	5.6%
Dominica	0.25	0.02	0.00	0.02	0.04	14.4%	0.02	0.00	0.02	0.04	17.0%
Dominican Republic	20.52	0.21	0.21	0.88	1.30	6.3%	0.22	0.28	1.17	1.67	8.1%
Grenada	0.39	0.06	0.01	0.02	0.09	23.4%	0.07	0.01	0.03	0.10	26.2%
Guadeloupe	8.62	0.03	0.01	0.09	0.13	1.5%	0.03	0.01	0.12	0.16	1.9%
Haiti	4.38	0.03	0.01	0.73	0.76	17.4%	0.03	0.01	0.97	1.01	23.0%
Jamaica	8.77	0.08	0.11	0.57	0.76	8.6%	0.08	0.15	0.76	0.98	11.2%
Martinique	9.90	0.04	0.01	0.08	0.13	1.3%	0.04	0.02	0.11	0.16	1.6%
Montserrat	0.03	0.00	0.00	0.00	0.00	9.7%	0.00	0.00	0.00	0.00	11.3%
Netherlands Antilles	2.70	0.09	0.06	0.05	0.19	7.0%	0.09	0.07	0.06	0.23	8.4%
Puerto Rico	86.73	0.27	0.18	0.44	0.90	1.0%	0.28	0.24	0.59	1.11	1.3%
Saint Kitts & Nevis	0.36	0.06	0.01	0.01	0.07	20.0%	0.06	0.01	0.01	0.08	22.0%
Saint Lucia	0.70	0.00	0.02	0.03	0.05	7.6%	0.00	0.02	0.05	0.07	10.0%
Saint Vincent & the Grenadines	0.37	0.00	0.01	0.02	0.03	7.0%	0.00	0.01	0.03	0.03	9.3%
Trinidad & Tobago	12.61	0.00	0.02	0.26	0.29	2.3%	0.00	0.03	0.35	0.38	3.0%
Turks & Caicos	0.18	0.00	0.02	0.01	0.02	13.0%	0.00	0.02	0.01	0.03	17.3%
U.S. Virgin Islands	3.10	0.11	0.08	0.02	0.21	6.7%	0.11	0.10	0.03	0.25	7.9%
TOTAL CARIBBEAN	**$212.40**	**$2.04**	**$1.19**	**$4.42**	**$7.65**	**3.6%**	**$2.10**	**$1.59**	**$5.90**	**$9.59**	**4.5%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table I-2a. Caribbean Region—High-Impact Scenario—Island Detail—2025, 2050

		HIGH IMPACT – 2025 ($US Billions)					HIGH IMPACT – 2050 ($US Billions)				
	GDP ($US Billions)	Storms	Tourism	Infrastructure	TOTAL	% of Current GDP	Storms	Tourism	Infrastructure	TOTAL	% of Current GDP
Anguilla	0.12	0.00	0.01	0.01	0.02	12.7%	0.00	0.02	0.01	0.03	25.4%
Antigua & Barbuda	0.75	0.07	0.04	0.04	0.15	19.6%	0.10	0.08	0.09	0.26	35.3%
Aruba	2.35	0.00	0.10	0.04	0.14	6.2%	0.00	0.20	0.09	0.29	12.3%
Bahamas	5.79	0.29	0.20	0.14	0.62	10.7%	0.45	0.39	0.27	1.11	19.2%
Barbados	2.54	0.00	0.09	0.13	0.21	8.4%	0.00	0.17	0.25	0.43	16.8%
British Virgin Islands	0.97	0.00	0.04	0.01	0.05	5.6%	0.00	0.09	0.02	0.11	11.2%
Cayman Islands	2.20	0.37	0.04	0.02	0.44	19.9%	0.58	0.09	0.05	0.71	32.1%
Cuba	38.06	0.85	0.24	2.15	3.24	8.5%	1.32	0.47	4.30	6.09	16.0%
Dominica	0.25	0.03	0.00	0.03	0.06	25.6%	0.04	0.01	0.06	0.12	46.1%
Dominican Republic	20.52	0.32	0.36	1.87	2.54	12.4%	0.49	0.71	3.74	4.94	24.1%
Grenada	0.39	0.10	0.01	0.05	0.15	38.9%	0.15	0.02	0.09	0.26	66.7%
Guadeloupe	8.62	0.04	0.02	0.20	0.25	2.9%	0.06	0.03	0.40	0.49	5.7%
Haiti	4.38	0.04	0.01	1.56	1.61	36.7%	0.06	0.02	3.11	3.20	73.0%
Jamaica	8.77	0.11	0.18	1.22	1.51	17.3%	0.18	0.37	2.43	2.98	33.9%
Martinique	9.90	0.05	0.02	0.18	0.25	2.5%	0.08	0.04	0.35	0.48	4.8%
Montserrat	0.03	0.00	0.00	0.00	0.01	16.6%	0.00	0.00	0.00	0.01	29.7%
Netherlands Antilles	2.70	0.13	0.09	0.10	0.32	12.0%	0.20	0.18	0.20	0.59	21.8%
Puerto Rico	86.73	0.41	0.30	0.95	1.66	1.9%	0.63	0.61	1.90	3.13	3.6%
Saint Kitts & Nevis	0.36	0.08	0.01	0.02	0.12	32.1%	0.13	0.02	0.04	0.19	53.6%
Saint Lucia	0.70	0.00	0.03	0.07	0.10	14.9%	0.01	0.05	0.15	0.21	29.5%
Saint Vincent & the Grenadines	0.37	0.00	0.01	0.04	0.05	14.1%	0.00	0.02	0.08	0.10	28.3%
Trinidad & Tobago	12.61	0.00	0.04	0.56	0.60	4.8%	0.00	0.08	1.12	1.20	9.5%
Turks & Caicos	0.18	0.00	0.03	0.01	0.04	23.3%	0.00	0.06	0.03	0.08	46.6%
U.S. Virgin Islands	3.10	0.16	0.13	0.05	0.34	11.0%	0.25	0.26	0.10	0.61	19.7%
TOTAL CARIBBEAN	**$212.40**	**$3.06**	**$2.00**	**$9.44**	**$14.51**	**6.8%**	**$4.73**	**$4.00**	**$18.89**	**$27.62**	**13.0%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

Table I-2b. Caribbean Region—High-Impact Scenario—Island Detail—2075, 2100

	GDP ($US Billions)	HIGH IMPACT – 2075 ($US Billions) Storms	Tourism	Infrastructure	TOTAL	% of Current GDP	HIGH IMPACT – 2100 ($US Billions) Storms	Tourism	Infrastructure	TOTAL	% of Current GDP
Anguilla	0.12	0.00	0.03	0.02	0.05	38.0%	0.00	0.04	0.02	0.06	50.7%
Antigua & Barbuda	0.75	0.15	0.11	0.13	0.39	52.6%	0.22	0.15	0.17	0.54	72.1%
Aruba	2.35	0.00	0.30	0.13	0.43	18.5%	0.00	0.40	0.18	0.58	24.7%
Bahamas	5.79	0.66	0.59	0.41	1.66	28.6%	0.95	0.78	0.54	2.27	39.3%
Barbados	2.54	0.00	0.26	0.38	0.64	25.2%	0.00	0.35	0.50	0.85	33.6%
British Virgin Islands	0.97	0.00	0.13	0.03	0.16	16.7%	0.01	0.17	0.04	0.22	22.4%
Cayman Islands	2.20	0.85	0.13	0.07	1.05	47.6%	1.22	0.17	0.09	1.48	67.2%
Cuba	38.06	1.94	0.71	6.45	9.10	23.9%	2.78	0.95	8.60	12.33	32.4%
Dominica	0.25	0.06	0.01	0.10	0.17	68.8%	0.09	0.02	0.13	0.24	94.2%
Dominican Republic	20.52	0.72	1.07	5.62	7.41	36.1%	1.03	1.43	7.49	9.95	48.5%
Grenada	0.39	0.22	0.03	0.14	0.39	99.2%	0.31	0.04	0.19	0.54	137.8%
Guadeloupe	8.62	0.09	0.05	0.59	0.73	8.5%	0.13	0.06	0.79	0.98	11.4%
Haiti	4.38	0.09	0.03	4.67	4.79	109.5%	0.13	0.04	6.22	6.40	146.3%
Jamaica	8.77	0.26	0.55	3.65	4.46	50.9%	0.37	0.74	4.87	5.98	68.1%
Martinique	9.90	0.12	0.06	0.53	0.71	7.2%	0.17	0.08	0.71	0.96	9.7%
Montserrat	0.03	0.01	0.00	0.01	0.01	44.2%	0.01	0.00	0.01	0.02	60.8%
Netherlands Antilles	2.70	0.30	0.28	0.30	0.88	32.5%	0.43	0.37	0.40	1.20	44.4%
Puerto Rico	86.73	0.93	0.91	2.85	4.69	5.4%	1.34	1.21	3.79	6.34	7.3%
Saint Kitts & Nevis	0.36	0.19	0.03	0.06	0.29	79.5%	0.28	0.04	0.09	0.40	111.2%
Saint Lucia	0.70	0.01	0.08	0.22	0.31	44.2%	0.01	0.11	0.29	0.41	59.0%
Saint Vincent & the Grenadines	0.37	0.00	0.03	0.12	0.16	42.4%	0.00	0.04	0.17	0.21	56.5%
Trinidad & Tobago	12.61	0.00	0.12	1.68	1.80	14.3%	0.00	0.16	2.24	2.40	19.0%
Turks & Caicos	0.18	0.00	0.09	0.04	0.13	69.9%	0.00	0.12	0.05	0.17	93.2%
U.S. Virgin Islands	3.10	0.37	0.39	0.15	0.91	29.4%	0.52	0.53	0.20	1.25	40.3%
TOTAL CARIBBEAN	**$212.40**	**$6.98**	**$6.01**	**$28.33**	**$41.32**	**19.5%**	**$10.00**	**$8.01**	**$37.77**	**$55.78**	**26.3%**

Sources: Authors' calculations. Amounts in 2007 dollars; percentages based on 2004 GDP.

APPENDIX II
TECHNICAL NOTES ON THE MODEL

SEA-LEVEL RISE

As we explained in our Florida study, our estimates for sea-level rise under the business-as-usual case diverge somewhat from the A2 scenario as presented in the 2007 IPCC report.[50] The authors of the IPCC 2007 report made the controversial decision to exclude one of the many effects that combine to increase sea levels—the accelerated melting of the Greenland and Antarctic ice sheets caused by feedback mechanisms such as the dynamic effects of melt water on the structure of the ice sheets. Without the effects of these feedback mechanisms on ice sheets, the high end of the likely range of A2 sea-level rise is just 20 inches (.51 meters), down from approximately 28 inches (.71 meters) in the IPCC 2001 report .

Accelerated melting of ice sheets was excluded from the IPCC's projections not because it is thought to be unlikely or insignificant—on the contrary, these effects could raise sea levels by hundreds of feet over the course of several millennia—but because they are extremely difficult to estimate. Indeed, the actual amount of sea-level rise observed since 1990 has been at the very upper bound of prior IPCC projections that assumed high emissions, a strong response of temperature to emissions, and included an additional ad hoc amount of sea-level rise for "ice sheet uncertainty" (Rahmstorf 2007).

This area of climate science has been developing rapidly in the last year, but, unfortunately, recent advances were released too late for inclusion in the IPCC process (Kerr 2007a, b; Oppenheimer et al. 2007). A January 2007 article by Stephan Rahmstorf in the prestigious peer-reviewed journal *Science* proposes a new procedure for estimating melting ice sheets' difficult-to predict contribution to sea-level rise (Rahmstorf 2007).

For the A2 emissions scenario on which our high-impact scenario is based, Rahmstorf's estimates of 2100 sea-level rise range from 35 inches (.89 meters) up to 55 inches (1.4 meters), with Rahmstorf's high-end figure including an adjustment for statistical uncertainty. As with the Florida study, for the purpose of this report we use an intermediate value that is the average of his estimates, or 45.3 inches (1.15 meters) by 2100; we similarly interpolate an average of Rahmstorf's high and low values to provide an estimate of 11.3 inches (.288 meters) for 2025, 22.6 inches (.575 meters) for 2050 and 34 inches (.863 meters) for 2075.

Table II-1. Two Future Climate Scenarios for the Caribbean Region

		2025	2050	2075	2100
Annual Average Temperature Increase *(in degrees above year 2000 temperature)*					
Low-Impact	°F	0.6	1.1	1.7	2.2
	°C	0.3	0.6	0.9	1.2
High-Impact	°F	2.4	4.9	7.3	9.7
	°C	1.3	2.7	4.1	5.4
Sea-Level Rise *(above year 2000 elevation)*					
Low-Impact	in	1.8	3.5	5.3	7.1
	cm	4.5	9.0	13.5	18.0
High-Impact	in	11.3	22.6	34.0	45.3
	cm	28.8	57.5	86.3	115.0

HURRICANE DAMAGES

We followed our 2007 Florida study in calculating low- and high-impact scenario projections for hurricane damages in each year.[51] Projected increases in these damages due to sea-level rise and storm intensity were calculated for both scenarios. The following assumptions from that study (derived from the scientific literature) were used:

Greater hurricane damages due to anticipated sea-level rise: a doubling of damages per meter of sea-level rise, SRL (factor = 2^{SRL}).

Table II-2. Hurricane Damages—Sea-Level Rise Factor

Sea-Level Rise	Low-Impact				High-Impact			
	2025	**2050**	**2075**	**2100**	**2025**	**2050**	**2075**	**2100**
SLR (m)	0.0450	0.0900	0.1350	0.1800	0.2875	0.5750	0.8625	1.1500
SLR Adj Factor	1.0317	1.0644	1.0981	1.1329	1.2205	1.4897	1.8182	2.2191

Greater storm intensity is assumed to double hurricane damages when atmospheric carbon dioxide doubles (factor = $CO_2^{\text{period end}} / CO_2^{2000}$, where CO_2^{2000} = 350ppm). This factor is not applied in the low-impact scenario, only in the high-impact scenario.

Table II-3. Hurricane Damages—Storm Intensity Factor

Storm Intensity	Low-Impact				High-Impact			
	2025	**2050**	**2075**	**2100**	**2025**	**2050**	**2075**	**2100**
CO_2 (ppm)	n/a	n/a	n/a	n/a	473.4	598.9	724.5	850.0
Storm Adj Factor					1.3525	1.7112	2.0699	2.4286

The effects for the high scenario are obtained by multiplying the two factors:

Table II-4. Hurricane Damages—Climate Change Adjustment Factor

Hurricane	Low-Impact				High-Impact			
	2025	**2050**	**2075**	**2100**	**2025**	**2050**	**2075**	**2100**
Total Adj Factor	1.0317	1.0644	1.0981	1.1329	1.6508	2.5492	3.7635	5.3893
	Sea Level Rise only				Sea Level Rise x Storm Intensity Factor			

The Florida study applied additional factors to account for growth in population and per capita GDP. These were not used in this Caribbean study because we make no assumptions about economic and population growth. Future impacts are expressed in terms of the current economy (in 2007 U.S. dollars, and as percentage of 2004 GDP).

LOSS OF TOURISM

We followed the World Bank study's calculations for the aggregate percentage total loss of tourist revenue to 2080 under both the low- and high-impact scenarios.[52] These were based on more detailed estimates for (a) reduced tourism due to rising temperatures (3.4 percent and 10.5 percent, respectively), (b) reduced sea/sun tourism due to shrinking beach area (1.8 percent and 16 percent), and (c) reduced eco-tourism due to loss of coral reefs, etc. (0.2 percent and 0.6 percent). To this we added the World Bank estimate for the cost of hotel room replacement, which we calculated to be about 0.2 percent of tourist revenue in the low-impact scenario and 2 percent in the high-impact scenario.

Reduced Tourism	Low-Impact	High-Impact
Warming temperatures	3.4	10.5
Loss of beaches	1.8	15.5
Reduced dive/eco-tourism	0.2	0.6
Facility Replacement	0.2	1.7
Tourism Expenditure Loss	5.6%	28.3%

Table II-5. Reduced Tourism—Detail Factors

Source: Authors' calculations from Haites et al. (2002)

This produced a total loss of 5.6 percent of tourist revenue in 2080 in the low-impact scenario and 28.3 percent in the high-impact scenario. The World Bank figures were projected for 2080, using 2000 as the base year; our study projects costs for 2025, 2050, 2075 and 2100. We used linear interpolation (i.e., we assumed the annual change in tourist revenue losses was equal to 1/80 of the World Bank figure for 2080, and applied that loss to every year from 2000 to 2100), resulting in the following percentage losses:

Table II-6. Reduced Tourism—Net Factor

Low-Impact (5.6% to 2080)				High-Impact (28.3% to 2080)			
2025	**2050**	**2075**	**2100**	**2025**	**2050**	**2075**	**2100**
1.8%	3.5%	5.3%	7.0%	8.8%	17.7%	26.5%	35.3%

For tourism spending, we used the 2007 figures from the World Travel & Tourism Council (expressed by WTTC in 2000 dollars, which we converted to 2007 dollars using the U.S. consumer price index). These figures were not available for four countries. For two (Dominica and Trinidad & Tobago), we used WTTC 2004 figures and for the other two (Montserrat and Turks & Caicos Islands) we used Caribbean Tourism Organization (CTO) 2004 figures.[53] Both sets of figures were originally expressed in 2004 dollars and were also adjusted to 2007 dollars using the U.S. consumer price index.

INFRASTRUCTURE DAMAGES

We used the World Bank calculations and methodology for the cost of replacing buildings (residential and other, excluding tourist facilities) and infrastructure; the data were converted to 2007 U.S. dollars and applied to the islands on a per household basis. The World Bank study estimated that 19 percent of the population in 2080 would be affected in the low-impact scenario and 66 percent in the high-impact scenario.

Table II-7. Infrastructure Damages—Affected Population

Low-Impact (19% to 2080)				High-Impact (66% to 2080)			
2025	**2050**	**2075**	**2100**	**2025**	**2050**	**2075**	**2100**
5.9%	11.9%	17.8%	23.8%	20.6%	41.3%	61.9%	82.5%

The majority of countries in the World Bank study were small islands; our study extends to some additional islands with the same profile, but also three much larger islands (Cuba, Dominican Republic/Haiti, and Puerto Rico) that have substantial interior areas, at least partially at higher elevations. We made the conservative assumption that in each scenario half as many households would be affected on these three islands.

BIBLIOGRAPHY

Beven, J. (2002). "Hurricane Michelle 29 October–5 November 2001." *Tropical Cyclone Report*, from http://www.nhc.noaa.gov/2001michelle.html.

Caribbean Tourism Organization (CTO) (2004). Annual Tourism Statistical Report. St. Michael, Barbados, Caribbean Tourism Organization.

Center for Integrative Environmental Research (CIER) (2007). The US Economic Impacts of Climate Change and the Costs of Inaction. College Park, MD, Center for Integrative Environmental Research, University of Maryland.

Centro de Información Gestión y Educación Ambiental (CIGEA) (2001). Panorama Ambiental de Cuba 2000 (Cuban Environment Outlook 2000) La Habana.

Cinzano, P. (2001). "Artificial Nighttime Sky Brightness." from http://apod.nasa.gov/apod/image/0108/artificialnight_dmsp_big.gif

Cuba (2001). Primera Comunicación Nacional a la Convención Marco de las Naciones Unidas sobre Cambio Climático (First National Communication to the United Nations Framework Convention on Climate Change).

ECLAC (CEPAL) (2007a). Addressing the impacts of climate change: Focus on the Caribbean, Economic Commission for Latin America and the Caribbean.

ECLAC (CEPAL) (2007b). Anuario estadístico de América Latina y el Caribe Economic Commission for Latin America and the Caribbean.

Haites, E., D. Pantin, M. Attzs, J. Bruce and J. MacKinnon (2002). Assessment of the Impact of Climate Change on CARICOM Countries. Environmentally and Socially Sustainable Development — Latin America and Caribbean Region, The World Bank.

Instituto de Hidrología Meteorología y Estudios Ambientales (IDEAM) (2001a). Colombia Primera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático.

Instituto de Hidrología Meteorología y Estudios Ambientales (IDEAM) (2001b). Executive Summary of Colombia's First National Communication to the United Nations Framework Convention on Climate Change.

Instituto de Hidrología Meteorología y Estudios Ambientales (IDEAM) (2001c). Vulnerabilidad y Adaptación de la Zona Costera Colombiana al Ascenso Acelerado del Nivel del Mar. Bogota, Ministerio del Medio Ambiente.

Instituto de Investigaciones Marinas y Costeras (INVEMAR) (2004). Informe del Estado de los Ambientes Marinos y Costeros en Colombia.

Intergovernmental Panel on Climate Change (2001). *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge UK, Cambridge University Press.

Intergovernmental Panel on Climate Change (2007a). *Climate Change 2007: Summary for Policy Makers. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK, Cambridge University Press.

Intergovernmental Panel on Climate Change (2007b). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, U.K., Cambridge University Press.

Kerr, R. A. (2007a). Pushing the Scary Side Of Global Warming. *Science.* 316: 1412–1415.

Kerr, R. A. (2007b). Scientists Tell Policymakers We're All Warming the World. *Science*. 315: 754–757.

Lawrence, M. B. and H. D. Cobb. (2005, January 7, 2005). "Hurricane Jeanne." *Tropical Cyclone Report,* from http://www.nhc.noaa.gov/2004jeanne.shtml.

Lise, W. and R. S. J. Tol (2002). "Impact of Climate on Tourist Demand." *Climatic Change* 55: 429–449.

Nagy, Caffera and Aparicio-Barrenechea (2006). Understanding the potential impact of Climate Change and Vulnerability in Latin America and the Caribbean.

National Oceanic & Atmospheric Administration. (2007, October 22). "Ocean and Coastal Management in Puerto Rico." *Ocean and Coastal Resource Management*, from http://coastalmanagement.noaa.gov/my state/p_rico.html.

Oppenheimer, M., B. C. O'Neill, M. Webster and S. Agrawala (2007). CLIMATE CHANGE: The Limits of Consensus. *Science*. 317: 1505–1506.

Rahmstorf, S. (2007). A Semi-Empirical Approach to Projecting Future Sea-Level Rise. *Science*. 315: 368–370.

Stanton, E. A. and F. Ackerman (2007). Florida and Climate Change: The Costs of Inaction. Medford, MA, Tufts University Global Development and Environment Institute and Stockholm Environment Institute—US Center.

The World Bank (2000). HIV/AIDS in the Caribbean: Issues and Options. A Background Report Human Development and Sector Management Unit Latin America and the Caribbean Region. The World Bank.

Toba, N. (2007). Economic Impacts of Climate Change on Caribbean Community — DRAFT. Environmentally and Socially Sustainable Development — Latin America and Caribbean Region, The World Bank.

Trotz, U. O. D. (2008). "Climate Change and Development in the Caribbean Sub-Region." Caribbean Community Climate Change Center

U.S. Geological Survey. (2006). "Fact Sheet (Puerto Rico) FS-051-96," from http://pubs.usgs.gov/fs/FS-051-96/.

United Nations Environment Programme (PNUMA) (2005). Perspectivas del medio ambiente en el Caribe. Nairobi, United Nations Environment Programme.

Uyarra, M., I. M. Cote, J. A. Gill, R. R. T. Tinch, D. Viner and A. R.Watkinson (2005). "Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states." *Environmental Conservation* 32(1): 11–19.

Vergara, W. (2005). Adapting to Climate Change: Lessons Learned, Work in Progress, and Proposed Next Steps for the World Bank in Latin America. *Latin America and Caribbean Region, Environmentally and Socially Sustainable Development Department*. The World Bank.

Vergara, W. (2007). Visalizing Future Climate in Latin America: Results for the application of the Earth Simulator. The World Bank.

Wilkinson, C. and D. Souter (2008). Status of Caribbean coral reefs after bleaching and hurricanes in 2005. Townsville, Australia, Global Coral Reef Monitoring Network–Reef and Rainforest Research Center.

World Rainforest Movement. (2001). "The Colombian Chocó: A megadiverse region in a megadiverse country . . . for how long?" from http://www.wrm.org.uy/bulletin/44/Colombia.html.

World Travel and Tourism Council (WTTC) (2004). The Caribbean: The Impact of Travel & Tourism on Jobs and the Economy.

World Travel and Tourism Council (WTTC) (2008). "Tourism Satellite Accounting Tool—Visitor Exports by country in 2007." from http://www.wttc.travel/eng/Tourism_Research/Tourism_Satellite_Accounting_Tool/.

World Wildlife Fund. (2001). "Chocó-Darién moist forests (NT0115)." from http://www.wwfus.org/wildworld/profiles/terrestrial/nt/nt0115_full.html.

Zapata Marti, R. (2006). Los efectos de los desastres en 2004 y 2005: la necesidad de adaptacion de largo plazo. *Estudios y perspectivas*, CEPAL.

NOTES

1 IPCC (2007a).

2 Though the regional average per capita GDP among the Caribbean island nations and dependencies is above $5,000 in 2007, more than 80 percent of the region's population of roughly 40 million lives in countries whose per capita GDP is below that figure. There is significant inequality both within and between individual Caribbean countries.

3 For Caribbean nations' debt burden see the World Bank's Development Data and Statistics, "Global Development Finance," http://www.worldbank.org.

4 "Higher prevalence rates are found only in sub-Saharan Africa, making the Caribbean the second-most affected region in the world." http://www.avert.org/caribbean.htm. See also The World Bank (2000).

5 Wilkinson and Souter (2008).

6 WTTC (2004) , amounts in 2004 dollars.

7 Lise and Tol (2002).

8 Uyarra et al. (2005).

9 PNUMA (2005).

10 For Caribbean nations' emissions of greenhouse gases see UNDP (2007) Human Development Report 2007/2008. Table 24 "Carbon dioxide emissions and stocks." http://www.undp.org.

11 Trotz (2008); ECLAC (2007a).

12 Haites et al. (2002). After the publication of the IPCC's Fourth Assessment Report (2007b), the World Bank commissioned an update to the Haites study, with completion expected in 2009. The draft of the update available at the time of this writing (Toba 2007) did not include key features such as high and low climate impact scenarios. The CARICOM (Caribbean Community and Common Market) countries in that study included the islands of Antigua & Barbuda, The Bahamas, Barbados, Dominica, Grenada, Jamaica, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago plus the continental countries of Belize and Guyana (Haiti and Monserrat became members of CARICOM after the World Bank study was conducted). For Florida, see Stanton and Ackerman (2007).

13 Our report includes the 10 islands in the World Bank study and these 14 additional island countries or dependencies: Anguilla, Aruba, British Virgin Islands, Cayman Islands, Cuba, Dominican Republic, Guadeloupe, Haiti, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Turks & Caicos and U.S. Virgin Islands.

14 We have omitted some impact categories included in Haites et al. (2002), for which the monetary estimates were very small.

15 The data come from the EM-DAT database compiled by the Centre for Research on the Epidemiology of Disasters (CRED), Université Catholique de Louvain, Brussels, Belgium. These data may understate actual storm damages, but we were unable to explore other complementary sources in greater detail within the scope of this report.

16 WTTC (2008).

17 Geometry dictates that larger islands have a smaller fraction of their land area as coastline compared to smaller islands.

18 ECLAC, 25 November 2004. "Hurricane season in the Caribbean causes more than US$2.2 billion in losses." http://www.eclac.org/cgi-bin/getProd.asp?xml=/prensa/noticias/comunicados/1/20371/P20371.xml&xsl=/prensa/tpl-i/p6f.xsl&base=/prensa/tpl-i/top-bottom.xsl.

19 Lawrence and Cobb (2005).

20 Cinzano (2001).

21 http://www.gobierno.pr/GPRPortal/Inicio/PuertoRico/.

22 Government Development Bank for Puerto Rico, Puerto Rico Fact Sheet (http://www.gdb-pur.com/economy/factsheet/documents/PR.Eco.Fact.Sheet.pdf).

23 NOAA (2007). See also the on-line documents from the May 8-10, 2007 roundtable of experts "Facing the Consequences of Climate Change in Puerto Rico," organized by The University of Puerto Rico at Mayagüez (UPRM): http://academic.uprm.edu/abe/ClimateChangePR.

24 University of Arizona, Department of Geosciences, Environmental Studies Laboratory http://geongrid.geo.arizona.edu/arcims/website/slrus48prvi/viewer.htm), has mapped the effect of sea-level rise between 1 and 6 meters.

25 CIER (2007).

26 USGS (2006) documents an example of the interplay and destructive feedback cycle between human coastal development and accelerated shoreline erosion rates near Rincón, in western Puerto Rico, noting how stabilization responses via structures like seawalls, "may result in the rapid destruction of local beaches".

27 Cuban Census, Table II.4 (www.cubagov.cu/oltras_info/censo/publacion.htm).

28 Climate descriptions (prior to 2001) are based on Cuba (2001).

29 Beven (2002) "Michelle was the strongest hurricane to hit Cuba since Hurricane Fox in October 1952. Preliminary reports from the government of Cuba indicate widespread damage over the central and western parts of the island, with the provinces of Matanzas, Villa Clara, and Cienfuegos the hardest hit. Ten thousand homes were reported destroyed with another 100,000 others damaged. Additional damage occurred to as yet uncounted businesses and other structures. Severe damage was also reported to the sugar cane crop near the path of the storm." Five deaths were reported.

30 Agence France-Presse, Havana, Nov 8, 2007, reported "[t]he worst flooding in 40 years in Cuba has left one person dead and almost 500 million dollars in damages, authorities said in a statement published Thursday." http://www.reliefweb.int/rw/rwb.nsf/db900sid/KHII-78S83N?OpenDocument.

31 Cuba (2001).

32 CIGEA (2001).

33 UNCTAD/WTO, "International Trade Statistics 2001-2005," http://www.intracen.org/tradstat/sitc3-3d/er192.htm.

34 See http://www.elnuevoherald.com/noticias/america_latina/cuba/story/177741.html. 30 new hotels were announced to be built by 2010, aiming to increase hotel rooms from 46,000 to 56,000 for international tourists. March 20, 2008, EFE. Or: http://www.sun-sentinel.com/news/local/cuba/sfl-0321havanadaily,0,6327367.column. "Cuba hopes 10,000 new hotel rooms will attract tourists", Ray Sanchez, March 21, 2008.

35 For Cuban GDP we use the national accounts published by ECLAC (2007b).

36 INVEMAR (2004).

37 World Wildlife Fund (2001); World Rainforest Movement (2001).

38 Vergara (2007). World Bank (www.worldbank.org "Colombia Data Profile").

39 Bladex, The Latin American Export Bank (http://www.blx.com "Colombia").

40 IDEAM (2001c). See also the IDEAM (2001b); IPCC (2007a Chapter 13).

41 Nagy et al. (2006).

42 IPCC (2001 Chapter 14); Vergara (2005).

43 More than half of the páramo is located in Colombia.

44 IDEAM (2001a).

45 IDEAM (2001a).

46 IPCC (2007a Chapter 13).

47 Zapata Marti (2006).

48 IPCC (2007a Chapter 13).

49 Nagy et al. (2006).

50 Stanton and Ackerman (2007).

51 Stanton and Ackerman (2007).

52 Haites et al. (2002).

53 CTO (2004).

PHOTO CREDITS

Cover (top) iStockphoto; (bottom) Photodisk
Inside front cover Central Intelligence Agency
Page 2 Noel Hendrickson/Getty Images
Page 3 iStockphoto
Page 4 iStockphoto
Page 5 iStockphoto
Page 6 iStockphoto
Page 8 iStockphoto
Page 9 iStockphoto
Page 10 iStockphoto
Page 11 Sexto Sol/Getty Images
Page 13 Amanda Clement/Getty Images
Page 14 iStockphoto
Page 16 iStockphoto
Page 18 iStockphoto
Page 19 iStockphoto
Page 21 iStockphoto
Page 22 iStockphoto
Page 23 iStockphoto