The GraceKennedy Foundation Lecture 2015

Why Climate Demands Change

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GraceKennedy Foundation

Published in February 2015
by the GraceKennedy Foundation
73 Harbour Street, Kingston
Jamaica, West Indies
Telephone: (876) 922-3440-9 Ext. 3540/1

ISBN 978-976-8041-33-3 (e-book)

Printed in Jamaica by
The Phoenix Printery Limited

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Acknowledgements

I wish to acknowledge those who have contributed to this lecture. I am grateful to:

- My family (dad, mom, Yvette, Amanda, Melanie, William, siblings and other extended family) for their unswerving support and constant encouragement.
- The Climate Studies Group, Mona for research assistance, especially Ms Felicia Whyte, and for being a place to bounce ideas and do research.
- The GraceKennedy Foundation and its chair, Professor Emerita Elsa Leo-Rhynie, for the honour.
- Caroline Mahfood, the Executive Director of the GraceKennedy Foundation for guidance and support.
- Charmaine McKenzie, for patience and for her skills at editing.
- The members of the UWI community for their encouragement and constructive criticism.
- The wider circle of friends, colleagues and communities, for honing perspective.

It is my hope that this lecture will contribute in some way to the regional effort to build climate resilient societies.

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Abbreviations

A1	High Emissions Scenario generated by the IPCC
A1B	Medium Emissions Scenario generated by the IPCC
A2	High Emissions Scenario generated by the IPCC
AOSIS	Alliance of Small Island States
API	Agricultural Production Index
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
B1	Low Emissions Scenario generated by the IPCC
B2	Low Emissions Scenario generated by the IPCC
CARICOM	Caribbean Community
CARSEA	Caribbean Sea Ecosystem Assessment
CCCCC or 5Cs	Caribbean Community Climate Change Centre
CIMH	Caribbean Institute for Meteorology and Hydrology
CSGM	Climate Studies Group, Mona
DTR	Diurnal Temperature Range
ECLAC	Economic Commission for Latin America and the Caribbean
GCMs	Global Climate Models
GDP	Gross Domestic Product
GHGs	Greenhouse gases
JPS	Jamaica Public Service Company Ltd.
NAH	North Atlantic High
PIOJ	Planning Institute of Jamaica
PRECIS	Providing Regional Climates for Impact Studies
RCMs	Regional Climate Models
RCPs	Representative Concentration Pathways
SAMOA	SIDS Accelerated Modalities of Action
SPI	Standardized Precipitation Index
SRES	Special Report on Emissions Scenarios
SST	Sea Surface Temperature
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USACE	U.S. Army Corps of Engineers

The GraceKennedy Foundation and GraceKennedy Foundation Lectures

The establishment of the GraceKennedy Foundation in 1982, in celebration of the company's 60th anniversary, has proven to be one of the most significant contributions that GraceKennedy has made to national development.

The vision of the Foundation is to have a positive impact on the quality of people's lives. It does this by focussing its assistance on two main areas: the environment and education. This is accomplished primarily through the provision of grants to charitable organizations; the scholarship and bursary programme; the funding of two Professorial Chairs at The University of the West Indies and the Annual Lecture Series.

This year's Lecture helps to highlight our longstanding commitment to preserving and protecting the environment. In 1982 we established the James Moss-Solomon Snr. Chair in Environmental Management, which has been integral in fostering research, innovation and leadership in this important field. Over the past two years the parent company has partnered with the Foundation to contribute $1m annually to the UWI Plastic Bottle Separation and Recovery Project. The funding is used not only for the UWI's initiatives but also to introduce recycling to our subsidiaries located in Kingston as we foster a culture of environmentally-conscious corporate citizenship.

We are aware that much more can be done and our hope is that the Lecture will be a springboard for further change, not only at GraceKennedy but throughout Jamaica and across the Caribbean region. We are confident that this Lecture will continue in the tradition of previous Lectures and will become an invaluable resource for all who seek a deeper understanding of national issues.

Copies of the book are distributed to schools and public libraries across the island, an e-book version is available online at www.gracekennedy.com, and the Lecture is streamed live via our YouTube channel in the hope that its reach will extend beyond those present at its delivery.

The Foundation hopes that this Lecture will generate much discussion, debate and ultimately positive change to our beautiful island, Jamaica.

Caroline Mahfood
Secretary/Executive Director
GraceKennedy Foundation

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The GraceKennedy Foundation Lecture, 2015
WHY CLIMATE DEMANDS CHANGE

The concept which led to the introduction, in 1989, of the GraceKennedy Lectures was an acknowledged need to use this medium to stimulate change in a variety of areas; positive change which would benefit individuals, communities, the society and indeed the world. The past 26 lectures have informed and challenged us, have recommended strategy and action and the 2015 Lecture, “Why Climate Demands Change”, addresses a phenomenon which not only demands our urgent attention but which is an issue of both local and global significance.

Our lecturer, Professor Michael Taylor, locates the issues associated with climate change within the context of the Caribbean and Jamaica in particular. The argument that climate demands change is based on an *inherent climate sensitivity* which small islands possess and which makes the impact of climate variations much greater than it is for larger countries. In the past, this impact has been positive for Jamaica, as the expected climate variability facilitates traditional economic activity such as agriculture and tourism. Reliance on the seasonal nature of Jamaica’s climate, however, means that change can alter the country’s inherent sensitivity, transforming it into what Professor Taylor describes as an *emerging vulnerability* to ongoing climate variations. This threatens the country’s *future sustainability* in the face of projected climatic changes.

Urgent priorities for Jamaica and the Caribbean in light of the danger posed by the vulnerability and the threat to sustainability are identified by Professor Taylor and they challenge us, at all levels of society, to change: our attitudes, our approaches and our actions relating to climate change and its issues. Consideration of vulnerabilities attributable to climate change and incorporation of strategies critical to ensuring national and regional sustainability are vital in the formulation of development plans and ought to be priorities at all levels.

Professor Taylor is passionate about this issue and he is ideally suited to inform and challenge us. His research provides us with interesting insights into how climate is connected to water, our health, and the agriculture and tourism sectors. The focus has been on determining, among other issues, how climate change impacts the economy, infrastructure, lifestyle and health of Caribbean nations and includes investigations on tropical storm modelling, sustainable water management, and incorporating climate change into agricultural planning. Of special interest is his work on the link between climate change and dengue, through the vector mosquito. Although dengue seemed to be under control in the 1980s, increased incidence since then may well be traced to a link between climate change and increasing numbers of the *Aedes aegypti* mosquito, which coincidentally also spreads the chikungunya virus.

Professor Taylor is a graduate of Campion College and The University of the West Indies, Mona Campus, where he obtained First Class Honours in his Bachelor's degree in General and Environmental Physics. Graduate work at the University of Maryland resulted in Master's and Doctoral degrees. Returning to his *alma mater* in 1999, Professor Taylor joined the faculty of the UWI as a Lecturer and was later promoted to Senior Lecturer and appointed Head of the Department of Physics in 2009. His professorial appointment came in 2013. Since 2007, he has been the Director of the Climate Studies Group, Mona (CSGM), a multi-country collaborative initiative that comprises a team of Physics lecturers who study climate variability and its impact on short-term changes in Caribbean climate. The CSGM serves as a central repository for opinion, analysis and expertise on climate change science and is widely regarded as a national and regional research entity to be consulted on matters related to the science of climate change. It is also a training ground for emerging regional climate scientists. Based on their research and analysis of data, the CSGM provides governments and private sector interests in the Caribbean with predictive models of regional climate several decades into the future, and so facilitates informed, efficient and effective planning.

Professor Taylor's research has contributed to fundamental theories on Caribbean climate variability and his work is widely published and frequently cited. He has also authored workbooks for teaching introductory level courses in Physics and sits on several regional scientific steering committees including the CLIVAR/VAMOS programme, a panel of 12 international experts who oversee the science programme for the World Climate Research Programme's Variability of the American Monsoon System. He has also organized several regional conferences and workshops on climate change.

A well-rounded individual, Professor Taylor has a great love for the arts and music. He is comfortable playing steel pan and at the keyboard of the piano and organ. His artistic talent was brought to the fore when he collaborated with his two brothers in writing the 1999 Pantomime "Baggarags". He is an active member of his church community and is the Director of the Bethel Youth Summer Employment Programme where he initiated an annual summer employment programme for 70 tertiary and high school students; this programme has been in operation for over 12 years.

It is no wonder that Professor Taylor is so well-rounded. He has been blessed with at least three excellent mentors: the first two are his parents who have been exemplary role models for him. His mother, Ann, encouraged his love of the arts; and we at the GraceKennedy Foundation recall the excellence of the Lecture delivered by his father Reverend Dr. Burchell Taylor in 1992 on Morality and Community. It is most satisfying to have the next generation continue the tradition of excellence. His other mentor and role model has been Nobel Prize winner and UWI Professor, Anthony Chen, who has encouraged and counselled him over the course of his academic career.

Professor Taylor has received a number of honours and awards. Internationally, he was the recipient in 1999 of the American Meteorological Society Global Change Scholar Award; in 2004 of the START International Young Scientist Award and in 2008, the Third World Academy of Science/Caribbean Academy of Science Young Scientist Award. Nationally, in 2005 he received the Scientific Research Council Young Scientist/Technologist Award. He has won the awards from the UWI Mona Faculty of Pure and Applied Sciences for Teaching and for Best Publication on four occasions and the award for Most Outstanding Research Activity in that Faculty twice. In 2012 he was named the Faculty's Most Outstanding Researcher. In 2013, the Council of the Institute of Jamaica awarded Professor Taylor the Silver Musgrave Medal for outstanding merit in the field of science.

Interviewed in 2009 by Petre Williams, Environment Editor for the *Jamaica Observer*, Professor Taylor identifies the source of his commitment:

> I will probably go back to my faith and suggest that we need to be good stewards of the environment. A part of stewardship is the responsibility to care for and to preserve and to protect and in a sense I see what I am doing as a small contribution to doing that. I would couple that, of course, with my interest in science.

The GraceKennedy Foundation is pleased and honoured to have Professor Michael Taylor increase our knowledge of the impact of climate change and variability on our lives and to impress on us the urgency of action to overcome our vulnerability in this regard.

Elsa Leo-Rhynie, CD, PhD
Chair, GraceKennedy Foundation
January 2015

Michael A. Taylor

THE LECTURE

Prologue
The calm before the storm

Climate change represents the gravest threat to survival and viability of small island states. – **S**IDS **A**ccelerated **M**odalities of **A**ction (SAMOA) Pathway

A number of recent extreme climatic events have helped to spark popular interest in and focus attention on climate change. Globally, these include the abnormally frigid winter in North America associated with the polar vortex in 2013–2014, superstorms Sandy (2012) in the North Atlantic and Haiyan (2013) and Nuri (2014) in the Pacific; the extreme floods in central Europe in 2013, the extreme summer temperatures in Australia in 2013 and the severe drought in east Africa in 2011–2012. Closer to home, the 2013 Christmas Day rains in the southeastern Caribbean, the prolonged region-wide drought of 2010, the drought of 2014 over the northwest Caribbean, and hurricanes Sandy (2012) and Tomás (2012) stand out. The events were notable not just because of their intensity but also because of the magnitude of the impact they had on life and livelihoods both during and after the event. In many cases – and this is particularly true of the Caribbean region – the impact was widespread and long lasting, and retarded economic development (see Box 1).

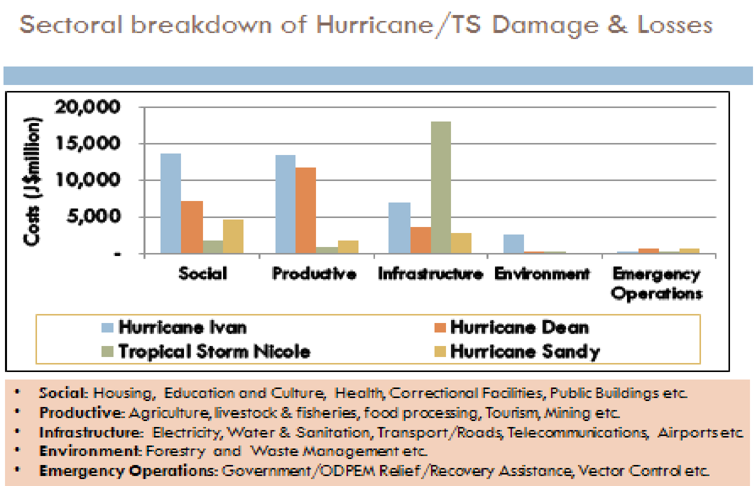
Some of the questions being asked as part of the current discussions on climate change include:

- Are the climate patterns we are now seeing part of a new and emerging trend? If so, what has changed or is changing to cause the new climate regime?
- Will the changes in climate continue into the future? How will future changes impact how we live and go about our daily lives?
- Is there anything we can do to halt the changes seen or do we just have to live with them? What can we do in response to the kind of climate patterns currently being seen or likely to be seen in the future?

In this book I first attempt to *simply answer the questions* using, as best as possible, the Caribbean as the reference point. So, the book examines whether the climate patterns of the Caribbean are in fact changing, whether they will continue to change, and whether they are consistent with changes seen in other parts of the world. Second, I attempt to establish *why answering* *these questions* is important for the Caribbean region. In this regard, the book also examines the peculiar role that climate plays in the lives of Caribbean people; how changes in climate impact the Caribbean way of life; why understanding the current and future changes in climate are important for development in the Caribbean; and what presently characterizes or should characterize the Caribbean response to changing climate patterns.

Box 1: The Cost of Climate

The diagram below shows sectoral estimates of damage and loss from some recent hurricanes and tropical storms which affected Jamaica. The costs can be significant per event but may vary in how they are distributed. The direct cost of damage, the associated repair and recovery costs and the 'downtime' all contribute to a general decline in economic performance during and after an event.



PIOJ Outlook after Hurricane Sandy: "Given the damage and loss associated with the passage of Hurricane Sandy, GDP projections were revised downwards. Real GDP is projected to contract by 0.1 per cent for fiscal year 2012/13, instead of the initial projection of growth of 0.3 per cent. This revision incorporates the adverse impact on output levels, production time as well as the damage to infrastructure. Also incorporated are developments within the international and domestic environments." (Planning Institute of Jamaica (PIOJ) 2013).

The book attempts to contribute to the understanding of climate change and its manifestations in the Caribbean region, and to use that understanding to advocate for a change in our approach to climate. A change in approach is necessary if the change in climate is established as true for the region. The book, however, also facilitates a brief review of how well the region is doing in its response to climate change given that almost two decades have now past since some of the first regional responses to the phenomenon.

Climate change cannot be discussed without heavily relying on the science of it. Every attempt is made to explain the science in terms which are simple but which do not compromise the accuracy, complexity and intended messages of the science. I encourage you, the reader, to embrace the science and the scientific terminology, and use them as an aid (as opposed to a deterrent) for exploring the associated issues surrounding climate change. Where necessary, explanatory boxes (such as Box 1) are offered to enhance understanding. To a great extent, regional science (that is, science about and emanating from within the region) is relied on, particularly since 'scale' is an important concept when considering climate change within the context of the small island states of the Caribbean. The regional science efforts of the past two decades have been beneficial to the 'downscaling' of global climate ideas, messages and concepts. In that regard, the role, importance and contribution of science and the regional science effort to Caribbean development is also an underlying theme and intended take-away, even if not explicitly stated.

Jamaica is often (but not solely) used to illustrate many of the points made in this book. You will, nevertheless, find that many of the conclusions drawn are applicable across the region due to the commonalities of location and lifestyle.

The book is structured as follows: Chapter 1 sets a context by explaining what is meant by climate change and to what it is attributable. The chapter also makes the case for why climate demands special attention in the Caribbean. Chapter 2 makes the case that the climate of the Caribbean is already changing and that as it is doing so, so too is the region's vulnerability to climate. Chapter 3 examines the future climate of the region and contemplates the future sustainability of the Caribbean in the absence of any deliberate response. The final chapter, Chapter 4, examines the region's response – what it is and what it could or should be.

Chapter 1
Climate in our bones
Inherent Sensitivity

The Caribbean is inherently climate sensitive – who we are and how we live is inextricably linked to climate.

The Climate Context

A full discussion of the science of why climate is changing is not possible given the limitations of this book. However, a good understanding of what is meant by climate change (versus, for example, climate variability) and some of the associated scientific issues is important and necessary for the later discussions in this and other subsequent chapters. In lieu of an extensive scientific discourse, four statements about climate change are offered and supported by scientific explanations. The four statements represent important scientific 'take-aways' which must be borne in mind when considering climate change in general and specifically in the context of the Caribbean.

Science Take-Away One: *There are distinctions to be made between weather, climate, climate variability and climate change.*

The first distinction to be made is between weather and climate. Whereas weather can be thought of as the day-to-day variations in climatic variables (for example, rainfall, temperature, humidity and wind), climate takes into account those variations over periods of time. Climate can be defined as average weather at a given location over a period of time; that is, it describes the average patterns in the climatic variables measured at a particular place over 'long' periods of time including seasons, years, and even longer.

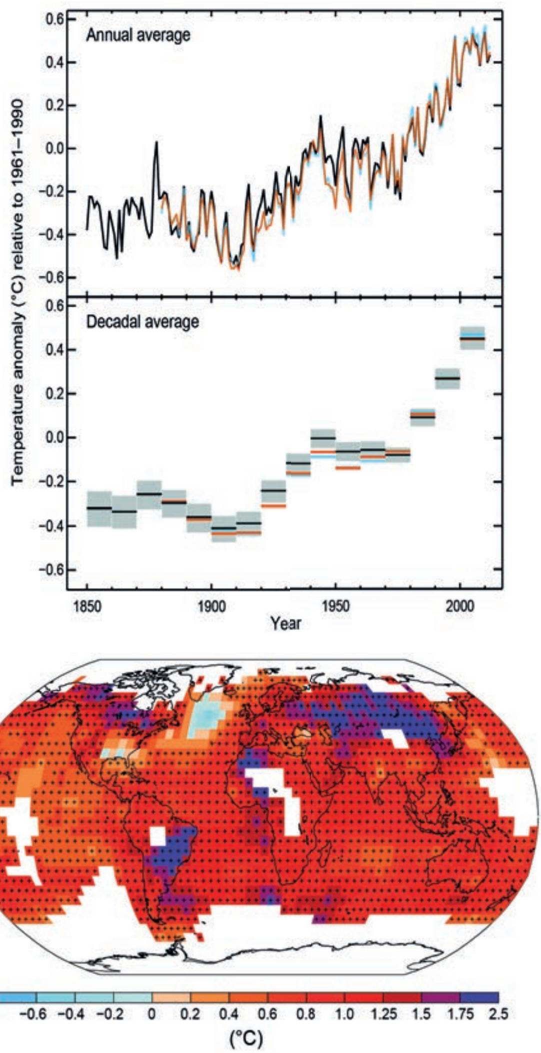
There is, similarly, a distinction to be made between climate variability and climate change. 'Short-term' (year-to-year, groups of years and even decadal) variations in climate variables are referred to as climate variability. For example, an examination of the average warming of the entire earth (land and ocean) over time (figure 1) shows that some years or even some groups of years are hotter or colder than others. In figure 1, adjacent peaks do not attain the same height. In comparison, 'climate change', is used to refer to large-scale and long-term shifts in the planet's climate.

Climate change occurs over multiples of decades and longer. In figure 1 it is represented by the distinct upward slant (or the linear trend) over the last one hundred years.

Figure 1

Top: Observed annual and decadal global mean surface temperature anomalies from 1850 to 2012 relative to the mean of 1961–1990. **Below:** Map of the observed surface temperature change from 1901 to 2012.

Source: IPCC (2013)



There are many things that can cause climate variability. (The causes of climate change are discussed below). For example, the El Niño[1] phenomenon is a known driver of climate variability in the Caribbean region. During the year of its onset and peaking, it decreases summer rainfall and hurricane activity across the region, often leading to drought. However, in the first half of the following year when its signal is declining, the pattern is reversed and the region is predisposed to flooding. Most of the known causes of climate variability have a cycle associated with them, which means that the climate variations that they induce are similarly regular and, to a certain extent, predictable. For example, an El Niño event usually has a cycle of appearance of three to six years.

Science Take-Away Two: *Global warming and climate change are not one and the same.*

The upward linear trend in the mean surface temperatures of the Earth seen in the last century and represented in figure 1 is referred to as global warming. It is the primary manifestation of climate change. The Earth has warmed by approximately 0.85°C between 1880 and the present. When the Earth warms, however, other changes are induced in the global Earth–atmosphere–ocean system. The term 'climate change' is used to capture both the warming phenomenon and the other manifestations of change. Table 1 lists six changes that have been observed globally that provide evidence of climate change over the last century, as reported in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change[2] (IPCC). It is the first four changes that are later examined in this book to provide evidence of a climate change signal in the Caribbean.

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1 El Niño refers to an abnormal warming (by a few degrees) of the sea's surface in the central and east-central equatorial Pacific. When an El Niño event occurs, the warming normally peaks during the northern hemisphere winter months and lasts for about a year.

2 The Intergovernmental Panel on Climate Change (IPCC) is an international scientific body under the auspices of the United Nations (UN). It was established in 1988 to review and assess the most recent scientific, technical and socioeconomic information produced worldwide relevant to the understanding of climate change.

Table 1

Six manifestations of climate change

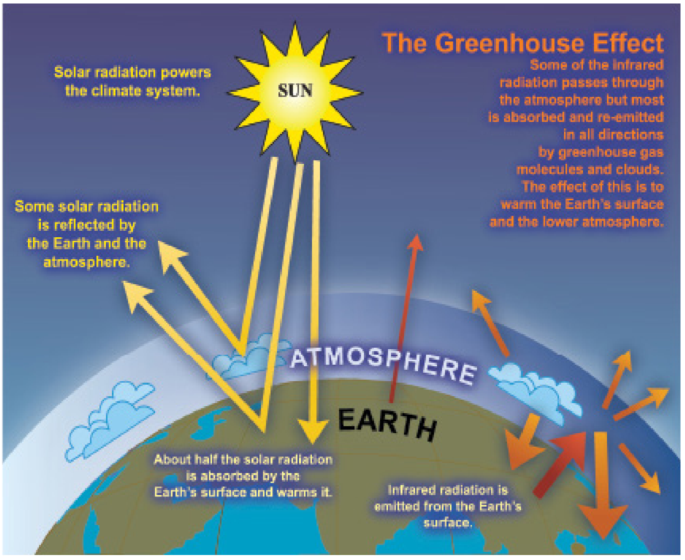
Higher temperatures	The globally-averaged, combined land and ocean surface temperature have warmed by approximately 0.85°C over the period 1880 to 2012.
Changing rainfall	Average Northern Hemisphere precipitation over the mid-latitude land areas has increased since 1901. There is lower confidence in trends for other area-averaged latitudes because of, among other things, limited data of sufficient length.
Sea level rises	The rate of sea level rise since the mid-nineteenth century has been greater than the mean rate observed during the previous two millennia. Over the period 1901 to 2010 global mean sea level rose by 0.19 m.
More extreme events	Changes in many extreme weather and climate events have been observed since about 1950. For example, it is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale. It is likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia. There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The frequency or intensity of heavy precipitation events has likely increased in North America and Europe.
Ocean acidification	Since the beginning of the Industrial Revolution, the pH of surface ocean waters has fallen by 0.1 pH. This is equivalent to an increase in acidity by approximately 30%.
Retreating glaciers, shrinking ice sheets, changing snow cover	Glaciers have continued to shrink almost worldwide, and the Greenland and Antarctic ice sheets have been losing mass over the last two decades. Arctic sea ice and Northern Hemisphere spring snow cover have continued to decrease in extent.

Science Take-Away Three: *Human beings are the primary driver of climate change.*

There are a number of natural factors that can cause the Earth's climate to change, including (i) changes in the Earth's orbit around the Sun, which have been responsible for cold glacial periods or 'ice ages' in the past; (ii) changes in the amount of explosive volcanic activity which temporarily alters atmospheric gas concentrations; and (iii) changes in the surface characteristics of the Earth. There is, however, overwhelming evidence that the global warming seen over the past century is not accounted for by these natural factors but rather by human influence. The IPCC (2013) notes that "it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century".

Box 2: Warming the Planet

As illustrated in the diagram below, the sun radiates energy. Approximately one third of the solar energy that reaches the top of Earth's atmosphere is reflected directly back to space, while the remaining two-thirds is absorbed by the Earth's surface and to a lesser extent by the atmosphere. The Earth, in turn, radiates its absorbed energy back to space, much of which is absorbed by greenhouse gases in the atmosphere and reradiated back to Earth. By so doing, the surface of the Earth is further warmed. The whole process is called the greenhouse effect. Without the natural greenhouse effect, the average temperature at the Earth's surface would be too cold to facilitate life as we know it. Unfortunately, the effect of human activities, primarily the burning of fossil fuels and clearing of forests, is to intensify greatly the natural greenhouse effect, and cause global warming.

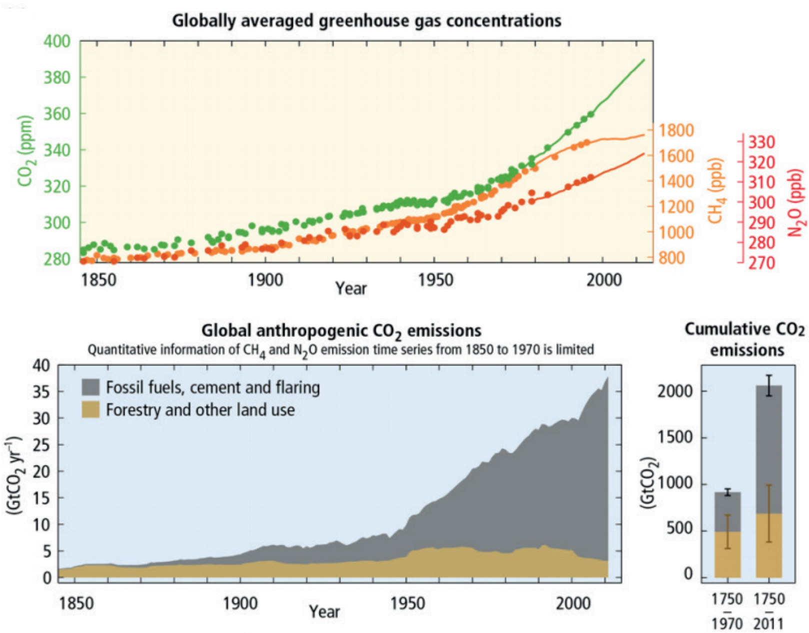


Human beings are influencing the Earth's climate by changing the concentration of greenhouse gases (GHGs) in the atmosphere and enhancing the greenhouse effect (Box 2). Three of the most important greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2). The amount of CO_2, CH_4 and NO_2 in the atmosphere has increased by approximately 40%, 150% and 20% respectively since the Industrial Revolution (figure 2, top panel). The increase in CO_2 is particularly significant because of the long residence time of CO_2 in the atmosphere – 1000 years (compared to 10 years for methane, for example).

Figure 2

Top: Atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2, top line), methane (CH_4, middle line), and nitrous oxide (N_2O, bottom line) determined from ice core data (dots) and from direct atmospheric measurements (lines). **Bottom:** Global anthropogenic CO_2 emissions from forestry and other land use as well as from burning of fossil fuel, cement production, and flaring.

Source: IPCC (2014)



The implication is that even if the world were to stop emitting CO2 today, future generations, including those in the Caribbean, will still have to live with the impact of present-day emissions.

It is also to be noted that as the atmosphere warms, the amount of water vapour it holds increases. Water vapour is also a greenhouse gas and the net effect is a further enhancement of the human-induced warming effect. In tandem, the IPCC (2013) notes that it is extremely likely that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the human-induced increase in greenhouse gas concentrations and other anthropogenic forcings (IPCC 2013).

It is the climate change due to *human influence* and not natural forcing that is the subject of current global debate and the focus of this book.

Science Take-Away Four: *The Caribbean is not a major emitter of greenhouse gases.*

The burning of fossil fuels (for transport, energy, industrial processes and electricity generation) is primarily responsible for the increased CO_2 of the last century (figure 2, bottom panel). About 78% of the total GHG emission increase seen between 1970 and 2010 was as a result of CO_2 emissions from fossil fuel combustion and industrial processes, with a similar percentage contribution for the period 2000–2010 (IPCC 2013). Agricultural processes and waste management processes, to a lesser extent, also contribute to CO_2 and other greenhouse gas emissions. Land use changes are also significant, such as the removal of forests and trees which serve as natural sinks for CO_2.

Efforts to address climate change must, then, of necessity address reducing greenhouse gas emissions. A significant part of the climate change discussion is how such reductions are to be achieved and who is to bear the brunt of the reduction effort given the obvious link between emissions and industrialization. It is the developed countries of the world that have emitted most of the anthropogenic greenhouse gases, with 10 countries being responsible for more than 60% of greenhouse gas emissions in 2011 (World Resources Institute, Climate Analysis Indicator Tool 2.0). The Caribbean's share of total global GHG emissions is very small and estimated at less than 1%.

The Climate Sensitivity of the Caribbean

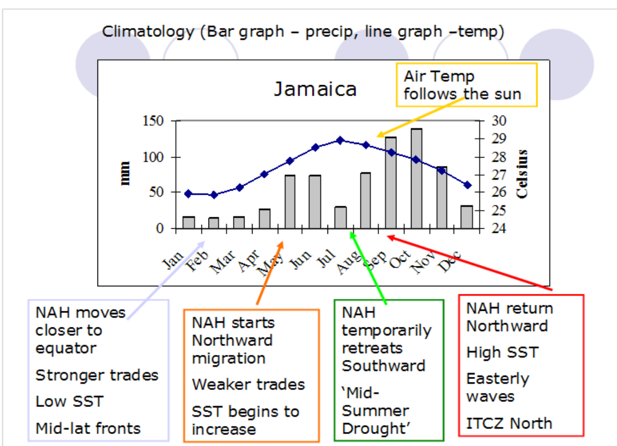
Understanding climate becomes important for the Caribbean given its inherent 'sensitivity' to climate. By sensitivity we mean that Caribbean countries – their economies, the daily ordering of the life of their people, and their natural systems – are extremely responsive to variations in climate on whatever timescale they occur (whether variability or change). In fact, the Caribbean is perhaps disproportionately sensitive to climate when compared to other regions of the world. The Caribbean's sensitivity to climate can be attributed to a number of reasons, of which four are suggested below.

On the one hand, the region's climate sensitivity is attributable to *the geographic location of the Caribbean* which gives rise to distinct climatologies or mean annual cycles of variation of its climate. The location of the

Caribbean region in the north tropical Atlantic but in close proximity to the tropical Pacific makes it subject to the influence of large-scale climatic drivers of both oceanic basins (for example, the north Atlantic subtropical high, the Inter-Tropical Convergence Zone, the easterly trade winds, warm oceanic pools, cold fronts, tropical depressions, storms and hurricanes). In tandem, these features contribute to distinct climatic seasons throughout the course of a year. For example, Jamaica's rainfall climatology features a dry season from December–April and a wet season from May–November (figure 3). Highest rain amounts are achieved in the latter part of the wet season, which also coincides with the peak hurricane season. Similarly, Jamaica's temperature climatology features hottest temperatures in summer (the hot season) with a July peak, and coolest temperatures in the first three months of the year (the cool season) (figure 3).

Figure 3

Rainfall (bar) and temperature (line) climatologies for Jamaica. Boxes track the changes in tropical Atlantic features which give rise to the rainfall climatology.

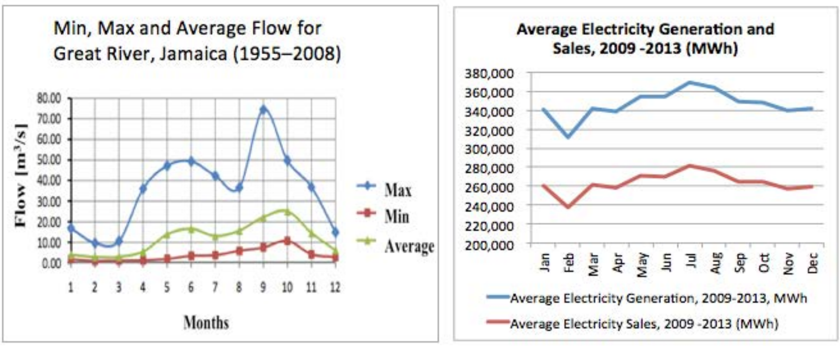


The cool-dry 'winter' and hot-wet 'summer' pattern is a characteristic of most of the Caribbean islands and is the backdrop against which Caribbean life has evolved and around which it still revolves. Consequently, the annual cycle of rainfall and temperatures is identifiable in a wide variety of indicators of Caribbean life and lifestyle, such as disease cycles, patterns of energy and water consumption, practices and operational cycles of businesses and governments, agricultural planting and reaping cycles, forest fire frequency, seasonal employment statistics, and the timing of recreational and sporting activities (see figure 4).

Figure 4

Climate cycles in Caribbean life. **Left panel:** The average flow for Great River in Jamaica reflects the bimodal pattern of rainfall. **Right panel:** The average electricity generation (top) and sales (bottom) for Jamaica reflects the summer peak in temperatures.

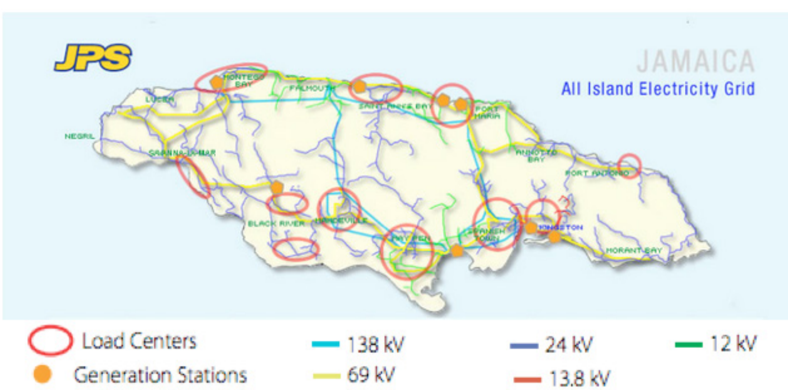
Sources: Inter-American Development Bank (2010)
and Jamaica Public Service Company Ltd. (2014).



Climate plays a significant role in the timings, cycles and general ordering of Caribbean life and there has come to be a dependence on the regularity and familiarity of its annual cycle.

Figure 5

Jamaica's electricity grid.
Source: Jamaica Public Service Company Ltd.



The region's climate sensitivity is, second, enhanced by *the geographic characteristics* of the constituent countries. Except for mainland countries (Guyana, Suriname and Belize), the small islands and cays which make up the Caribbean are: (i) low lying (for example, the Bahamas, most of the Grenadines, and Barbuda); (ii) volcanic, with mountainous interiors and very short coastlines (for example, St. Kitts and Nevis, St. Lucia, St. Vincent, Dominica, Grenada, and Montserrat); or (iii) possess a combination of both hilly interiors and limited coastal plains (for example, Antigua, Barbados, Haiti, Jamaica and Trinidad and Tobago). In most cases the combination of size and topography restricts the available land for development and forces the dependence on narrow coastal areas and/or steep hillsides for the location of major cities, key infrastructure (such as ports, airports, hospitals, major highways), large-scale agricultural plots, economic and industrial zones, and major population settlements (Pulwarty, Nurse and Trotz 2010; Simpson et al. 2010; Lewsey, Cid and Kruse 2004). Figure 5 shows the location of the electricity grid network for Jamaica, which largely rings the coastline. More than 50% of the Caribbean region's population resides within 1.5 km of the coast (Mimura et al. 2007). In the absence of large swathes of interior flat land, most of the major infrastructure and facilities of the Caribbean islands are exposed and susceptible to climatic hazards and their impact, including coastal erosion, coastal flooding and landslides.

Third, the region's climate sensitivity is rooted in its dependence on economic activities such as agriculture and tourism which, in their present forms, are very *dependent on favourable climatic conditions and natural resources*. The direct and indirect linkages between these sectors and climate (temperature, rainfall amounts, extreme events) are well documented (for example, Ebi, Lewis and Corvalan 2006; Donner, Knutson and Oppenheimer 2007; Simpson et al. 2010). Both tourism and agriculture represent majority employers – approximately 30% and 13% respectively of the regional labour force (Pulwarty, Nurse and Trotz 2010; World Travel and Tourism Council 2008) – and contribute significantly to the GDP of most Caribbean countries. In Jamaica, agriculture contributed 6.8% of GDP and employed 18.1% of the labour force in 2012 (PIOJ, 2013b), while in 2013, tourism and travel accounted for 7.7% of GDP and employed 7% of the labour force (World Travel and Tourism Council 2014). Both sectors help account for the strong link between livelihoods and climate in the Caribbean.

Finally, the climate sensitivity of the region arises from the fact that *rainfall is a key determinant of water resources* in the Caribbean (Cashman, Nurse and Charlery 2010). The CARICOM member states rely primarily on either groundwater, surface water or rainwater harvesting or various combinations of all three for their potable, industrial, sewerage and agricultural water supply (see Table 2). These sources are recharged by rainfall during the course of the year and in particular, summer rainfall, making the region's water sector extremely sensitive to variations in rainfall. There are, in fact, several islands in the Caribbean which can be defined as water scarce with respect to natural freshwater resources; these are Barbados, Antigua and Barbuda, St. Kitts and Nevis and the Bahamas (Farrell et al. 2010). Even for those countries where water scarcity does not exist at the national level, disparities with respect to the amount of rainfall received in a given location and/or physical conditions can result in water scarcity at the local level.

Table 2

Water profiles for selected Caribbean countries

Country	Water source	Agriculture - usage	Climate change vulnerability	References
Jamaica	Groundwater resources (84%) Primarily from limestone aquifers Surface water (16%)	Irrigation (75% – 1985)	Drought Saline intrusion (coastal aquifers) Storms and sea-level rise	USACE (2001) Simpson et al. (2009) Chase (2008)
Dominica	Surface water (rivers)	Rain-fed (very little irrigation)	Turbidity – storms, drought	USACE (2004a) Simpson et al. (2009)
Antigua	Desalination (75% dry season vs 60% wet season) Groundwater (20% dry season vs 15% wet season) Surface water (5% dry season vs 25% wet season)	Irrigation from surface water (20% of withdrawals)	Sea levels (water table high)	USACE (2004a) Simpson et al. (2009)
Barbuda	Groundwater Surface water		Sea levels (water table high) Drought	USACE (2004a) Simpson et al. (2009)

St. Kitts & Nevis	Groundwater (primary), Surface water	Rain-fed (85%), Irrigated (15%)	Sea level rise High temperatures (high evaporation rates) Drought	USACE (2004a) Simpson et al. (2009)
Barbados	Groundwater (79%) Desalination	Irrigated (11%)	Drought	Government of Barbados (2001) Chase (2008)
Trinidad & Tobago	Surface water (52%) Groundwater (32%) Desalination (12%)	Irrigated agriculture (3–6% of usage)	Drought Sea level rise for coastal aquifers	Government of T&T (2010)
Grenada	Surface water		Drought High temperatures	Simpson et al. (2009) Department of Economic Affairs (2001)
The Bahamas	Groundwater Desalination		Salt water intrusion Storms Sea level rise Drought	USACE (2004b) Simpson et al. (2009) Chase (2008)
Belize	Groundwater (95% rural areas) Surface water (90%)		Drought	Simpson et al. (2009)
St. Lucia	Surface water (100%)		Drought	Chase (2008)
British Virgin Islands	Desalination (60%) Groundwater (40%)		Drought	Chase (2008)

When combined, the four factors noted (that is, the evolution of Caribbean life around distinct climate cycles determined by geographic location, the impact of size and geography which limits life to climate sensitive zones, the economic dependence on climate-sensitive sectors and the natural environment, and the dependence of water stock on rainfall) ensure that the Caribbean is a place of inherent and heightened sensitivity to climate. Together, they ensure that the climate sensitivity of the region is:

- Embedded – Firmly entrenched and almost inextricable from Caribbean existence. For example, even if one could diversify economic endeavours to favour less climate-sensitive activities, the sensitivity arising from space limitations due to size and topography cannot be (easily) diminished.

- Pervasive – Interwoven into and across most sectors/spheres which define Caribbean existence. This is via direct influence (for example, the importance of rain to water security) or indirect influence (such as the rippling impact of too much or too little rain on food security, economic activity, and labour force productivity).
- Significant – This is in comparison to many other regions of the world where only one, two or three of the four factors may be at play.

Climate, then, is an integral part of who we are and how we operate in the Caribbean. Put another way, it is in the distinctions that are made between 'mango season' versus 'sorrel time'; in our feeling that a beach is really just a short ride away; in a natural acceptance of, and the broad smile given to the backpacking foreigner riding local transportation; and in the patchwork road surfaces resulting from newly filled holes alongside already weathered patches from the last rainy season. Climate is in our bones.

The recognition of an inherent (embedded and pervasive) and heightened (significant) sensitivity to climate should be sufficient to place climate, always, on the radar of all Caribbean citizens and, in particular, in the field of view of those who plan for Caribbean life at various levels (community, national and regional) and in both the private and public sectors. That is, there is a case to be made that even if there were no climate change, climate is still deserving of more than passing attention in the Caribbean simply because of the inherent climate sensitivity of the region.

This is not to suggest that there is no attention currently being given to climate and its pervasive presence. For example, the disaster and emergency management communities have successfully capitalized on a general awareness of the hurricane season to urge preparedness. The extent, however, to which national resources get mobilized for road repair or drain cleaning prior to the wet season; or the extent to which community mitigation measures are put in place against forest fires or a dengue outbreak in anticipation of the dry and late wet seasons respectively; or the extent to which households or small businesses actually make preparations at the start of the hurricane season (as opposed to the day before an event), may be better indications of the level of attention afforded to climate especially when there are competing demands on resources and attention.

Notwithstanding, the inherent climate sensitivity of the region makes a compelling case for climate (even beyond climate change) to be given sustained attention in the Caribbean, in particular in the region's planning processes.

Chapter 2
When it rains it pours
Growing Vulnerability

Climate change is transforming our inherent climate sensitivity into a vulnerability.

Our Climate Has Changed

Even with limitations on available records – short time series, sparse distribution, inhomogeneities – there is sufficient evidence that the climate of the Caribbean is changing. The change is seen in a number of ways.

Warmer Temperatures

The mean warming trend previously noted for the Earth over the past century is also evident in Caribbean temperature records. Stephenson et al. (2014) provide a comprehensive analysis of temperature trends across the Caribbean using data from 1960 to 2010 (figure 6). They suggest that the warming is manifesting itself in the region as:

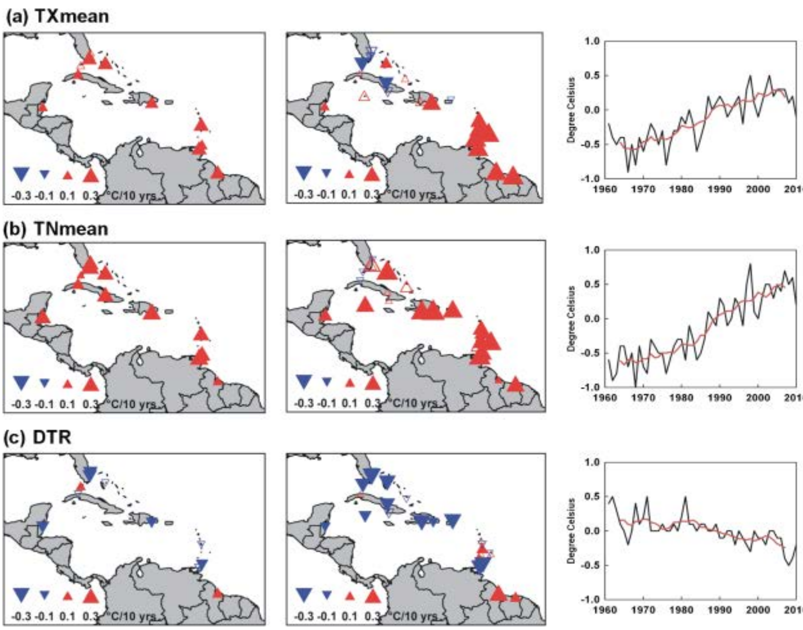
- An increase in daytime temperatures. The average temperature during the day has increased by approximately 0.19°C/decade since 1960. The basinwide increase in temperatures is indicated by the spread of upturned triangles in row one of figure 6 and by the upward slope in the time series plot in the top right panel.
- A greater rate of increase in night-time temperatures. The average night-time temperature has increased by approximately 0.28°C/decade since 1960. The basinwide increase is indicated by the spread of upturned triangles in row two of figure 6 and by the (steeper) upward slope in the time series plot in the middle, far right panel.
- A decrease in the difference between daytime and night-time temperatures or the diurnal temperature range (DTR). The basinwide decrease is indicated by the spread of downturned triangles in row three of figure 6 and by the downward slope in the time series plot in the bottom right panel.
- An increase in the occurrence of extremely warm temperatures. Very hot days have increased by 3.31% or 12 more days per year, and very hot nights by 4.07% or 15 more days per year.

- A decrease in the occurrence of extremely cold temperatures. Very cool days have decreased by 1.80%/decade or 6 fewer days per year, and very cool nights by 2.55%/decade or 9 fewer days per year.

Figure 6

Trends in (a) daytime temperatures (TXmean), (b) night-time temperatures (TNmean) and (c) diurnal temperature range (DTR). Left panels show the trends for 1961–2010; middle panels show the trends for 1986–2010; and right panels present the time series for area averaged anomalies for 1961–2010 relative to a 1981–2000 climatology. Upward (downward) pointing triangles indicate positive (negative) trends. Solid triangles correspond to trends significant at the 5% level. The size of the triangle is proportional to the magnitude of the trend. Red colour indicates warming, blue indicates cooling trends in (a) and (b); blue colour indicates that the daily minimum is increasing more than the daily maximum in (c). The red line in the right panels is a 7-point running mean.

Source: Stephenson et al. (2014)



In terms of human perception, the changes in temperature translate into days and (in particular) nights feeling hotter than they used to, a lack of significant night-time relief from hot daytime temperatures, and a sense that the hot days and nights associated with summer are starting earlier and persisting longer in the year.

Other studies by Alexander et al. (2006) and Aguilar et al. (2005) show that the trends in the Caribbean are consistent with the rest of the globe and with nearby Central America and northern South America (including their Caribbean coasts). Analysis for individual Caribbean countries (to the extent that records are available) shows similar magnitude of changes and trends (McSweeney et al. 2010). The region is warming.

Variable Rainfall

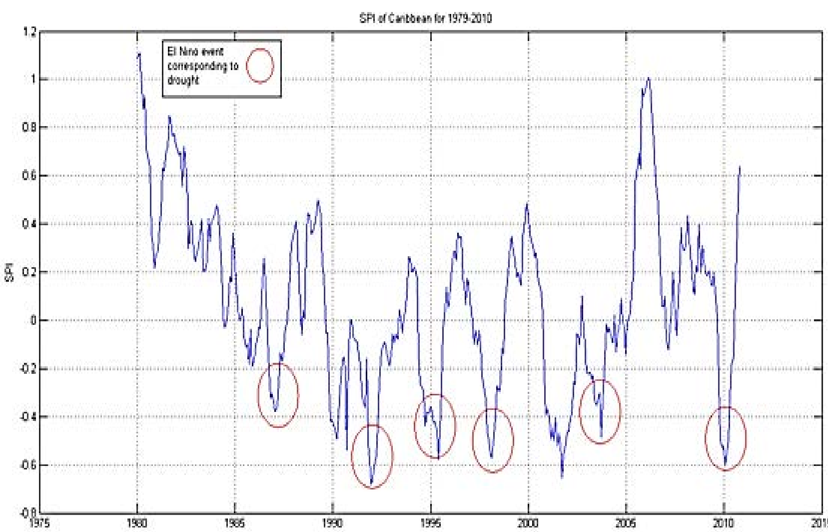
Trends in Caribbean rainfall are not as marked as for temperature because total rainfall amounts vary significantly from year to year. Climate *variability* is the dominant mode of variation in the Caribbean rainfall record. The variability is driven by the strong associations between Caribbean rainfall and the large-scale drivers of global climate. For example, as previously noted, an El Niño event dries out much of the Caribbean rainfall season in the year of its occurrence (figure 7) but induces heavy rain and flood events in the first half of the following year (Taylor, Enfield and Chen 2002). La Niña events do the opposite. Not surprisingly, then, the El Niño and La Niña cycles are easily discernible in the rainfall record (figure 7).

There has, however, been an increase in the frequency, severity, and duration of El Niño events since the 1970s (Stahle et al. 1998; Mann, Bradley and Hughes 2000). This implies that there should be a similar increase in regional rainfall extremes (floods and drought) over the same period. Recent climatic events in the Caribbean, including the prolonged and basinwide drought of 2009–2010 and the north Caribbean drought of 2014, seem to support this. Gamble et al. (2010) note that in St. Elizabeth, Jamaica, "farmer perceptions of increasing drought might reflect relative changes [in the rainfall patterns of] the early (April–June) and principal (August–November) growing seasons. Specifically, many farmers commented in interviews that drought is becoming more prevalent." The already variable rainfall regime, then, appears to be becoming even more variable.

The strong variability (or swings between extremes) in the rainfall record means that *trends* in total rainfall amounts, as determined from the longest records, tend to be small and not significant. On the contrary, there are discernible trends in the intensity, frequency and duration of rainfall events. That is, there is a noticeable shift in the 'character' of regional rainfall. Stephenson et al. (2014) make the point that "although no significant increases are to be found in the annual total rainfall amounts, [both] the intensity of daily rainfall and the heavy rainfall events [have] been significantly rising over the past 25 years." This, they suggest, is also occurring against the background of a small but gradual increase in consecutive dry days, which is a measure of dry conditions. These changes are more pronounced for sub-regions and in particular for the northwestern (the Bahamas, Cuba, Jamaica, the Cayman Islands) and southeastern (Trinidad and Tobago, Curaçao, Guyana, Suriname) Caribbean, and in the later records. The implication is that whereas an overall drying or wetter trend is not evident, the number of dry days between rain events is increasing, and when rain occurs it tends to be heavier – that is, when it rains it pours. This has implications for increased flood risk, though other factors including land use and human settlement in flood plains also play significant roles in flooding.

Figure 7

Standardized Precipitation Index (SPI) for the Caribbean using for the period 1979 to 2010. Recent El Niño years are indicated by circles. SPI is a probability of drought index determined from rainfall records. Very low values (approaching 1) indicate severe drought.

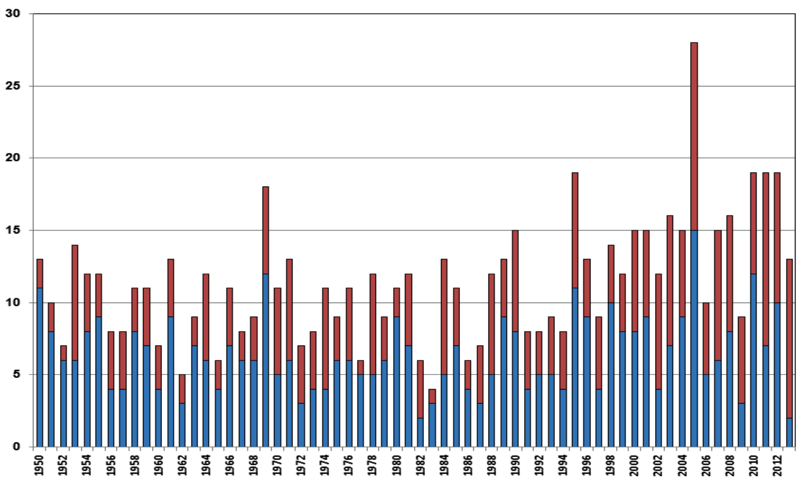


An Increase in Tropical Storms and Hurricanes

Beginning in 1995, the number of observed tropical storms and hurricanes in the tropical Atlantic has shown a dramatic increase (figure 8). The number of named tropical storms and hurricanes averaged 14.5 and 7.6 per year respectively from 1995 to 2009, compared with 11.6 and 6.1 per year between 1980 and 1994 (Pulwarty, Nurse and Trotz 2010).

Figure 8

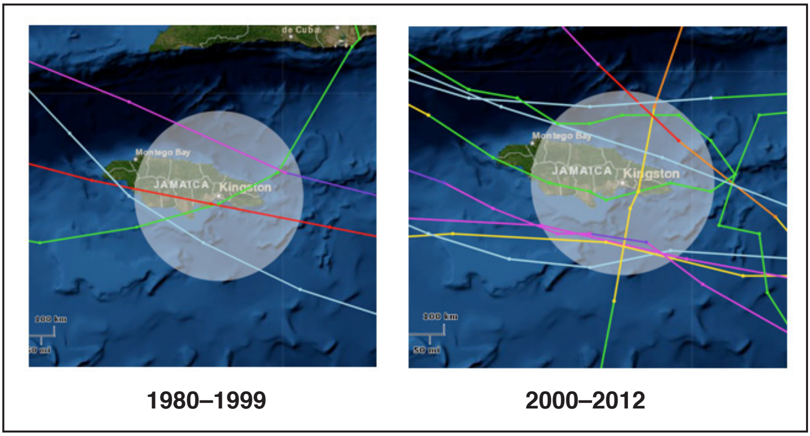
The number of North Tropical Atlantic storms (red) and hurricanes (blue) from 1950–2013.
Source: NOAA.



The observed increase in the last 20 years was in spite of three years (1997, 2002 and 2007) of low hurricane incidence which coincided with El Niño events. For Jamaica, the increase translates into 11 storms and hurricanes tracking within 200 kilometres of the island since 2000 compared to only 4 storms and hurricanes in the 20 years preceding that (figure 9).

Figure 9

Tracks of hurricanes or tropical storms passing within 200 km of Jamaica during the period 1980–1999 (left) and 2000–2012 (right).
Source: HURDAT Database.



It is important to note that the increase in the number of observed tropical storms and hurricanes in the last 15 years is perhaps more attributable to the region being in the positive (warm) phase of a longer term fluctuation called the Atlantic Multidecadal Oscillation – more a function of climate variability. The role of global warming with respect to hurricanes is yet to be better quantified (Goldenberg et al. 2001; Landsea et al. 2010). Notwithstanding, both the frequency and duration of hurricanes have exhibited statistically significant increasing trends in recent times. Webster et al. (2005) note that there has been an almost doubling of category 4 and 5 hurricanes. While the number of intense hurricanes has been rising, the maximum intensity of hurricanes has, however, remained fairly constant over the recent past.

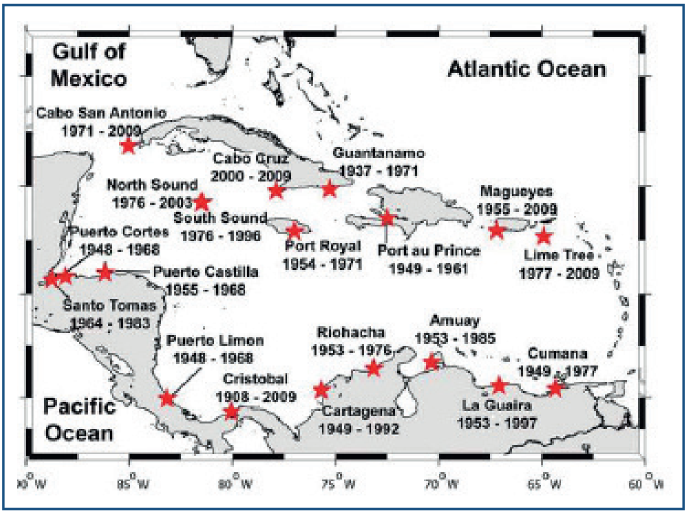
Rising Sea Levels

One consequence of warmer surface temperatures has been sea-level rise due to the expansion of ocean water, melting of mountain glaciers and small ice caps and, to a lesser extent the melting of the Greenland and Antarctic Ice Sheets. The rate of observed sea-level rise has increased from the mid-nineteenth to the mid-twentieth centuries. Between 1901 and 2010, the rate of mean global sea-level rise was estimated at 1.9 mm/year as measured by tide gauges (IPCC 2013). In the last 20 years, the estimated rate increased significantly to 3.2 mm/year as determined from satellite altimetry (IPCC 2007). Regional observations made between 1950 and 2009 suggest that the rate of rise in the Caribbean is between 1.7 and 1.9 mm/year, which is near the global mean (Church et al. 2004; Palanisamy et al. 2012; Torres and Tsimplis 2013). There is, however, likely to be non-uniformity across the region due to differential tectonic displacement within the basin (Hendry 1993; Gamble 2009) as indicated in Table 3.

Table 3

Tide gauge observed sea-level trends for Caribbean stations. (Adapted from Torres & Tsimplis 2013). Map shows location of the tide gauge stations and time series start and end years.

	Trend mm/year	Gauge corrected
P. Limon	1.76±0.8	2.16±0.9
Cristobal	1.96±0.1	2.86±0.2
Cartagena	5.36±0.3	5.46±0.3
Riohacha	4.86±1.1	4.86±1.1
Amuay	0.26±0.5	0.26±0.5
La Guaira	1.46±0.3	1.56±0.3
Cumana	0.96±0.5	0.76±0.6
Lime Tree	1.86±0.5	1.56±0.5
Magueyes	1.36±0.2	1.06±0.2
P. Prince	10.76±1.5	12.26±1.5
Guantanamo	1.76±0.4	2.56±0.6
Port Royal	1.66±1.6	1.36±1.6
Cabo Cruz	2.26±2.8	2.16±2.8
South Sound	1.76±1.5	1.26±1.5
North Sound	2.76±0.9	2.26±0.9
C. San Antonio	0.86±0.5	0.36±0.5
Santo Tomas	2.06±1.3	1.76±1.3
P. Cortes	8.66±0.6	8.86±0.7
P. Castilla	3.16±1.3	3.26±1.3



A New Climate Regime

The cumulative impact of warmer days and nights, higher sea levels, more intense rain events and more frequent hurricanes is the gradual but clear emergence of a new climate regime. The new climate regime is characterised by (i) unfamiliarity, (ii) unpredictability, and (iii) unreliability.

1. Unfamiliarity

Although the Caribbean is used to climate variability there is a sense of unfamiliarity brought about by the magnitude and intensity of the climate extremes currently being experienced. That is, some of the recent events are of a nature unknown in recent times and the severity brings with it the sense of 'treading on unfamiliar territory'. The Meteorological Service of Jamaica noted that the drought of 2009–2010 (Box 3) was the "worst drought in twenty-five years and as a result there wasn't enough rainfall to keep up the water distribution from the National Water Commission's facilities to many parishes, especially to the highly populated Kingston and St. Andrew" (Trotman and Farrell 2010). Prime Minister Ralph Gonsalves of St. Vincent, similarly noted that the Christmas Eve (2013) rains which dumped 15 inches in St. Vincent and the Grenadines, St. Lucia and Dominica in 24 hours and resulted in significant destruction and death, was "a disaster of a proportion the likes of which we have not seen in living memory".

The Secretary General of the Organisation of American States (OAS), José Miguel Insulza mentioned the "unreasonable nature of the [Christmas Eve] rains".[3] A number of other localized flooding events in various parts of the Caribbean in recent times have similarly helped to shaped public sentiment about a new and unfamiliar climate regime. Trinidad and Tobago, in particular, has experienced severe and often unexpected flooding in the past few years, due to heavy rains (for example: 4 October 2014, flash flooding in South Trinidad; 24 October 2014, flood rains in Tobago; 13–16 November 2014, floods in northeast and central Trinidad; 13 September 2103, flood in west Trinidad; 26 November 2013, floods in central and south Trinidad).

2. Unpredictability

The predictability of Caribbean climate has advanced significantly in recent years through the efforts of a number of regional institutions to gain an understanding of its primary drivers. These include the Climate Studies Group, Mona, at the UWI; the Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados, and the Instituto de Meteorología in Cuba. There is, for example, far greater knowledge today of how El Niño affects the region's rainfall over the course of its onset through decline (see, for example, Giannini et al. 2000; Taylor et al. 2002). Since El Niño events are routinely forecasted with relative skill six to eight months in advance, this affords some amount of predictability for Caribbean climate extremes induced by their occurrence. Notwithstanding, Farrell et al. (2010) note that the greatest challenge associated with the 2009–2010 El Niño-induced drought was "the region's inability to recognise the onset of the drought and its severity". Despite the efforts to enhance predictability and provide a measure of foresight, there is still a growing sense of an emerging unstable and unpredictable climate regime. If the element of surprise is to be reduced, there is a clear need for even greater scientific endeavours aimed at improving our understanding of our climate, its variability and its changes, and how those changes are manifesting themselves particularly on the sub-regional and sub-national scales. Recent advances such as the Caribbean Drought and Precipitation Network and the application of the

3 http://www.theguardian.com/commentisfree/2013/dec/31/storms-caribbean-uk-climate-change

Caribbean Precipitation Outlook to forecasting drought and its duration have the potential to substantially increase the capability of the region to address existing deficiencies and better cope with future situations.

3. Unreliability

There is a growing feeling of 'unreliability' about the region's climate occasioned by its being unfamiliar and unpredictable. The reassurances once offered by the regularity of the climate cycles on which Caribbean life has come to depend are gradually being replaced by uncertainty and a feeling that one can no longer rely on the timings and occurrences of climate that used to be. In the region there is a strong dependence on seasonal rainfall – particularly on the smaller islands – for water for domestic and agricultural use. The late rainfall season (September–November) is particularly important for the replenishment of water stock in advance of the dry season at the beginning of the following year and to ensure sufficient supplies until the onset of the rainy season again in May–June. It is the absence of the expected late season rains of 2009 and the late onset of the rainy season in 2010 that made the 2009–2010 drought so severe in its impact, particularly for the agricultural sector (see Box 3). In recent years, Caribbean farmers have also lamented the lack of reference points in the climate (or even associated biodiversity) on which to base judgements for planting and reaping (Gamble 2010). There is, additionally, much anecdotal evidence about the changes in flowering and fruit seasons throughout the region, though the science to support the observations is sparse.

Box 3: The 2009–2010 Drought

During 2009 and into 2010, most of the Caribbean experienced a severe to extreme drought. Drought conditions began in the southern and eastern Caribbean in October 2009 and quickly spread northward, with significant declines in rainfall being recorded across the entire Caribbean through the first half of 2009. The drought was coincident with the emergence of a strong El Niño event in summer 2009, which lingered through mid-2010. Farrell et al. (2010) noted that the most significant declines in rainfall were experienced in Grenada at the Point Salines International Airport, where the decreasing rainfall totals began earlier than at other regional stations and where the rainfall in 2009 was the lowest in 25 years of records. Guyana and Dominica, which are known for abundant rainfall, were also significantly affected by the 2009–2010 drought. Farrell et al. (2010) further point out that the impact was felt most by the region's farming community and water resources sector. For example, production from the banana industry in Dominica was approximately 43 % lower in 2010 compared to the previous year.

Left : A section of the Rio Minho in May Pen, Clarendon, Jamaica during drought conditions.
Right: A water truck filling up from a river along the Mandela Highway in St. Catherine, Jamaica. Source: http://jamaica-gleaner.com/gleaner/20140721/news/news92.html

From mid-2009 through to the first quarter of 2010, several Caribbean countries including Jamaica, Dominica and St. Lucia reported significantly lower than normal flows in many of their streams. In Antigua and Barbuda, the Potswork Reservoir, which is the largest surface water impoundment on the island and which supplies most of the 22% of annual water supply derived from surface water sources on the island, was nearly dry during March 2010. Many Caribbean countries were forced to implement water use restrictions.

A Growing Vulnerability

As a new climate regime emerges, the vulnerability of the Caribbean region to climate variation is becoming more and more evident. Vulnerability is a function of sensitivity, exposure and capacity to cope (IPCC 2007). Using this definition, it is not hard to see that the Caribbean has always been vulnerable to climate, given its inherent climate sensitivity, as noted in the previous chapter. The pervasive nature of the sensitivity, also alluded to in the previous chapter, means that the vulnerability of the region is across all its sectors and, likewise, evident in all spheres of Caribbean life (Table 4).

Table 4

Some recent examples of climate impact in the Caribbean

Macro-economy	The total cost of damage and loss associated with hurricane Tomás in St. Lucia amounted to 42.4% of GDP and 47% of public external debt (ECLAC 2011a). In Jamaica, hurricane Ivan (2004), hurricane Dean (2007) and tropical storm Nicole (2010) caused damages amounting to 8%, 3.4% and 1.9% of GDP, respectively (various PIOJ reports). Hurricane Ivan inflicted approximately 200% of GDP damage on Grenada and the Cayman Islands (CCRIF 2010).
Infrastructure	An assessment of the impact of hurricane Ivan (2004) on Grenada suggests that 90% of housing stock was damaged, telecommunications losses were equivalent to 13% of GDP, and damage to schools and education infrastructure was equivalent to 20% of GDP (OECS 2004). Flash floods in December 2013 significantly damaged infrastructure in St. Vincent and the Grenadines and St. Lucia. There was substantial damage to roads and bridges, with impact concentrated in areas with the highest levels of poverty. Damage amounted to 15% of GDP in St. Vincent and the Grenadines and 8% of GDP in St. Lucia (World Bank Press Release, March 2014).
Tourism	Hurricane Ivan destroyed or damaged 90% of guest rooms in Grenada's tourism sector, equivalent to 13% of GDP (OECS 2004). Hurricane Tomás caused damage and losses amounting to three times that of tourism's contribution to GDP in St. Lucia (ECLAC 2011a). Hurricane Sandy (2012) reportedly resulted in significant losses for the Atlantis resort in The Bahamas. The storm cost the resort 2,000 room nights and a weekend casino tournament before affecting major source markets as it shut down travel across the eastern United States. The Lynden Pindling International Airport (LPIA) suffered a 4.8% decline in arrivals in 2013, which was mainly attributed to hurricane Sandy cutting into a key market, the US East Coast (*Global News Matters*, 2014).

Health	Reported cases of dengue are correlated with both temperature and rainfall, with warming of early months of the year bringing earlier onset of reported dengue cases and epidemics such as occurred in Trinidad and Tobago, 1997–1998 (Amarakoon et al. 2006). Hurricane Tomás (2010) caused serious damage to the health sector in St. Lucia: (i) damage to the physical plant caused the decommissioning of the hospital in Dennery; (ii) seven people were reported to have lost their lives, five were reported missing and 36 suffered a variety of physical injuries; and (iii) data from the Ministry of Health suggested that there was a 47% increase in under-5 gastroenteritis for 2010 over the 2009 figures. Much of this may be attributable to the effects of the water situation caused by hurricane Tomás (ECLAC 2011a). Hurricane Sandy in 2010 caused nearly 80 deaths in the Caribbean: 60 in Haiti, 11 in Cuba, 2 in the Bahamas, 2 in the Dominican Republic and 1 in Jamaica, with approximately 1.8 million people affected in Haiti, according to the United Nations relief agency (UNDP News Centre 2012).
Agriculture	The agricultural sector of Grenada suffered a loss equivalent to 10% of GDP due to hurricane Ivan in 2004. The hurricane caused an estimated delay of 10 years in the availability of cocoa and nutmeg, two of the island's main crops, for economic benefit (Mimura et al. 2007). The 2009–2010 drought severely affected the banana industry in Dominica, with production approximately 43% lower in 2010 compared to the previous year. This resulted in a significant reduction in banana exports to the UK and a reduction in foreign exchange earnings (Farrell et al. 2010). Similarly, the 2010 onion and tomato crops in Antigua and Barbuda decreased by 25% and 30% respectively, due to water stressed conditions (FAO 2013). In St. Vincent and the Grenadines, hurricane Tomás in 2010 caused widespread destruction in the agricultural sector, with bananas and plantains suffering an almost 98% loss in the affected areas (CDEMA 2010).
Biodiversity	Decreases in Jamaican dry season rainfall have been found to reduce food availability and hence the physical condition of migratory birds wintering on the island, as well as their spring departure times (Studds and Marra 2007). The devastating coral bleaching event of 2005 was caused by anomalously high sea surface temperatures in the Eastern Caribbean and North Atlantic; for example, 90% of coral was affected in the British Virgin Islands (Donner, Knutson and Oppenheimer 2007).

Water	Potworks Reservoir, an important surface water source for the island of Antigua, was left dry after a 2003 drought (Farrell, Moseley and Nurse 2007). During the 2004–2005 Cuban drought events, 2.6 million people were forced to rely solely on truck-borne water (Pulwarty, Nurse and Trotz 2010). Water supply capacity in St. Lucia decreased from 17 million gallons per day (MGD) to 0.14 MGD following the passage of hurricane Tomás, 29–31 October 2010. There are 28 water production facilities in St. Lucia and up to November 3, 2010, only one was operational (CDEMA 2010).

However, the changing climate and, in particular, the heightened intensity of its events, is not only showing up obvious vulnerabilities, but bringing to the fore the vulnerability of sectors and areas of Caribbean life which were previously veiled because of their secondary linkages. In other words, whereas the impact of a climatic event is usually immediately evident in some sectors or areas of Caribbean life because of their direct climate linkages (for example, the water and agriculture sectors given their direct dependence on rainfall, or health through direct climate linkage to vector abundance), other areas of Caribbean life benefitted from a dampening effect because of an indirect or secondary linkage to climate. This means that if the magnitude of the climatic extreme was relatively weak, the climate ripple might not have been felt in the sector of secondary influence. This, however, may not be the case any more in the emerging climate regime as, for example, greater pooling of water under more intense rainfall can quickly lead to loss of productivity through absenteeism as more and more of the workforce falls prone to illnesses (including to new and emergent diseases) modulated by climate. The point is made by the headlines of the Jamaican newspapers during the 2014 drought. As the drought persisted, the headlines quickly transitioned from a concentration on the direct impact on agriculture and available piped water to its effect on biodiversity (bush fires), education (school closures), energy (hydroelectricity and power outages) and the economy (small business and economic productivity) (figure 10). In effect, climate change is transforming inherent sensitivities, even if once masked, into real vulnerabilities.

It would also be true to suggest that under the new climate regime, new vulnerable groupings are emerging as a result of an expanded exposure to the climate threat. As sea levels rise, new areas become vulnerable to storm surge and higher wave heights. The eye of hurricane Dean passed within

80 km south of Kingston and caused storm surges reaching up to 13 m in height along the eastern and southern coasts (figure 11). The highest wave was recorded at Sandshore, in Manchioneal, Portland, on the northeast coast, and the run-up for the waves ranged between 20 and 130 m from the shoreline. The results were extensive inland damage to buildings (houses, recreational and commercial structures) and roadways, the loss of livestock and other agricultural products and tons of debris washed onshore. Sea level rise is also resulting in beach erosion. Robinson et al. (2012) reported the net average shoreline recession for the Long Bay area in Portland, Jamaica, between 1971 and 2008 as 8.4 m or about 23 cm per year. CARSEA (2007) noted that 70 per cent of Caribbean beaches are eroding at rates of between 0.25 and 9 m per year. Sea level rise and continued coastal erosion are placing previously distant infrastructure directly under threat, even in the absence of a severe storm event.

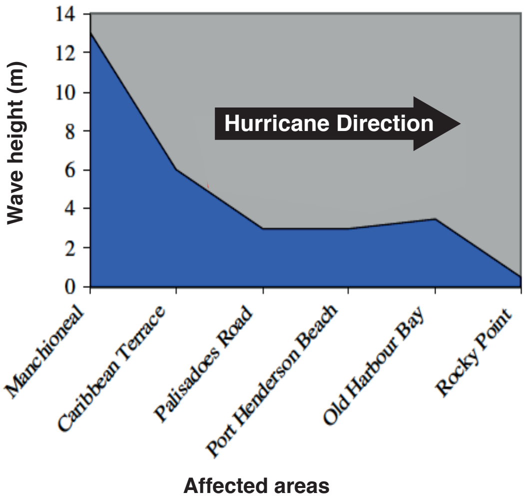
Figure 10

The 2014 drought in the Jamaican news

In addition to coastal settlements and infrastructure, examples of other emerging vulnerable groupings and sectors that require attention under the new climate regime include endemic fauna and flora, outdoor workers, the homeless, the chronically ill, the elderly and very young, those suffering from respiratory problems, and small businesses.

Figure 11

Hurricane Dean storm surge heights and affected communities in Jamaica.
Source: Prepared by PIOJ, 2008, based on data provided by
Mines and Geology Department, Jamaica.



Finally, the emerging climate regime is also challenging the capacity of the Caribbean to cope with climate impact. It is not just the magnitude of the climatic events that presents a challenge but also the recurrent nature of the threats under the new climate regime. In the last 14 years (since 2000) Jamaica has been affected by 12 tropical storms, hurricanes or intense rain events (Table 5). Each event has cost the country a percentage of its GDP for recovery efforts and, combined, they have resulted in losses and damage amounting to approximately $128.54 billion (data from the PIOJ, State of the Climate 2012 Report). During hurricane Sandy (2012), the greatest impact was on the social sector (health, housing and education), which accounted for 48 per cent of the total cost. Yet, even while coping with hurricanes, there have been in between, significant droughts (2005, 2009–2010, 2014), which also affected the country significantly. For example, for Jamaica, combined costs from the 2005 drought due to forest and bush fires, losses in the agricultural sector and as a result of government mitigation measures were in excess of J$340m. Jamaica's Ministry of Water, Land, Environment and Climate Change estimates similar levels of expenditure for the trucking of water alone during the 2014 drought.

Recurrent climate extremes likewise affect individual sectors such as agriculture (figure 12), as well as other area of Caribbean existence such as its biodiversity. The mangrove forests of the Portland Bight area of Clarendon, Jamaica, were not able to recover from the destruction of hurricane Ivan in 2004 due to the subsequent passage of hurricane Dean in 2007.

Table 5

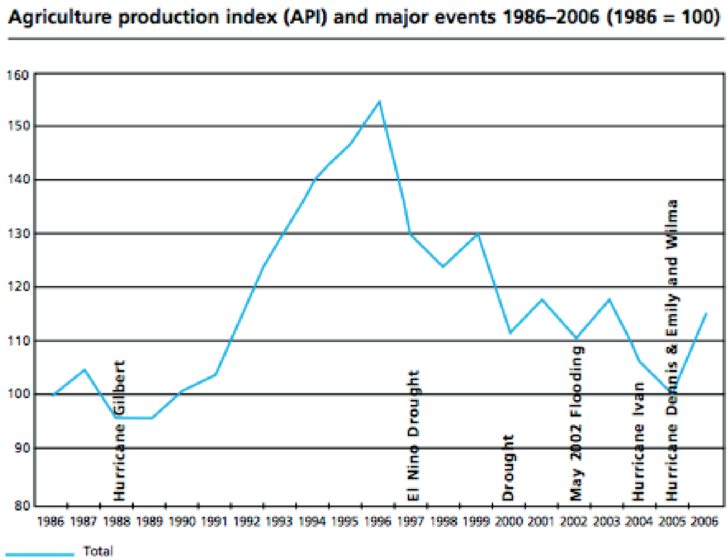
Estimated economic impact of recent extreme climate events on Jamaica
***Source:* Various PIOJ reports**

Event	Year	Category	Impact (% GDP)
Hurricane Michelle	2001	4	0.8
May/June Flood Rains	2002		0.7
Hurricane Charley	2004	4	0.02
Hurricane Ivan	2004	3	8.0
Hurricanes Dennis and Emily	2005	4	1.2
Hurricane Wilma	2005	5	0.7
Hurricane Dean	2007	4	3.4
Tropical Storm Gustav	2008		2.0
Tropical Storm Nicole	2010		1.9
Hurricane Sandy	2012	1	0.9

Figure 12

The agriculture production index (API) for Jamaica 1986–2006. The API provides a measure of relative performance in the sector across the export, domestic, meat, poultry and fisheries subsectors. The average API from 1986 to 2006 shows a close relationship with extreme climate events.

Source: PIOJ (2010).



A Case, then, for Consideration

Available records from the recent past support, then, the idea that the climate of the region is changing in some significant ways, including more intense climate extremes and changes in the frequency of their occurrence. The result is an emerging climate regime marked by unfamiliarity, unpredictability and unreliability, and which is enhancing the region's vulnerability to climate. The growing vulnerability makes a strong case for climate not just to have the attention of Caribbean stakeholders but also for climate to be a *consideration* in the planning of and for Caribbean life. Climate and how it is changing must be on the agenda of those who plan for Caribbean development at various levels, whether they be local or community leaders, in the public or private sector, or national or regional bodies. For example, the governments of the region must make climate a consideration in planning at the sectoral level because of the direct vulnerability of some sectors like agriculture, tourism and health, as well as because of the increasing impact on those with seemingly less obvious linkages. Similarly, the private sector cannot escape making climate an issue for consideration given the direct impact it has on their infrastructure, cost of operation (for example, energy and water costs) and the productivity of its labour force.

Chapter 3
A disaster in the making
Threatened Sustainability

The climate will continue to change in ways that will make future impacts significant challenges to our sustainability.

Determining Future Climate

Climate models are scientific tools which are used to project future climates. They are computer models which enable the simulation of the large-scale systems of the atmosphere by incorporating the latest scientific understanding of the physical processes of the atmosphere, oceans and the Earth's surface using comprehensive mathematical descriptions. There are two types of climate models from which information on future climates can be gleaned – global climate models (GCMs) and regional climate models (RCMs). Whereas GCMs simulate climate across the entire globe, their scales are coarse, generally of a few hundred kilometres and, as such, their results represent only 'first guesses' for the small islands of the Caribbean. To achieve information more representative of the scale of the region, RCMs are used. RCMs simulate climate at higher resolutions (50 km or less) but over smaller areas using GCM output as their boundary conditions. There is a multi-country regional science initiative currently underway to produce RCM projections for the Caribbean region.[4]

A range of assumptions have to be made about what the future world might look like in order to come up with the climate projections. The combination of assumptions about future population, economic growth, energy use and technology are captured in storylines and reported on in the Special Report on Emissions Scenarios (SRES) (Nakićenović et al. 2000). The SRES presents 40 different storylines or scenarios divided into four families (A1, A2, B1 and B2), capturing various changes in the global development factors. Each storyline represents a plausible and possible future. The storylines are used to determine future GHG emissions which

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4 The PRECIS-Caribbean Initiative is a collaborative research effort involving Cuba, Jamaica, Barbados, Belize and Suriname to produce downscaled climate scenarios for the Caribbean using the PRECIS RCM. PRECIS stands for Providing Regional Climates for Impact Studies. http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00235.1

are then fed into the GCMs and RCMs. Box 4 provides more information on scenarios. For regions like the Caribbean, results are often presented for the entire ensemble of future scenarios or for low (for example, B2), medium (for example, A1B) and high (for example, A1 or A2) emission scenarios to provide a range of possible futures.

In the IPCC's latest Assessment Report, a new set of scenarios referred to as "Representative Concentration Pathways" (RCPs, as opposed to the older "SRES scenarios") are utilized. The four RCPs (as opposed to the 40 SRES scenarios) cover a larger set of mitigation scenarios and were selected to have different targets in terms of impact on the atmosphere at 2100. Box 4 also provides more information on RCPs.

The results presented herein are derived from both GCMs and RCMs, using both the SRES scenarios and RCPs, and run through to the end of the current century. The science of modelling tells us that the climate of the Caribbean region will continue to change, in the following ways.

Much Warmer Temperatures

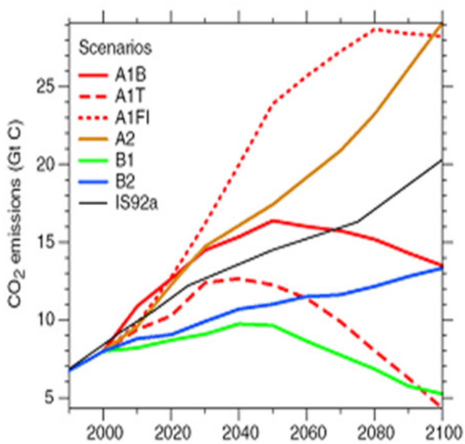
Irrespective of the scenario used or technique employed, the Caribbean is expected to continue warming through to the end of the century. The models indicate that the mean annual temperature of the Caribbean increases steadily under climate change such that by the end of the current century the region is warmer by 1.0°C to 3.5°C (top panel, figure 15). By the end of the century, the probability of extreme warm seasons is 100% and the magnitude of the warming is 'large' in comparison to historical warming (bottom panel, figure 16). The warming is everywhere across the region and greater over the bigger islands (Cuba, Hispaniola and Jamaica) (figure 16). The magnitude of change is about the same for all times of the year.

Box 4: SRES Scenarios and RCPs

The SRES scenarios are storylines of future global development (Nakićenović et al. 2000). SRES scenarios quantify how GHG emissions could change over the twenty-first century in the absence of policy interventions to reduce the emissions. There are 40 different SRES scenarios divided into four families (A1, A2, B1 and B2), each with an accompanying storyline which describes the relationships between future greenhouse gas emission levels and driving forces such as demographic, social and economic and technological developments. The families represent a range of equally plausible possible futures – from low emission to high emission futures. For example, the A-Family or High-Emissions Scenarios describe a future world of very rapid economic growth, a global population that peaks in mid-century and declines thereafter, with the rapid introduction of new and more efficient technologies. The A2 storyline describes a very heterogeneous world and the underlying theme is self-reliance and preservation of local identities. The B-Family describes relatively Low Emissions Scenarios. The B2 storyline describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability.

Figure 13

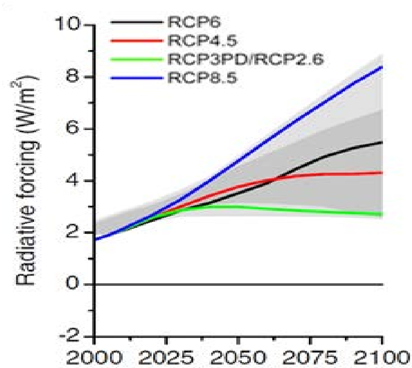
Projected future carbon emissions for the SRES emission scenarios. The higher-emission scenario (A1fi) corresponds to the highest dotted line, while the lower-emission (B1) scenario is indicated by the solid line (Nakićenović et al. 2000).



Representative Concentration Pathways or RCPs are defined by their total radiative forcing (cumulative measure of human emissions of greenhouse gases from all sources expressed in Watts per square metre) pathway and level by 2100. Like the SRES scenarios, the RCPs specify concentrations and corresponding emissions but are not directly based on socioeconomic storylines. Instead, the four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6), and one scenario with very high greenhouse gas emissions (RCP8.5). The RCPs can thus represent a range of twenty-first century climate policies, as compared with the no-climate policy of the SRES scenarios. As with the SRES scenarios, the RCPs should be considered plausible and illustrative and do not have probabilities attached to them. It is, however, noted that many do not believe RCP2.6 is feasible without considerable and concerted global action.

Figure 14

Radiative Forcing of the Representative Concentration Pathways, taken from van Vuuren et al. (2011). The light grey area captures 98% of the range in previous integrated assessment modelling scenarios, and dark grey represents 90% of the range.



Other things to note about future regional temperatures from the modelling studies are:

- The region-wide warming is consistent with projections for other parts of the globe.
- The results are consistent with temperature projections obtained using other non-modelling methodologies, for example, Statistical DownScaling (Wilby, Dawson and Barrow 2002). Statistical modelling of selected stations suggests warming in Trinidad of 2.2°C/1.6°C, Barbados of 2.3°C/0.7°C and Jamaica of 2.0–3.0°C/1.5–2.3°C by the end of the century (Chen, Chadee and Rawlins 2006).
- There will be substantial increases in the frequency of days and nights that are considered hot in current climate. For many Caribbean countries, hot days and nights by present standards occur up to 95% of all days by the 2090s (McSweeney et al. 2010).
- There will be substantial decreases in the frequency of days and nights that are considered cold in current climate. For many Caribbean countries, these events are expected to become exceedingly rare by the end of the century (McSweeney et al. 2010).
- Land areas warm more than ocean areas (Karmalkar et al. 2013; Campbell et al. 2010).

- Sea surface temperatures in the Caribbean are projected to increase at a similar rate as near surface atmospheric temperatures but with slightly smaller magnitudes (Simpson et al. 2010).

Figure 15

Top: Projected annual temperature change for the Caribbean relative to 1986–2005 for the four RCPs. Bottom: Projected percentage change in annual rainfall amounts for the Caribbean relative to 1986–2005 for the four RCPs. Diagrams generated using KNMI Climate Explorer.

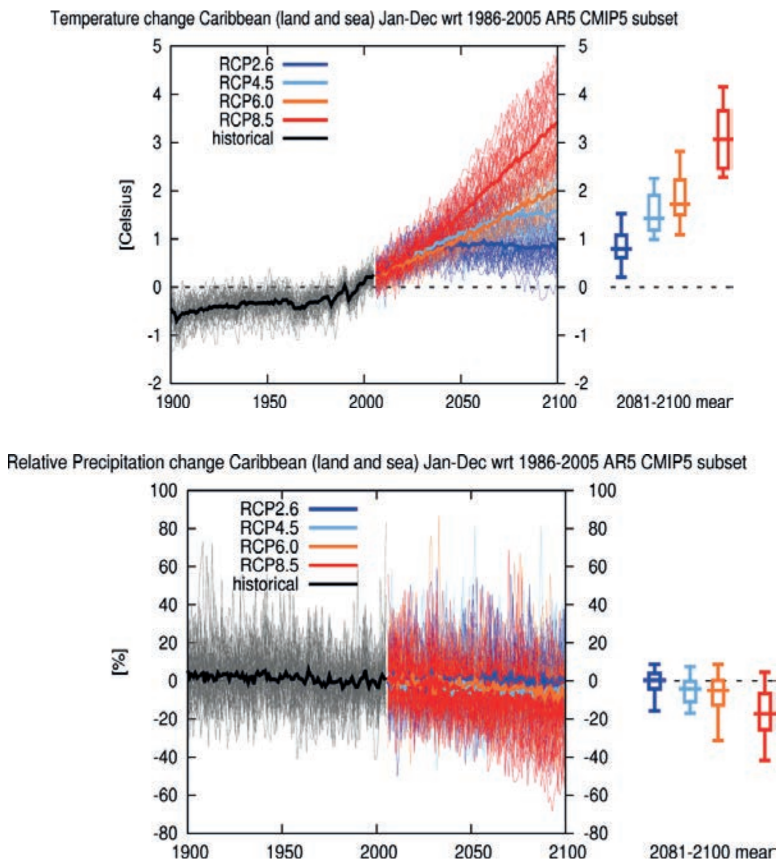
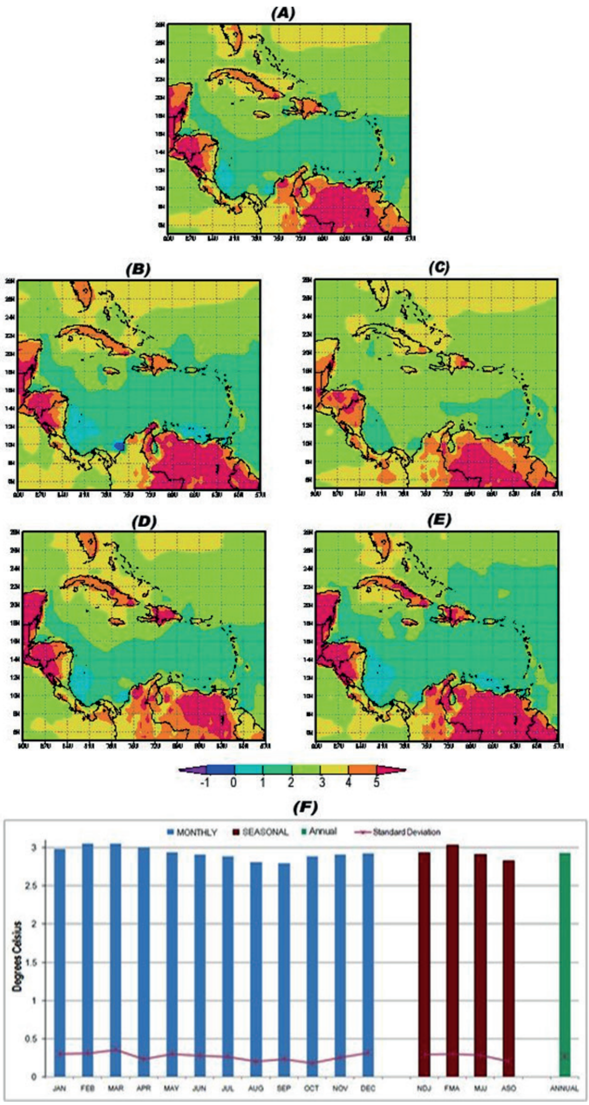


Figure 16

Temperature projections for 2071–2100 relative to 1961–1990 under the A2 scenario. Absolute change is presented. Panels (a), (b), (c), (d), and (e) represent changes in annual, November– January, February–April; May–July, and August– October temperatures. Panel (f) shows monthly, seasonal and annual changes calculated by averaging over the basin. The solid red line represents one standard deviation as calculated from the observed data. (Adapted from Campbell et al. 2010)



Still Variable Rainfall but Drier in the Mean

Most projections for the Caribbean suggest that by the end of the current century there will be less rainfall. The global models indicate that the region will receive anywhere from -1 to -20 per cent less rainfall over the course of a year by 2100 (bottom panel, figure 17). The regional models project slightly higher maximum mean drying in the main Caribbean basin by the end of the century – between 25% and 30% (Karmalkar et al. 2013; Campbell et al. 2010). The annual mean decrease in rainfall will be felt across the entire region without exception (figure 17), though not necessarily uniformly so. For example, the far north Caribbean (western Cuba and the Bahamas) may have smaller decreases in annual totals than the rest of the Caribbean basin.

The projected drying is most pronounced in the Caribbean wet season (May through October). In the early wet season (May through July), the GCMs project that by the 2080s, the western Caribbean is drier by 30–40% while the eastern Caribbean is drier by 20–30%. (The RCMs suggest the same pattern but with greater magnitudes up to 50%). By the late wet season (August through October), the proportional drying is 10–25% in the western Caribbean and 20% in the eastern Caribbean. Overall, the region around Haiti and the Dominican Republic shows the largest decrease during both periods. The larger projected decreases in rainfall in the early wet season smooth out the characteristic bimodal shape of the rainfall pattern in the western Caribbean but keeps the shape of the seasonal rainfall cycle unchanged in the eastern Caribbean. In comparison, the dry season experiences very little proportional decrease in rainfall, with even small increases in rainfall in the far northwest Caribbean, especially over the Bahamas.

The mean drying pattern will firmly establish itself towards the middle of the current century implying that, until then, variability (year-to-year, and decadal swings between drought and floods) will dominate the rainfall pattern, as suggested by figure 15. Even after mid-century, variability will likely still be a feature of the Caribbean pattern but superimposed upon the drying trend. By the end of the century, the GCMs suggest only a 3% chance of an extremely wet year compared to present day conditions but a 39% chance of an extremely dry year.

Some of the modelling studies also support the idea that the proportion of total rainfall in heavy events for most of the Caribbean decreases towards the end of the century, even as there are more dry days (McSweeney et al. 2010; Campbell et al. 2010).

The UNDP Country Profiles (McSweeney et al. 2010)[5] are a useful compilation of mean GCM projections of rainfall and temperature for individual countries for three future timeslices (2030, 2050 and 2080), using the SRES scenarios. Generally, the observations per country about their future rainfall regimes support the conclusions above. For example, they suggest that:

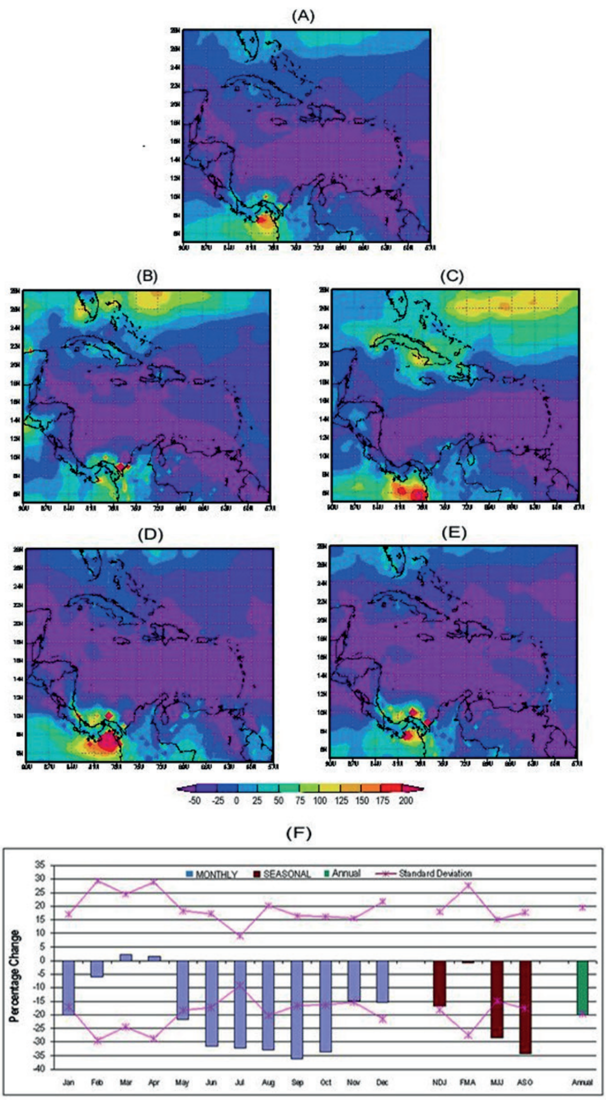
- By the 2030s the median change in rainfall for most countries hovers just below zero and it is towards mid-century that the projected long-term drying trend onsets. It is noted that it is when median values hover near zero that there is greatest uncertainty in the projections, as model consensus on a trend in one particular direction is low.
- The median decrease in rainfall is larger in magnitude for every Caribbean country examined towards the end of the century, that is, compared to near term projections.
- The median drying trend for most countries is robust in September, October and November, and comparable to the values for the annual drying. It is the drying of the normally wet period that is the most significant contributor to the overall drying.
- The pattern of drying appears to establish itself earlier in the countries of the eastern Caribbean, irrespective of scenario, with these islands also experiencing some of the greatest changes in rainfall amounts.
- Rainfall decreases in the northwest Caribbean appear to be slightly smaller than for the eastern Caribbean, and the Bahamas may not see an establishment of the dry pattern until later towards the end of the century.

5 http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/

Figure 17

Rainfall projections for 2071–2100 relative to the 1961–1990 percentage change is presented. Panels (a), (b), (c), (d), and (e) represent changes in annual, November–January, February–April; May–July, and August– October temperatures. Panel (f) shows monthly, seasonal and annual changes calculated by averaging over the basin. The solid red line represents one standard deviation as calculated from the observed data.

(Adapted from Campbell et al. 2010)



More Intense but not Necessarily More Hurricanes

The IPCC Special Report on Extremes (IPCC 2012) offers five summary statements with respect to projections of future hurricanes under climate change which are relevant to the Caribbean. They are listed in bold below. The IPCC notes that:

- **There is low confidence in projections of changes in hurricane genesis, location, tracks, duration, or areas of impact.** Where hurricanes form and their subsequent tracks are strongly modulated by known modes of atmosphere–ocean variability (such as El Niño events which tend to suppress tropical Atlantic storm genesis and development. The accurate modelling of these hurricane characteristics is therefore very dependent on a model's ability to reproduce these modes of variability. At present, that skill varies considerably across models and as such there is still considerable uncertainty in model-derived projections of these behaviours.

- **Based on the level of consistency among models, and physical reasoning, it is likely that tropical cyclone-related rainfall rates will increase under climate change.** Since water vapour in the tropics increases due to warmer surface temperatures, there is an expectation for increased heavy rainfall near the hurricane centre. Typical projected increases in rainfall rates for the late twenty-first century are +20% to +30% in the hurricane's inner core, and a smaller increase (~10%) at radii of 200 km or larger.

- **It is likely that the global frequency of hurricanes will either decrease or remain essentially unchanged.** Some recent research suggests that Atlantic hurricanes and tropical storms may decrease in number. Other studies do not suggest any change in frequency.

- **An increase in mean tropical cyclone maximum wind speed is likely, although increases may not occur in all tropical regions.** Modelling studies (for example, Emanuel 2007; Knutson et al. 2010; Bender et al. 2010) are consistent in suggesting that global warming will cause stronger storms by the end of the twenty-first century as measured by maximum wind speed increases of +2% to +11%.

- **While it is likely that overall global frequency will either decrease or remain essentially unchanged, it is more likely than not that the frequency of the most intense storms will increase substantially in some ocean basins.** Bender et al. (2010) project a 28% reduction in the overall frequency of Atlantic storms but an 80% increase in the frequency of category 4 and 5 Atlantic hurricanes over the next 80 years using a moderate emissions scenario. Knutson et al. (2013) show similar trends.

In summary, whereas it is not clear that the region will have more hurricanes, when they do form they are likely to be more intense.

Higher Sea Levels

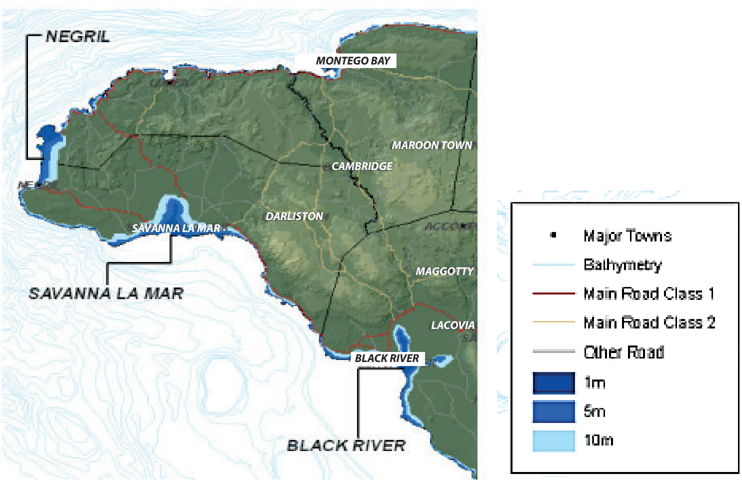
Table 6 provides a range of estimates for end-of-century sea level rise globally and in the Caribbean Sea under a number of scenarios. The combined range for the globe over all scenarios spans 0.18–0.51 m by 2100 relative to 1980–1999 levels. The future rise in the Caribbean is not projected to be significantly different from the projected global rise. A number of other studies (such as Rahmstorf 2007; Rignot and Kanargaratnam 2006; Horton et al. 2008, IPCC 2013), however, suggest that the upper bound for the global estimates is conservative and could be up to 1.4 m. The results of Perrette et al. (2013) suggest the same magnitude of change for the Caribbean Sea – a higher upper bound of up to 1.5 m by the end of the century. The mid-century change is projected to be between 0.24 and 0.30 m between 2046 and 2065 (IPCC 2013).

To grasp the sense of what a 1-metre sea-level rise could mean, figure 18 shows the coastal regions of western Jamaica that stand to be inundated because of storm surge associated with sea-level rise up to 10 m. Another study estimates that a 1-metre rise in sea level will affect some 8% of major tourism resorts in Jamaica while under a 2-metre rise, approximately 18% will be adversely affected (UN ECLAC 2011). To protect these resorts it is estimated that some 22 miles of coastal protection will be needed at a minimum cost of US$92.3 million to a high of US$993.8 million (UN ECLAC 2011).

Table 6
Projected increases in global mean sea level (m)

Source & Scenario	Global mean sea level rise by 2100 relative to 1980–1999	Caribbean mean sea level rise by 2100 relative to 1980–1999 (± 0.05m relative to global mean)
IPCC (2007) B1	0.18–0.38	0.13–0.43
IPCC (2007) A1B	0.21–0.48	0.16–0.53
IPCC (2007) A2	0.23–0.51	0.18–0.56
Rahmstorf (2007)	Up to 1.4m	Up to 1.45 m
Perrette et al. (2013)		Up to 1.50 m

Figure 18
Coastal vulnerability of western Jamaica to sea level rise/storm surge.
Source: Mona Geo-Informatics Institute



The Impact of Future Climate Change

Notwithstanding the attendant uncertainties associated with the science of climate modelling and projections, the resulting estimates of future climate provide a basis for impact studies. That is, a reasonable initial guess at how climate parameters will change facilitates attempts to quantify the resulting impact on the sectors and spheres of Caribbean existence, particularly in the face of inaction. A number of studies have been done (though still not nearly enough) on the future impact of climate change on the Caribbean region, with many focussing on critical livelihood and economic sectors (tourism, agriculture, water, health, energy) and the most vulnerable populations of the present and those likely to emerge in the future. For example, a series of recent studies by the United Nations Economic Commission for Latin America and the Caribbean (UN ECLAC) attempt to establish not just the physical impact but also the economic cost to the Caribbean associated with future climatic changes.[6] The studies assess 8 critical sectors across 14 countries.

The Appendix of this book includes a set of tables listing some current and anticipated effects of climate change on some of the key areas of Caribbean life, gleaned from a variety of sources. The tables should not be taken as a listing of all possible effects (since some cannot yet be anticipated) but rather, they should be considered as illustrating the range of possibilities under climate change. The tables highlight that the impact of climate change is a function of sensitivity and vulnerability and so, in as much as the latter are pervasive, so too will be the future impact of climate change. The impact of climate change will be ubiquitous – across all areas of Caribbean life – and this makes appropriate action in response to it a requirement as opposed to an option if quality of Caribbean life is to be maintained.

There are some other things about the nature of the impacts which are suggested by the tables and which must become important considerations when action in response to climate change is being contemplated.

1. In the face of inaction, the impact due to climate change *will likely only grow*, but will do so at different rates and be of differing magnitudes. The creeping nature of sea level rise and ocean acidification, or the gradual warming of temperatures or the slow onset of overall drier conditions will make some of the resulting impacts discernible only after a time, especially when the affected system is making gradual (and many times unconscious) adaptive adjustments to accommodate the changes as they are being experienced.

   This is particularly true of the impact on biodiversity: for example, the alteration in timing of growing seasons or changes in mating and

6 http://www.cepal.org/cgi-bin/getProd.asp?xml=/portofspain/noticias/paginas/0/44160/P44160.xml&xsl=/portofspain/tpl-i/p18f.xsl&base=/portofspain/tpl/top-bottom.xsl

reproductive cycles and the appearance of new invasive species or the decline in abundance or disappearance of species due to unfavourable conditions. Likewise, shoreline retreat, or increased or new incidence of certain diseases, decreasing viability of some livelihood options and migratory patterns of populations to avoid growing risk are also effects which share this characteristic. On the other hand, the impact of an intense hurricane on physical infrastructure or of prolonged drought on quality of daily life are likely to be more immediately devastating.

In either case action is required. There is a strong case for identifying and ongoing monitoring of appropriate indicators to track the impact of climate change and for the development of a suite of actions that are both anticipatory and responsive. There is also a case being made for concerted research spanning a range of disciplines to help better define the responsive action required.

2. A closely related point is that, in the face of inaction, the cumulative effect of compounding and concurrent impacts may result in *thresholds being attained and exceeded*. Beyond the thresholds, effects may snowball such that responsive actions as we now know them may prove limited or null in their effectiveness or just too costly to implement. Mora et al. (2013) try to determine the timing of 'climate departures' or the "year when the projected mean climate of a given location moves to a state continuously outside the bounds of historical variability". They suggest that disruptions in ecology and society may be tied to these dates. They show that unprecedented climates "will occur earliest in the tropics and among low-income countries, highlighting the vulnerability of global biodiversity and the limited governmental capacity to respond to the impacts of climate change". In some cases the climate departure date determined by Mora et al. (2013) is imminent. For example, temperature departures or the first year when even the coldest mean temperatures achieved thereafter is warmer than the warmest temperatures experienced to date, occur earliest in the tropics – in the early 2020s through to mid-2030s for the Caribbean (Table 6). Of all cities analyzed, Kingston will be the second city to reach this threshold (in 2023). Other climate departures, they determine, have already been exceeded. Mora et al. (2013) found that ocean acidity already exceeded its historic bounds in 2008 (give or take three years).

Table 7

The year of climate departure for selected world cities for two future scenarios
***Source:* Mora et al. (2013)**

Country	**City**	**High emissions scenario (RCP8.5)**	**Stabilization scenario (RCP4.5)**
Antigua and Barbuda	St. John's	2033	2047
Argentina	Buenos Aires	2066	2094
Australia	Perth	2042	2072
Bahamas	Nassau	2029	2041
Barbados	Bridgetown	2034	2046
Belize	Belmopan	2034	2048
Brazil	Rio de Janeiro	2050	2079
Cameroon	Yaounde	2025	2032
Canada	Ottawa	2047	2072
China	Beijing	2046	2078
Costa Rica	San José	2037	2058
Cuba	Havana	2031	2045
Dominica	Roseau	2034	2048
Dominican Republic	Santo Domingo	2026	2033
Germany	Berlin	2061	2090
Grenada	St. George's	2032	2042
Guyana	Georgetown	2029	2039
Haiti	Port-au-Prince	2025	2030
Jamaica	Kingston	2023	2028
Mexico	Mexico City	2031	2050
St. Kitts and Nevis	Basseterre	2033	2047
St. Lucia	Castries	2034	2047
St. Vincent and the Grenadines	Kingstown	2033	2046
Trinidad and Tobago	Port of Spain	2032	2044
USA	Orlando	2046	2074

Mora et al. (2013) further argue that the impact of climate departures is likely to be particularly significant on tropical biodiversity since regions like the Caribbean are not only home to the greatest diversity of species on the planet but also, the species are adapted to a stable climate with historically narrow bands of variability. It is very easy, then, for small changes to exceed what a species can tolerate. Species like coral already seem to be pushing up against their environmental limits (Wilkinson and Souter 2008).

There is a clear case being made for action – action characterized by urgency. The study by Mora et al. suggested a global departure date of 2047 after which the climate is going to move into a realm that has not been seen in the last 150 years. However, it also indicates that if GHG concentrations were to be stabilized to an 'optimistic' level (538 parts-per-million of atmospheric carbon dioxide), the global date of departure would be pushed back to 2069.

It is also to be noted that although Mora et al. emphasized climate-derived thresholds, it is not hard to envision that similar thresholds exist in the socioeconomic realm. There may be a similar departure point in time when it can be projected that the cumulative impact of climate change causes an index of development and/or quality of life to move beyond the range of historical variations and therefore requires the rethinking of current approaches to dealing with the particular issue. For example, the combined effect of accelerated sea-level rise and recurrent intense hurricanes will likely make current standards for design and siting of critical social infrastructure quickly move past their effectiveness. There will be need for new approaches to physical development and planning in regions like the Caribbean which have limited land space and high coastal to land ratios.

3. It is also evident from the impact tables that the effect of climate change is *unequally distributed and will disproportionately affect some sectors or communities* of peoples more than others. In the face of inaction some of the inequities which are already being seen will only increase as climate changes intensify. It is a recognition of this that is driving the call for special treatment of small island developing states (SIDS) in the Samoa Pathway, for example, and other similar global intergovernmental resolutions. The Samoa Pathway is the outcome document of the Third SIDS conference held in late 2014. The Samoa Pathway reaffirmed "that small island developing States remain a special case for sustainable development in view of their unique and particular vulnerabilities," and acknowledged that "climate change and sea-level rise continue to pose a significant risk to small island developing States

and their efforts to achieve sustainable development and, for some, represent the gravest threat to their survival and viability". The unequal distribution of the effects of climate change is also the basis for the push for dedicated international funding such as the Green Fund to support SIDS in actions aimed at mitigating against and adapting to the impact of climate change. Note that the idea is for targeted global action, with the target being the most vulnerable nations.

It is not hard to see that the latter principle of targetted action will have to be increasingly applied at the national level, especially where limited resources exist. For example, there are some sectors which are more vulnerable than others using the measures of sensitivity, exposure, and capacity to cope, and whose vulnerability will grow significantly and potentially faster, given the current projections. The water sector stands out given the almost exclusive dependence of Caribbean existence on rainfall and the speedy transmission of the rippling effects of drought throughout most areas of Caribbean life. Climate change is projected to reduce already limited water resources to the point that they become insufficient to meet demand during low rainfall periods (Cashman et al. 2010). There are other sectors that could similarly be identified for priority attention and action. Developing nations have been encouraged to identify these sectors in their periodic communications with the United Nations Framework Convention on Climate Change (see for example Jamaica's first and second National Communications).[7] It is stressed, however, that a call to prioritizing actions is not a call to inaction on the part of those not so prioritized but which will still be affected.

There are, likewise, some social groupings which will bear the disproportionate impact of climate change. The list of some of the most vulnerable is as alluded to before and includes the urban poor, subsistence farmers, the physically challenged, children and the elderly. In the economic sector this may include small businesses, and the natural environment could also be singled out as disproportionately burdened. All of these groupings have the least capacity to cope with the impact of climate change, which will only continue to diminish in the face of inaction. These groupings and entities must be prioritized

7 http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php

and targetted to enhance their resilience and ensure their survival. There must also be recognition, where possible, by these same groupings and entities, of their unique positions so that their vulnerability is considered when making decisions over which they have control – for example, in the use of resources available to them or as they attempt to build capacity. It is also not hard to see the potential for climate change to create social unrest when it exacerbates existing inequities or creates new ones. We can identify among the inequities unequal access to key resources or unequal access to climate information, which may put some at greater risk or give unfair advantage to others. During the droughts of 2010 and 2014, protests due to the lack of available water were not uncommon in Jamaica.

The Cost of Inaction

In the face of changing climate, there is a cost to inaction. Some studies have attempted to quantify that cost. The Stockholm Environment Institute (Bueno et al. 2008), for example, attempted an examination of the potential costs to the Caribbean if greenhouse gas emissions continue unchecked. The cost of inaction they define as the difference between an 'optimistic' scenario and a 'pessimistic' scenario. The former assumes the world begins taking action in the very near future and greatly reduces emissions by mid-century, with additional decreases through to the end of the century. In the pessimistic scenario (also called the 'business-as-usual' scenario), greenhouse gas emissions continue to increase rapidly through to the end of the current century. The difference between the two scenarios is interpreted as the potential savings from acting in time to prevent the worst economic consequences of climate change – or otherwise put, 'the cost of inaction'.

The Stockholm study projected costs based on three categories of climate change effects: (i) hurricane damage, extrapolated from average annual hurricane damage in the recent past; (ii) tourism losses, assumed to be proportional to the current share of tourism in each economy; and (iii) infrastructure damage due to sea-level rise and exclusive of hurricane damage, which is projected as a constant cost per affected household. Considering just these three categories, the study estimates that the Caribbean's annual cost of inaction will be US$22 billion annually by 2050 and $46 billion by 2100 or 10% and 22%, respectively, of the Caribbean economy in 2004.

For Jamaica, the costs as a percentage of 2004 GDP are: 13.9% in 2025, 27.9% in 2050, 42.3% in 2075, and 56.9% by 2100 (Table 8). Even if the numbers are conservative, the conveyed message is that inaction is costly.

Table 8

Cost of global inaction on climate change as a percentage of 2004 GDP for the Caribbean region

***Source:* Bueno et al. (2008)**

Country	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
The 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
St. Kitts & Nevis	16.0	35.5	59.5	89.3
St. Lucia	12.1	24.3	36.6	49.1
St. Vincent & the Grenadines	11.8	23.6	35.4	47.2
Trinidad & Tobago	4.0	8.0	12.0	16.0
Turks & Caicos Islands	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%

The picture that emerges, then, is one of a region whose future sustainability is threatened in the face of inaction. The goal of sustainable development, when seen as a balance of the traditional pillars – the economic, the social and the environmental – is significantly challenged under future climate change and in the face of inaction. Climate change will have a profound impact on the Caribbean region's geophysical, biological and socioeconomic systems and will deplete national budgets, compromise livelihoods and exacerbate poverty. Climate change has the potential to offset any gains made in the pursuit of priority development objectives such as food security, access to basic services such as clean water, sanitary living conditions and energy, education, and combatting poverty. Among other things, climate change will transform the environment into a hazard and as such, economic development cannot be premised on it as is currently the case in many of the islands of the region. Jamaica's goal to become the place of choice to live, work, raise families, and do business by 2030 is under threat from climate change.

The projections of future climate make the clear case, then, for action which is – among other things – anticipatory and responsive, urgent and timely, and targetted and transformative. In light of this, climate change must be afforded more than passing attention and must be more than just a consideration in regional planning. Instead, there must be deliberate and sustained efforts aimed at the incorporation of climate change into the development plans of all the countries of the region. This is explored in the final chapter.

Chapter 4
A climate for change
Urgent Priority

Climate change is an issue of our times – one that the Caribbean cannot avoid contending with, preferably through voluntary action, now as opposed to later, and with a paradigm shift in thought and action equivalent to the shift necessitating it. – Taylor et al. (2012)

In Pursuit of Resilience

In the face of the region's inherent sensitivity to climate, its growing vulnerability, and the threat posed to its future sustainability, *climate clearly demands change. But what kind of change is being demanded*?

First, there is a demand for a change in how we perceive the issue of climate and in the importance we place on the issue. We cannot keep doing things as we have always been doing them – not acknowledging the impact and real threat of climate change to Caribbean existence as we now know it.

It is fair to say that as a region we have been making some real and commendable strides with respect to this demand. In some respects the region may be seen as a global leader in this regard. For example, the formation of the Caribbean Community Climate Change Centre (5Cs) in 2005 by CARICOM is evidence that the region recognizes the need for sustained attention to the issue. The mandate of the 5Cs is to coordinate the Caribbean region's response to climate change. An important output has been the development of a regional framework plan (Box 4), which is meant to provide the member countries of CARICOM with a strategic approach for coping with climate change.

Box 4: Regional Framework for Achieving Development Resilient to Climate Change

At the request of CARICOM Heads of State participating in the First Congress for the Environmental Charter and Climatic Change, held at Ávila Mountain, Caracas, 11–13 October 2007, the Caribbean Community Climate Change Centre prepared a **Regional Framework for Achieving Development Resilient to Climate Change**. The framework was approved in July 2009, and defines CARICOM's strategic approach for coping with climate change. It is guided by five strategic elements and some 20 goals designed to significantly increase the resilience of

the CARICOM member states' social, economic and environmental systems. It provides a roadmap for action by member states and regional organizations over the period 2009–2015, while building on the groundwork laid by the Caribbean Community Climate Change Centre (CCCCC) and its precursor programmes and projects in climate change adaptation. It also builds upon the extensive work undertaken by governments, regional organizations, NGOs and academic institutions in recent years assessing the impact of a changing climate. The strategic elements of the framework are: (i) mainstreaming climate change adaptation strategies into the sustainable development agenda of CARICOM states; (ii) Promoting the implementation of specific adaptation measures to address key vulnerabilities in the region; (iii) promoting actions to reduce greenhouse gas emissions through fossil fuel reduction and conservation, and switching to renewable and cleaner energy sources; (iv) encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impact of a changing climate; and (v) promoting action to derive social, economic, and environmental benefits through the prudent management of standing forests in CARICOM countries.

To take forward and deliver the strategic elements and goals identified in the Regional Framework, the Heads of Government subsequently mandated the preparation of an Implementation Plan for the framework. The Implementation Plan was approved in 2012. It defines the region's strategic approach for coping with climate change for the period 2011–2021 and involves: (i) establishing how regional and country bodies will work together; (ii) securing investment to support the action plan; and (iii) proposing a monitoring and evaluation system.

Both the Framework and the Implementation plan are available from the CCCCC website http://www.caribbeanclimate.bz . Text adapted from CCCCC website.

At the national level, in 2011 Jamaica set up a ministry with climate change as part of its name and mandate, while several Caribbean countries have special units devoted to climate change, with many of them strategically sited (for example, in the Office of the Prime Minister) to emphasize the importance placed on the issue. Additionally, many countries have developed or are developing national climate change policies and many ministries or coordinating regional entities have developed or are developing specific action plans for dealing with climate impacts (examples are the Caribbean Regional Fisheries Mechanism (CRFM), Caribbean Agricultural Research and Development Institute (CARDI) and the Caribbean Public Health Agency (CARPHA)).

Significant strides have also been made in regional climate science. At the turn of the current century, there was a dearth of climate change science information for the region and of information reflective of the small island scale. There has been a concerted effort by regional universities and regional scientists to fill this gap. The PRECIS project referred to in Chapter 3 is a good example of this. The legacies of the effort include awareness and better understanding of how climate is changing on varying timescales and a body of climate science knowledge relevant to the Caribbean region, which can be drawn upon for designing strategies and decision-making.

As a result of the initiatives and efforts noted above (and others), it is becoming increasingly clear that there needs to be a widescale response by, and from within the region, to climate change. The initiatives and efforts are helping to make the case that action is an imperative and not an option. Importantly, the initiatives and efforts are also helping to make it clear that the goal of the region's response to climate can only be one thing – building climate resilience. When climate resilience is achieved the system has the capacity to absorb, maintain function and move beyond the external stress imposed on it by the changing climate regime. Climate resilience is the goal and must be at the heart of the region's response to climate change.

It is fair, then, to say that some of the pieces are falling into place, though one cannot claim that the efforts and initiatives are sufficient or even nearly enough. In spite of having had the benefit of at least two decades of heightened awareness about the issue one cannot define the Caribbean region as resilient and one may be even hard pressed to suggest that it is far along the path to resilience. In one sense, this is understandable since we are only just coming to an understanding of how climate change is unfolding and manifesting itself in the region. Yet, on the other hand, one can understand the desire for greater evidence of resilience taking root, especially since regional and national initiatives with good goals and reasonable achievements and which targetted climate change can be traced back to at least the 1990s (see Table 9).

Table 9

Examples of recent regional climate change initiatives which have yielded action plans or recommendations for building resilience to climate change.
***Source:* CCCCC (5Cs), http://caribbeanclimate.bz/projects/projects.html**

Initiative		**Objective**
Caribbean Planning for Adaptation to Climate Change Project (CPACC)	1997–2001	Build capacity in the region for climate change, vulnerability assessments and adaptation planning.
Adaptation to Climate Change in the Caribbean Project (ACCC)	2001–2004	Increase technical capacity of regional climate research groups, formulate adaptation strategies for health, food and water risks, include climate change in physical planning and increase public awareness.
Mainstreaming and Adaptation to Climate Change (MACC)	2004–2007	Cost-effective identification and reduction of climate risks and vulnerability and increase in public awareness.
Special Programme on Adaptation to Climate Change (SPACC)	2007–2011	Support the implementation of pilot adaptation projects in St. Lucia, Dominica and St. Vincent and the Grenadines in response to the impact of climate change on natural coastal resources.
Pilot Project for Climate Resilience (PPCR)	2010–	Provide incentives for scaled-up action and transformational change in integrating consideration of climate resilience in national development planning consistent with poverty reduction and sustainable development goals. Regional pilots: Dominica, Grenada, Haiti, Jamaica, St. Lucia, St. Vincent and the Grenadines, as well as regional track.

A reflection on the regional response to date suggests that even with our current efforts at recognizing the importance of climate change as an issue, we are still doing many things the way we have always done them. This, even as our present climate is nudging us (in the case of gradual change) or pushing us (in the case of unfamiliar extremes) to even greater change. The very climate that has forced itself to the fore and demanded that it be an issue to contend with is now also demanding that we stop and take stock of how we have been doing so.

At the very least, there seems to be a disconnect and/or inconsistency between our recognition of the magnitude and scope of the problem and the nature of our response. Urgency, scope, and widescale commitment (by all stakeholders, not just governments) seem to be gaps in our present response strategy. Taylor et al. (2012) suggest that, "Climate change is an issue of our times – one that the Caribbean cannot avoid contending with, preferably through voluntary action, now as opposed to later, and with a paradigm shift in thought and action equivalent to the shift necessitating it." The shift may be happening but the paradigm shift may not have occurred as yet. Our present climate is suggesting that recognition is no longer sufficient if resilience is to be achieved.

Moving Beyond Recognition

Part of the problem is that even with recognition, our attitudes may still be a stumbling block to resilience. Our current attitudes towards climate change seem to be a mix of some or all of the following:

1. **Complacency.** The creeping nature of some of the climatic changes seen trigger complacency toward them. With complacency, there is recognition of the change – for example, a strong feeling that the summer nights are the hottest we have ever felt – but this is followed by an accommodation of the change, perhaps by getting a fan which is then used all night. The danger with accommodation is its emphasis on getting through the present stress without much thought for the changing nature of the threat. That is, when complacency sets in we simply accommodate the climate change, not recognizing that climate change is making no similar effort to accommodate us. Accommodation very often premises itself on the easiest or most convenient option, which may not be the best option for long-term resilience. Complacency therefore leaves us unprepared for possibly more extreme manifestations of the threat in the future or the exceedance of a climate threshold and, in so doing, does not facilitate resilience building.

2. **Amnesia.** There is often an "out of sight, out of mind" attitude to climate, in particular to its extremes. With this mindset, the focus is on handling the current discomfort (for example, the impact of a prolonged drought), which may even be accompanied by longer term plans for dealing with the underlying issues when the immediate crisis is over (for example, plans for new water storage facilities). Amnesia, however, preys upon the relief offered by the end of the crisis, which is usually accompanied by putting aside the long-term plans or gradually forgetting the discomfort once normality is attained. The cycle is then repeated at the next occurrence of the threat. The danger with amnesia is that it engenders a shortsighted approach to climate and it does not recognize that under climate change the next manifestation of the extreme may render the strategies used the last time ineffective. In that respect, it leaves us always unprepared and in a 'catch-up' mode, and does not facilitate resilience building.

3. **Minimization.** The quoted magnitude of the climate changes seen to date can seem small – a 1^{o}C rise in temperature over a century or a sea-level rise rate of 1.9 mm every year. This sometimes leads to the impact being interpreted as insignificant and a minimization or dismissal of the threat, or the feeling that there is still sufficient time to deal with the issue before it becomes a 'real' threat. To minimize the threat, however, is to overlook the compounding effect of climate change; for example, small changes in ocean surface temperatures significantly increase the strength of tropical storms and hurricanes, or small rises in sea level magnify the storm surge as well as to miss the fact that the change will not always be so invisible or minimal and easy to overlook. A mindset of minimization leaves us unprepared for both present and future threats and does not facilitate resilience building.

4. **Resignation.** Taken in tandem, the projections (higher temperatures, variable and less rainfall, stronger hurricanes, and rising sea levels) present a daunting picture of the future world which can lead to inaction as a result of a sense of fatalism – despondency about what can be done anyway. In another sense, the coupling of the projections of devastation under climate change and interpretations of end-time conditions by some faith communities can similarly evoke resignation since the impact of climate change is then seen as inevitable.

Resignation, however, ignores the fact that climate change is a game-changer with the potential to significantly alter life as we now know it. The inaction that resignation engenders then marginalizes the rights of a future generation to at least the same quality of existence as the current generation. In so doing, resignation can act counter to efforts to build resilience.

5. **Uncertainty.** The Jamaican government commissioned a Knowledge, Attitudes and Practices Behavioural Survey in 2012 as part of its preparation activities under the Pilot Project for Climate Resilience (PPCR) (PIOJ 2012). Of the National Household Survey sample, most people (82.6%) indicated that they had heard the term 'climate change,' with most (56.4%) also able to associate it with a variation in global climate, temperature or weather patterns. However, the majority also indicated that they did not know much or anything about the risk it posed to their community and that they had no idea or were not sure what could be done to prevent or lessen the effect of climate change on the community. Uncertainty can sometimes be the enemy of action as opposed to the impetus for action, as it provides an excuse for doing nothing. The tentativeness it produces slows down efforts aimed at resilience building, particularly when urgent and decisive action is required.

The danger posed by the aforementioned attitudes is that they all acknowledge that the climate is changing (as opposed to, for example, denying the existence of climate change), yet still lead to an underestimation of the scope of actions needed to prepare for present and future climate regimes. Complacency leads to a lack of proactive preparation; amnesia leads to a lack of adequate preparation; minimization leads to a lack of urgent preparation; and resignation and uncertainty may lead to a lack of any preparation at all. Present climate demands a change of attitude, even in the face of recognition of its importance, if resilience is the goal.

Taking Some Things into Consideration

When our attitudes are such that we move beyond recognition of climate change as an issue, the previously noted imperative to action comes into play. Our current climate is demanding that if the action is to build climate resilience, then it cannot always be impulsive or reactive (although reactive action is a necessary part of the response to climate given its unpredictable nature); rather, it must be skewed towards careful and thoughtful action which takes some things into consideration. Resilience-engendering action should give consideration to at least the following things:

1. **Letting the risk guide the response.** There is significant value in undertaking vulnerability risk assessments as they help define the scope of the response needed. With this approach, the nature and scope of the response is, as best as possible, guided by research and science. The case is therefore being made for data gathering and monitoring, where the data is climate, socioeconomic and biophysical data. The case is being made for coordinated and supported research to enhance our understanding of how the climate is varying, the socioeconomic and biophysical linkages with climate, and the boundaries within which the effects will manifest themselves. When research is used to define the risk it provides the justification for the responsive action, it helps to target the response, and it inspires confidence that the response will be effective even though climate is unpredictable.

2. **Prioritizing adaptation in response.** Even if there were global consensus to stop greenhouse gas emissions today, there would have already been a commitment by the world to climate change due to the residence time of the GHGs already emitted in the atmosphere. Adaptation to the new and emerging climate regimes is rightly recognized as a priority and a no-regrets option in the CARICOM framework for building resilience (Box 3). Whereas seemingly credible arguments can be given to delay mitigation as an action (see point 3 below), the region's inherent climate sensitivity and growing vulnerability make adaptation a necessity.

   Since the region's sensitivity and vulnerability are pervasive, adaptation strategies must target all spheres of Caribbean life. This justifies a sectoral approach to response strategies (for example, agriculture, tourism and water) as has been the general strategy throughout the region. The sectoral approach facilitates prioritizing response in the face of resource constraints, and further makes the case for coordinated data-gathering and research, particularly research which refines the climate–sectoral linkages. Table 10 provides examples of some sectoral adaptation strategies proposed for the Caribbean region.

Adaptation is not for governments alone to do, and there are growing calls, for example, for the private sector to recognize its own need to adapt to the new and emerging climate regimes of the present and the future. Creation of adaptation plans by the private sector is as much for their own sake as for the sake of the entire country through the contribution a viable future sector would make to national sustainability and development. A number of farming communities across the Caribbean have also recognized the need to adapt – see, for example, *Good Practices: Disaster Risk Reduction Case Studies from Jamaica* (CSGM 2013) – and are doing so to their benefit. Examples of their actions include modification of their planting techniques, establishment of community water catchment tanks, the formation of farmers' cooperatives, and the use of greenhouse farming.

There are multiple models for planned adaptation (see, for example, Tompkins et al. 2005). A scan of the various national plans reveals a wide profile of actions which are, as would be expected, "necessarily broad and varied and determined by a number of factors, including the intended target of the proposed action (individual, community, national, regional), the underlying purpose of the action (coping versus surrender or retreat), the ability to resource the action, and the 'driver' of the action (top-down, government-led models or bottom-up, community-driven)" (Taylor et al. 2013). Whatever the model, adaptation must be a feature of a resilience-building response.

Table 10
Examples of sectoral adaptation strategies and actions proposed for the Caribbean region

Sector	Adaptation Strategies and Actions	Reference Documents
Water	Establish an agency to execute integrated water resources management.	National Adaptation Strategy to Address Climate Change in the Water Sector in Belize (Belize Enterprise for Sustainable Technology 2009).

	Strengthen the existing human resource capability and capacity in the water sector for improved management practice.	Development of a National Water Sector Adaptation Strategy to Address Climate Change in Jamaica (CCCCC 2009).
	Increase public awareness and education on water culture and climate change.	
	Investment in hydrological and water quality monitoring, and dissemination of data to the stakeholder community.	
	More integration and stricter enforcement of physical planning laws and regulations to reduce risks to life and property from extreme rainfall and coastal flooding events.	
	Identify and replicate best practice programmes in local community and stakeholder engagement.	
	Continue programmes to increase efficiency in water storage and delivery systems.	
Agriculture	Develop and identify, by 2017, drought- and flood-resistant, and salt- and temperature-tolerant varieties of staple and commercial crops, drawing upon local and indigenous knowledge, for commercial use. Regionally-coordinated activity, undertaken in all Caribbean countries.	An Assessment of the Economic and Social Impacts of Climate Change on the Agriculture Sector in the Caribbean (ECLAC 2013)
	Develop and promote new and alternative food supplies and/or sustainable production systems, including sustainable land management.	
	Implement fiscal and other policies and incentives to allow farmers and the private sector to invest in agriculture and food production in the Caribbean	
	Initiate Caribbean Community public education, awareness and outreach programmes on food, nutrition and health in the context of climate change. Create an enabling environment to facilitate behavioural change via fiscal incentives.	
	Develop and implement strategies to secure, store and distribute food supplies and germplasm, particularly for use during low production periods and at times of natural disaster and other emergencies.	

Health	Improve post-disaster prevention measures through collaboration of relevant health sector stakeholders and the Office for Disaster Preparedness and Emergency Management.	Climate Change Risk Profile for Jamaica (CARIBSAVE 2012).
	Build a supply of public health resources for the surveillance, prevention and control of vector-borne diseases.	
	Improve the use of technology in the health sector through, for example, (i) early disease warning systems, and (ii) the use of alternative energy sources such as renewable energy (wind, tide and solar) to improve the resilience and stability of basic utilities.	
	Conduct assessments focussing on the links between health, tourism and climate change.	
Tourism	Create conditions to enable adaptation: for example, increase awareness of the dangers of climate change and the urgency for action.	An Assessment of the Economic Impact of Climate Change on the Tourism Sector In Jamaica (ECLAC 2011b).
	Integrate adaptation with development, for example, policy options will have to be considered for tourism infrastructure in a variety of areas such as: (i) designs may have to be encouraged to deal with alternative methods of cooling buildings in increasingly hot climates to counteract rising energy costs, and (ii) physical planning issues will require building lines to be moved back from eroding coasts.	
	Protect natural resources, for example by: (i) building sea walls to protect against storm surges or, alternatively, explore ecological options for protection (for example, vegetated sand dunes) rather than heavy infrastructure, (ii) developing management plans for coastal and wetland attractions, and (iii) planning strategically for inland tourism development zones to provide alternatives to coastal tourism land use policies.	

Energy	Establish regional and national targets for the reduction of greenhouse gas emissions in the energy sector and implement appropriate mitigation actions relevant to the energy sector.	CARICOM Energy Policy (CARICOM, 2013)
	Ensure the sustainability of the electricity sector through increased use of renewable energy, improved legislative and regulatory framework and cross-border trade of electricity generated from indigenous renewable energy sources.	
	Ensure that energy is supplied and consumed in a manner that creates minimal adverse impact on the environment.	
	Develop and implement a regional strategy to develop and maintain strategic regional reserves of crude oil and energy products to be accessed in time of emergency or crisis.	
	Support the development and implementation of a regional rapid response strategy for the restoration of electricity facilities.	
	Collaborate to develop a comprehensive energy sector disaster response plan focussed on all technologies deployed in the region.	

3. **Prioritizing mitigation in response.** The severity of the climate change threat is dependent on the levels of GHG concentration in the atmosphere. There is no global consensus as yet on what the future levels must be but the Alliance of Small Island States (AOSIS) has called for targets that will limit the mean temperature increases to no more than 1.5°C (AOSIS 2009). Proposed limits (whether by AOSIS or others) are seen as 'tipping points' beyond which small changes in temperature will cause irreversible consequences. Achieving these limits is dependent on mitigation – actions that can be taken to reduce greenhouse gas emissions.

   Many argue that reductions in GHGs must primarily be the responsibility of the big emitters – the USA, EU, and China – and that the Caribbean should have no burden placed on it to reduce its emissions as it is a minor emitter of GHGs and deserves a chance at industrial development. It seems incongruous, however, that the

Caribbean should absolve itself of the shared global responsibility to cut GHG emissions when it is amongst the most vulnerable to the consequences if emissions are not reduced. If anything, it seems that the region should consider carefully and even propose its own models for differentiated mitigation targets for developed versus developing countries. Since current emission levels are unsustainable, all countries will eventually have to cut back on emissions. It is prudent, then, that small islands like those in the Caribbean which are in development mode should factor mitigation responses now into their suite of responses.

For the Caribbean, mitigation should target preservation of forests, waste reduction, and all areas of energy usage: electricity generation, road, shipping and aviation transportation, industry and building. In the latter case, reduction in GHG emissions would come from a combination of more efficient use of fossil fuels and greater use of renewable energy technologies. A transitioning to a low-carbon economy would have the spin-off effect of reduced economic costs, increased productivity and improved quality of life. It would be a win–win for the region. Mitigation as a response strategy lends itself to coordination by national governments and regional policy-setting and economic groupings. However, it is also the response strategy that best links individual responsibility and corporate good. For example, efficient use of electricity, recycling of waste and the planting of trees all reduce carbon emissions, contribute to sustainable development, and link the individual to the global. More use should be made of this characteristic of mitigation in the region.

4. **Climate change is not the only game in town.** There are limited resources for development in most Caribbean countries. The same resources must eradicate hunger and poverty, fight crime, provide equitable access to education, health services and basic amenities (water, electricity and sanitation), achieve gender equality, build resilient infrastructure to disasters (climatic and non-climatic), treat with social injustice, sustain consumption and production patterns, protect and restore terrestrial and aquatic ecosystems, and deal with climate change. The cost of adaptation is great (Table 11), though the cost of inaction is higher (– see again Table 8), and in that respect

climate change may be required to play second fiddle to other equally pressing developmental goal costs.

Table 11

Estimates of adaptation costs in developing countries for 2010–2015
***Source:* Agrawala and Frankhauser (2008)**

Source	US$ billion p.a.	Comments
World Bank (2006)	9–41	Cost of climate-proofing foreign direct investment, gross domestic investment, official development assistance flows.
Stern (2006)	4–37	Update with slight modification of World Bank (2006).
Oxfam (2007)	>50	Based on World Bank, plus extrapolation of costs from national adaptation programmes of action and poverty reduction strategies.
UNDP (2007)	86–109	World Bank, plus costing of poverty reduction strategy targets and better disaster response.

However, because climate change has the potential to influence all of the other development goals due to its pervasive nature and to continue driving up the attendant costs to pursue such goals in the future, there is great merit in exploring the synergies between responding to climate change and the pursuit of a sustainable development agenda. That is, many of the adaptation strategies suggested in Table 10 are identical to the kinds of action that are needed to ensure sustainable development. Careful consideration and deliberate exploitation of the overlap between potential responses should be done at the point of response formulation. Leveraging the synergies will ensure that limited resources are most efficiently used and have maximum impact. A similar kind of consideration should be given to the overlap between climate change response strategies and those needed for disaster risk reduction.

5. **Well-intentioned responses can unfairly disadvantage.** It has already been noted that some groupings are more vulnerable than others and as a result, impacts of climate change are disproportionately distributed. At the level of social groupings, it is also not hard to see that it is the poor who have limited ability to cope with climate risks due to inadequate access to proper shelter, health care and nutrition. Their limited resources also hinder their ability to easily recover from climate

disasters. Parts of the ecosystem are similarly more vulnerable, including plants and animal species which are under threat due to alterations of the climatic envelope in which they survive. In a real sense, climate change singles out the already disadvantaged.

In crafting mitigation and adaptation responses care must be taken not to further disadvantage the already disadvantaged or create new disadvantaged groups. Diverting or damming rivers or streams to create new domestic water sources for urban regions might put at a disadvantage those who, upstream, already depend on them or the ecosystems they support for their livelihood. Providing a paid service for the delivery of trucked water during prolonged periods of drought places those who cannot afford to pay at a disadvantage. Similarly, access to information is not equal even in the age of technology, and so providing a climate service, for example, a climate forecast or pricing and market information to farmers must, as best as possible, be mindful of the inequity and strive to provide equal and timely access to the information and service by all. The response should not unfairly put one set of stakeholders at an advantage or disadvantage simply because of the side of the divide on which each falls.

The ethics of responding to climate change are not consistently examined or routinely discussed as part of response strategies. There should be, as best as possible, fairness in the distribution of both the burdens of climate change and the benefits of appropriate response.

6. **Education is critical to ensuring buy-in.** Since adaptation inevitably demands a change in behaviour and/or thought, response strategies must factor in public education and awareness. Awareness engenders change and it is a change in attitude and approach that is being demanded. Since response strategies will target multiple levels of society, public education and awareness must similarly target all levels (such as government, community and individual) and all ages, and must utilize traditional (such as newspapers, radio, television and workshops) and newer communication methodologies (for example, cell phones and social media groups). Educating those most likely to be affected by a response strategy about why the strategy is necessary engenders buy-in and helps facilitate commitment to the effort and its eventual success.

7. **Targetting present variability as a means of responding to future change.** Climate change has the characteristics of unfamiliarity and unpredictability and there are limitations to what present science can tell us about what might happen in the future. Additionally, even when the climate risk is already known the resources may not be adequate to account for the climate change factor (for example, the increase in intensity of the next storm due to climate change). In these instances, inaction may still not be the best option. Rather, options premised on present-day variability of the climate should be considered as they will dampen the effect of the future threat even if they fall short. A well-formulated, present-day response to recurring and prolonged drought might put a community in better stead to tackle the later onset of the long-term drying trend than if no response was attempted at all.

   There is always a possibility, however, of creating new risk, by giving a false sense of resilience. Some actions might help today but be ineffective in the long run. For instance, the World Bank notes that, "coast-defending mangrove plantations may not survive sea level rise or salinization," or "small dykes that protect lowlands from chronic floods might encourage settlements that would then be threatened by more severe floods". In these instances where the response strategy is formulated in the absence of full knowledge of the risk, there is value in ongoing monitoring to measure the first sign of a threat.

8. **Risk-taking may be a demand of climate.** Some responses may require a risk to be taken to deal with the growing threat of climate, especially when the threat is moving outside the bounds of what is known. This is particularly true when the known response strategies are proving to be no longer sufficient and/or cost-effective. When a risky response is seen as the only option, education of those likely to be affected about the consequences of its success or failure is paramount. So, too, is careful consideration of the ethics of action or inaction and continuous monitoring, data gathering and scientific analysis. Risk is not careless when supported by these considerations.

Incorporation Is the Key

In the end, however, the greatest hindrance to the region's resilience-building efforts may be the lack of sustained responses to climate change. Many countries in the region are stuck in the 'consideration' mode. Responses to climate are considered only when they are part of a project, are externally funded as a pilot project, after an extreme event and when there is no other option, for political expediency or as an afterthought or 'add-on' after the other 'real' problems are dealt with. When this is the case, the response to climate change comes in fits and starts and the resilience built is sometimes quickly eroded thereafter because it was tied to the project funds or duration; did not have the widescale commitment of all affected stakeholders; did not adequately address the consequences of the actions taken because of initially limited resources; did not find a way to institutionalize the benefits gained; or was not part of a broader plan of action. The resilience engendered from a reforestation project aimed at slope stabilization and livelihood protection or from shoring up a coastal road will be lost if the behaviour and subsequent livelihoods of those initially responsible for cutting the trees are not also addressed, or there is no process for subsequent monitoring and maintenance of the shoreline structure. Similarly, the resilience engendered by a new channel built with project funds to quickly drain excess water in intense rain events or a revised policy on setbacks will be quickly eroded if waste management is not also considered to prevent the channel from being blocked by garbage or if enforcement mechanisms are not put in place.

To overcome this, in part, climate demands incorporation into our daily planning. That is, present climate is demanding not just recognition or consideration when convenient but also, among other things: (i) an everyday awareness of climate change as an issue; (ii) a reasonable understanding of the risks posed by climate variability and change; (iii) a foreknowledge of the gaps which need to be filled to ensure resilience (and which should be the target of project funds); (iv) the explicit accounting for of climate when new decisions (big or small) are being made that will affect development, livelihoods and daily living; (v) a proactive approach to mitigating against yet to be manifested threats, including an identification of potentially beneficial partnerships; and (vi) the active seeking out and grasping of opportunities to build resilience within the context of an already articulated vision for coping with the climate threat. Otherwise put, there is a demand for the mainstreaming of climate consideration into daily activities to ensure that resilience built by responses, as best as possible, is sustained. The act of mainstreaming attempts to routinize the consideration of climate. There must be mainstreaming of climate into the plans and daily operations of everyone – individual households, physical communities and communities of like mind or purpose (such as churches and schools), the private and public sectors, and governments and regional bodies.

Interestingly, with mainstreaming comes the possibility of being ahead of the game – through the foreknowledge it engenders as a result of active consideration of both the threat and the needed response to ensure resilience. There is, therefore, the chance of capitalizing on possibilities as they present themselves for building resilience (for example, funding opportunities) and even capitalizing on the opportunity the very changes in climate may bring (such as new business opportunities from the demand for efficient cooling). Mainstreaming, then, provides the opportunity for climate to be a contributor to the development process as opposed to derailing it. Undoubtedly, mainstreaming will take effort and, as has been shown by current response efforts, will not be automatic. However, it is perhaps the key to accelerating the resilience-building effort and the region's sustainability. Mainstreaming, then, is an urgent priority.

Some Recommendations

Mainstreaming benefits from finding entry points in existing activities and either inserting new actions to fill a gap or strengthening existing actions so that the net result is greater resilience. This chapter closes by offering some recommendations for building resilience among Caribbean nations, which can be immediately acted upon even in the face of limited resources. The first two recommendations are for a strategy and an activity directly related to climate change. However, the other recommendations target existing activities or strategies not necessarily overtly linked to climate but which, if prioritized, refocussed, strengthened or accelerated, would engender resilience. Governments are the natural focus; the Jamaican 2012 Knowledge, Attitudes and Practices Behavioural Survey shows that 80% of the people feel that the government should be doing more to deal with climate change. They are the focus only because of the reach that they have and the potential to affect entire populations. Notwithstanding, many of the recommendations rely on and can be acted upon by sub-national groupings including individuals, communities of all kinds, and the private sector.

The list is not to be taken as comprehensive but rather suggestive of 'low-hanging fruit' which can have a great impact with respect to building resilience to climate change. There is no prioritizing intended in the ordering of the recommendations.

1. **Climate Change Education for All.** There should be dedicated effort aimed at finding all entry points to educate about climate change. Since the impact is on all, education must be for all and by all and not just left to governments. Advantage should be taken of opportunities for sustained education, for example, writing climate change into the curricula of the formal educational process (basic school through to university), into professional training courses, into continuing education credits and into Sunday and Sabbath schools. Advantage should also be taken of the occasional opportunities – community meetings, service and youth clubs, camps and company retreats. Multiple modes, media and messages should be employed. Contextually relevant material should be commissioned and made easily accessible and a special effort made to target the most vulnerable groupings.

2. **A Climate Change Response Registry.** When response is: (i) so dependent on external funding as it is now, (ii) often project-based, and (iii) being initiated at various levels (community to regional), then coordination of climate change activities becomes critical to leveraging the current situation for maximum efficacy. A registry should exist where all climate change activities irrespective of scale or initiator are registered. This would serve multiple purposes, including: building awareness of ongoing activities and the creation of a simple listing to prevent the duplication of effort, leveraging diverse efforts to fill a gap or ensure sustainability of the resilience built, offering templates of possibilities for those contemplating response, and providing a starting point for those considering future actions to access or be pointed to available resources.

3. **The Strengthening of Community Groupings and Community Governance.** Community groups are often the first responders to extreme situations and, outside of disasters, represent sustained 'on the ground capacity'. Encouraging vibrant community groupings of whatever form and investing in the strengthening of community governance through all levels, up to the local government level, will have the spin-off effect of facilitating resilience or at least creating a

scenario that can be exploited for resilience building. For example, community groups can assist in: (i) environmental governance, since the environmental resource is often within the communities, (ii) sustained monitoring and data gathering in support of early detection and warning of creeping climate threats, (iii) immediate response in extreme climatic situations especially when the terrain makes response difficult, and (iv) the dissemination of information. Strengthening community capacity is building resilience.

4. **Promoting Values and Attitudes.** Stewardship, equitable and fair use of resources and the common good are important principles in sustainable development. These principles also provide, in the face of climate change: (i) a justification for individual through to national response, (ii) overarching guidelines when formulating individual through to national responses, and (iii) overarching guidelines for behaviour and decision-making in the midst of or in the aftermath of a climatic threat. An ongoing values and attitudes campaign can contribute to the resilience-building effort. There is the potential for faith-based communities to take the lead in this effort.

5. **Prioritizing Water.** There is already evidence that water is likely 'the issue of climate change' for an already water-stressed Caribbean region. Because of its direct and cross-cutting nature (water impacts agriculture, quality of life, energy, development, health, livelihoods and ecosystems, among other things) any attempts to ensure water security (even independent of climate change) are also direct attempts at building climate resilience – both in the water sector and across the other spheres of Caribbean life and existence in which it factors. Prioritizing must target all levels of society and be undertaken by all levels of society. Prioritizing includes emphases on efficient capture, storage, distribution and usage and the preservation of water sources. Moderate investments, financial or otherwise, done now with respect to water by governments, the private sector, communities and individuals will yield exponentially bigger and more beneficial results, particularly when it comes to climate resilience.

6. **Prioritizing Transportation, in Particular, Roads.** Roadways are critical for linkage and access. Coastal roadways, which are already under threat in many regions, are often the only way to move people, water

and goods around. Prioritizing their shoring up, as well as maintaining or building new interior roads (and highways) which facilitate coast-to-coast access are important development strategies which have the spin-off effect of building resilience. Under climate change there is need for quick and easy movement of people and supplies, whether to the point of greatest need or away from an imminent threat. Efficient movement is also a mitigation strategy through reduction of emissions. The rehabilitation and construction of roads is expensive and developing countries should leverage global climate change financing coming on stream to assist in the process. The issues previously noted in this chapter as necessary considerations for addressing climate change should come into play, especially when determining the siting of new roads.

7. **Prioritizing Disaster Risk Management.** The potential for climate disasters only increases in the climate changed future. There should be a prioritizing of integrated risk management approaches such as anticipatory risk management (ensuring that future development reduces rather than increases risk), compensatory risk management (taking action to mitigate the losses associated with existing risk) and reactive risk management (ensuring that risk is not reconstructed after disaster events), as priority should also be placed on having strong and effective disaster preparedness and response mechanisms which are adequately and always resourced and enabled. Both will facilitate climate resilience. The responsibility of disaster risk management falls on all of us, from individual through to governments and the region as a whole.

8. **Always Considering the Environment.** The environment and the natural world are currently exploited for economic development, yet they are often secondary considerations in decisions related to economic development. A degraded environment only exacerbates the impact of climate change threats, and the environment is already among the most vulnerable groupings. The environment is one of a few areas (energy and waste being two others) that facilitate both adaptation and mitigation responses in the resilience-building effort. Even when compromise on the environment is required it must not be such that it is unfairly placed at a disadvantage. Mainstreaming consideration of the environment in decision-making and even displaying a bias

towards the environment with respect to protection and preservation, will build climate resilience.

9. **Joined-Up Government.** Sectoral adaptation strategies are a good approach to mainstreaming climate change in daily operations. The pervasive nature of climate change, however, demands that plans and actions developed for one sector take into consideration the impact on and the plans and actions of another sector. Targets set must be consistent across sectors; for example, the mix of fuels in energy diversification must be consistent with mitigation targets to reduce CO_2 emission. In addition, sustainability of the resilience created may depend on collaboration across two sectors. A dedicated climate change coordinating unit can act as a conduit and a link. Notwithstanding, even an emphasis on strengthening mechanisms that facilitate cross-sectoral consultations and considerations will facilitate efforts towards resilience.

10. **Recognizing the Value of Science and Research.** Climate resilience will be achieved on the basis of targetted and evidenced-based responses. Knowledge of the present and future climate and the links between climate and life, help define the nature and scope of the threat, help justify response, engender buy-in, and afford evaluation of the best responses. Having an already established and strong research community will facilitate quick responses to problems that arise regarding climate and enable the answering of local or context-specific issues that may also arise. Providing ongoing incentives for interdisciplinary research, commissioning research to fill gaps, and the deliberate use of research in development will only build resilience.

11. **Fostering Innovation and Entrepreneurship.** Climate change is presenting challenges not previously seen. By having a vibrant and enabling environment for the development and quick deployment of new and creative solutions, the opportunity would already exist for responding to new challenges such as those that will be thrown up by climate change. New solutions also represent new opportunities for entrepreneurship. Fostering an enabling environment for entrepreneurship is, in effect, a resilience-building activity. The private sector has a critical role in creating such opportunities.

12. **Regionalism.** There is merit in a regional approach to dealing with issues where individual nations each have limited resources. In the context of climate change, both a regional negotiation mechanism and a common position have already accounted for the issues of small islands gaining the attention of the world. Both have been key to making the case for urgent action and obligatory aid, that is, given the particular vulnerabilities of all small island developing states. There is merit also in regional sector groupings and alliances tackling common threats like climate change as they not only leverage the limited resources but also help standardize modalities of operation and response and facilitate the sharing of best practices. All this facilitates the mainstreaming of climate change. Maintaining and strengthening regionalism is a resilience-building exercise.

13. **Developing a Communication Strategy.** Having in place efficient modalities for communication, which can be exploited as needed to convey the risks, uncertainties, threats and opportunities resulting from climate change, will contribute to the resilience building effort.

Epilogue
Behind every dark cloud …
Present Opportunity

Climate has changed. Climate will change. Climate demands change.

There can be no doubt that climate change is an issue of our times. What this book has attempted to do is explore both the importance and necessity of considering climate – variability and change – by the Caribbean region. I have made the case that there is an inherent sensitivity of the region to climate for various reasons and this demands that attention be placed on climate as an issue. Under an already varying climate, the region's vulnerability to climate is growing and so there is also a demand that serious consideration be given to the risks posed by climate to Caribbean existence. If the kind of consideration needed is not given and action not taken the Caribbean region's future sustainability is threatened in light of the future projections of climate. The accompanying demand is for sustained action which will build climate resilience through the mainstreaming of climate considerations into planning for development and the daily routines of Caribbean life. Action is required on the part of all.

Achieving climate resilience will, however, require changes in both our attitudes and approaches to climate. Herein lies the key message of this book. If nothing else, it must be seen that the present represents an opportunity to shape the kind of region we want in the future, notwithstanding the threat posed by climate change. The insights already gained through science and research contribute to the opportunity – to be forewarned is to be forearmed. There is the real opportunity, then, to use our present understanding of climate risks to ensure that climate change does not derail development. There is an opportunity to take the same issue that causes the concern – climate change – and use it as a rallying call for implementing the kind of changes that will ensure sustainability through resilience building and ultimately lead to the future viability of the region – as a place to live, work, play, and do business. We must seize the opportunity now.

References

Agrawala, S., and S. Fankhauser, eds. 2008. *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments.* Paris: OECD.

Aguilar, E. et al. 2005. "Changes in Precipitation and Temperature Extremes in Central America and Northern South America, 1961–2003." *Journal of Geophysical Research* 110: D233107. doi:10.1029/2005JD006119.

Alexander, L., X. Zhang, T.C. Peterson, et al. 2006. "Global Observed Changes in Daily Climate Extremes of Temperature and Precipitation." *Journal of Geophysical Research* 111: DO5109. doi:10.1029/2005JD006290.

Alliance of Small Island States (AOSIS). 2009. *Declaration on Climate Change 2009*. http://www.sidsnet.org/aosis/documents/ AOSIS%20Summit%20 Declaration%20Sept%2021%20FINAL.pdf.

Amarakoon, D.A., A.A. Chen, S.C. Rawlins et al. 2006. "Retrospective Study." In *Climate Change Impact on Dengue: The Caribbean Experience*, edited by A.A. Chen, D.D. Chadee and S. Rawlins. 66–77. Mona, Jamaica: University of the West Indies, Climate Studies Group, Mona.

Bender, M.A., T.R. Knutson, R.E. Tuleya et al. 2010. "Modeled Impact of Anthropogenic Warning on the Frequency of Intense Atlantic Hurricanes." *Science* 327: 454–58.

Bueno, R., C. Herzfeld, E.A. Stanton, and F. Ackerman. 2008. *The Caribbean and Climate Change: The Cost of Inaction*. Medford, MA: Tufts University.

Campbell, J.D., M.A. Taylor, T.S. Stephenson, et al. 2010. "Future Climate of the Caribbean from a Regional Climate Model." *International Journal of Climatology*. doi:10.1002/joc.2200.

Caribbean Sea Ecosystem Assessment (CARSEA). 2007. *Caribbean Marine Studies, Special Edition. A Sub-Global Component of the Millennium Ecosystem Assessment*, edited by J. Agard, A. Cropper, and K. Garcia.

Cashman, A., L. Nurse and J. Charlery. 2010. "Climate Change in the Caribbean: The Water Management Implications." *The Journal of Environment & Development* 19(1): 42–67.

CCRIF. 2010. "CCRIF – A Natural Catastrophe Risk Insurance Mechanism for Caribbean Countries." Presented at the IDB Capacity Building Workshop on Climate Change Adaptation and Water Resources in the Caribbean, 22–23 March 2010, Trinidad and Tobago.

CDEMA. 2010. "Summary of Impact of Hurricane Tomás on CDEMA Participating States of St. Lucia and St. Vincent and the Grenadines: Damage, Response Actions, Immediate

Recovery and Rehabilitation Needs." http://www.cdema.org/HurricaneTomasSummaryofImpactandNeedsAssessment.pdf.

Chen, A.A., D.D. Chadee and S. Rawlins, eds. 2006. *Climate Change Impact on Dengue: The Caribbean Experience.* Mona, Jamaica: University of the West Indies, Climate Studies Group, Mona.

Church, J.A., N.J. White, R. Coleman et al. 2004. "Estimates of the Regional Distribution of Sea-Level Rise over the 1950–2000 Period." *Journal of Climate* 17: 2609–625.

Climate Studies Group, Mona (CSGM). 2012. State of the Jamaica Climate: Past and Future. Information for Resilience Building. GOJ.

Climate Studies Group, Mona (CSGM). 2013. "Good Practices: Disaster Risk Reduction Case Studies from Jamaica." Produced for the Government of Jamaica. EU/UNEP/GOJ CCADRR Project.

Department of Economic Affairs. 2001. "National Report on Integrating Management of Watersheds and Coastal Areas in Grenada. Report of the Department of Economic Affairs, Ministry of Finance, St. George's." Prepared for the Caribbean Environmental Health Institute.

Donner, S.D., T.R. Knutson and M. Oppenheimer. 2007. "Model-Based Assessment of the Role of Human-Induced Climate Change in the 2005 Caribbean Coral Bleaching Event." *Proceedings of the National Academy of Sciences of the United States of America* 104: 5483–488.

Ebi, K.L., N.D. Lewis, and C. Corvalan. 2006. "Climate Variability and Change and their Potential Health Effects in Small Island States: Information for Adaptation Planning in the Health Sector." *Environmental Health Perspectives* 114: 1957–963.

ECLAC. 2001. "Assessment of the Damage Caused by Flood Rains and Landslides in Association with Hurricane Michelle, October 2001: Implications for Economic, Social and Environmental Development." http://repositorio.cepal.org/bitstream/handle/11362/27516/LCcarG672_en.pdf?sequence=1

ECLAC. 2011a. "Macro Socio-Economic and Environmental Assessment of the Damage and Losses Caused by Hurricane Tomás: A Geo-Environmental Disaster. Towards Resilience." https://www.finance.gov.lc/resources/download/290.

ECLAC. 2011b. "An Assessment of the Economic Impact of Climate Change on the Tourism Sector in Jamaica." http://idbdocs.iadb.org/wsdocs/getDocument.aspx?Docnum=38580137.

Emanuel, K. 2007. "Environmental factors affecting tropical cyclone power dissipation." *Journal of Climate* 20: 5497–509. doi: http://dx.doi.org/10.1175/2007JCLI1571.1.

FAO. 2013. "Status of Disaster Risk Management Plans for Floods, Hurricanes and Drought in the Agriculture Sector: A Caribbean Perspective." http://www.fao.org/docrep/018/i3341e/i3341e.pdf.

Farrell, D., L. Moseley and L. Nurse. 2007. "Managing Water Resources in the Face of Climate Change: A Caribbean Perspective." In *Proceedings of the 8th Annual Sir Arthur Lewis Institute of Social and Economic Studies (SALISES) Conference*, UWI, St. Augustine, Trinidad, 26–28 March.

Farrell, D., A. Trotman and C. Cox. 2010. "Drought Early Warning and Risk Reduction: A Case Study of the Caribbean Drought of 2009–2010."

Gamble, D.W. 2009. "Caribbean Vulnerability: Development of an Appropriate Climatic Framework." In *Global Change and Caribbean Vulnerability: Environment, Economy and Society at Risk?*, edited by D. McGregor, D. Dodman, and D. Barker. 22–46. Kingston, Jamaica: University of the West Indies Press.

Gamble, D.W., D. Campbell, T.L. Allen et al. 2010. "Climate Change, Drought, and Jamaican Agriculture: Local Knowledge and the Climate Record." *Annals of the Association of American Geographers* 100(4): 880.

Giannini A., Y. Kushnir, and M.A. Cane. 2000. "Interannual Variability of Caribbean Rainfall, ENSO and the Atlantic Ocean." *Journal of Climate* 13: 297–311.

Global News Matters. 2014. "Caribbean Risk Outlook: Hurricane Season Has Arrived." https://globalnewsmatters.com/caribbean-risk-outlook-hurricanes/.

Goldenberg, S., C. Landsea, A. Mestas-Nunez and W. Gray. 2001. "The Recent Increase in Atlantic Hurricane Activity: Causes and Implications." *Science* 293(5529): 474–79.

Government of Barbados. 2001. "State of the Environment Report 2000 GEO Barbados." Barbados: Ministry of Physical Development and Environment. http://www.pnuma.org/deat1/pdf/GEOBarbados2000.pdf.

Government of Jamaica, Ministry of Agriculture and Fisheries. 2014. Operational Plan 2014–2015. http://www.moa.gov.jm/AboutUs/MoAF-2014-2015-Operational-Plan.pdf.

Government of Trinidad and Tobago. 2010. National Assessment Report on the Five-Year Review of Progress Made in Implementation of the Mauritius

Strategy for Further Implementation of the Barbados Programme of Action.

Guardian. 2013. "We Ignore the Disastrous Storms in the Caribbean at our Peril." December 31. http://www.theguardian.com/commentisfree/2013/dec/31/storms-caribbean-uk-climate-change.

Hendry, M. 1993. "Sea-Level Movements and Shoreline Change." In *Climatic Change in the Intra-Americas Sea,* edited by G. Maul. 115–61. London: Edward Arnold.

Horton, R., C. Herweijer, C. Rosenzweig, J.P. Liu, V. Gornitz and A.C. Ruane. 2008. "Sea Level Rise Projections for Current Generation CGCMs Based on the Semi-Empirical Method." *Geophysical Research Letters* 35: L02715. doi:10.1029/2007GL032486.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. Cambridge, UK and New York: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, edited by C.B Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor and P.M. Midgley. Cambridge, UK, and New York: Cambridge University Press.

IPCC. 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley. Cambridge, UK and New York: Cambridge University Press.

IPCC. 2014. *Climate Change 2014: Synthesis Report. Summary for Policymakers*, edited by R.K. Pachauri and L Meyer. Geneva, Switzerland: IPCC. http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_SPMcorr2.pdf.

Inter-American Development Bank. 2010. "Development of the Great River Small Hydro Project." Report prepared by IT Power Ltd. http://www.pcj.com/dnn/Portals/0/Documents/LAE%20No4-Great%20River%20Final%20Report%20vFinal.pdf.

Jamaica Public Service Limited. All Island Electricity Grid. http://www.myjpsco.com/about-us/jamaicas-electricity-grid/.

Jamaica Public Service Limited. 2014. "Electricity Generation and Consumption Statistics, 2009–2013."

Karmalkar, A.V., M. New, M.A. Taylor, J. Campbell, T. Stephenson et al. 2013. "Review of Observed and Projected Changes in Climate for the Islands in the Caribbean." *Atmosfera* 26(2): 283–309.

Kelly, Daviot. 2014. "Buying Water Putting a Strain on Budgets." *Jamaica Gleaner*, July 21. http://jamaica-gleaner.com/gleaner/20140721/news/news92.html.

Knutson, T.R., J.L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J.P. Kossin, A.K. Srivastava and M. Sugi. 2010. "Tropical Cyclones and Climate Change." *Nature Geoscience* 3: 157–63. doi:10.1038/ngeo779.

Knutson, Thomas R. et al. 2013. "Dynamical Downscaling Projections of Twenty-First-Century Atlantic Hurricane Activity: CMIP3 and CMIP5 Model-Based Scenarios." *Journal of Climate* 26: 6591–617. doi: http://dx.doi.org/10.1175/JCLI-D-12-00539.1.

Landsea, C., G.A. Vecchi, L. Bengtsson and T.R. Knutson. 2010. "Impact of Duration Thresholds on Atlantic Tropical Cyclone Counts." *Journal of Climate* 23(10). doi:10.1175/2009JCLI3034.1.

Lewsey, C., G. Cid and E. Kruse. 2004. "Assessing Climate Change Impacts on Coastal Infrastructure in the Eastern Caribbean." *Marine Policy* 28: 393–409.

Mann, M.E., R.S. Bradley and M.K. Hughes. 2000. "Long-Term Variability in the ENSO and Associated Teleconnections." In *ENSO: Multi- scale Variability and Global and Regional Impacts*, edited by H.F. Diaz and V. Markgraf. 357–412. New York: Cambridge University Press.

McSweeney, C., M. New, G. Lizcano and X. Lu. 2010. "UNDP Climate Change Country Profiles: Improving the Accessibility of Observed and Projected Climate Information for Studies of Climate Change in Developing Countries." *Bulletin of the American Meteorological Society* 91: 157–66.

Mimura, N., L. Nurse, R.F. McLean et al. 2007. "Small Islands. Climate Change 2007: Impacts, Adaptation and Vulnerability." In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson. 687–716. Cambridge, UK: Cambridge University Press.

Mora, C. et al. 2013. "The Projected Timing of Climate Departure from Recent Variability." *Nature* 502(7470): 183–87.

Nakicenovic, N. and R. Swart, eds. 2000. *Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York: Cambridge University Press.

Organisation of East Caribbean States (OECS). 2004. "Grenada: Macro Socio-Economic Assessment of the Damages Caused by Hurricane Ivan." Castries, St. Lucia: OECS.

Palanisamy, H., M. Becker, B. Meyssignac, O. Henry and A. Cazenave. 2012. "Regional Sea Level Change and Variability in the Caribbean Sea Since 1950." *Journal of Geodetic Science* 2(2): 125¬–33.

Perrette, M. et al. 2013. "A Scaling Approach to Project Regional Sea Level Rise and its Uncertainties." *Earth System Dynamics* 4: 11–29.

Planning Institute of Jamaica. 2002. "Jamaica: Macro-Socio-Economic and Environmental Assessment of the Damage Done by Flood Rains and Landslides May 2002." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/May%202002%20Flood%20Rains.pdf.

Planning Institute of Jamaica. 2004. "Jamaica Macro-Socio-Economic and Environmental Assessment of the Damage and Loss Caused by Hurricane Ivan, Sept 10-12, 2004." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/Hurricane%20Ivan.pdf.

Planning Institute of Jamaica. 2005a. "Assessment of the Socio-Economic and Environmental Impact of Hurricanes Dennis and Emily on Jamaica." http://www.pioj.gov.jm/portals/0/sustainable_development/dennis%20emily%20report.pdf.

Planning Institute of Jamaica. 2005b. "Assessment of the Socio-Economic and Environmental Impact of Hurricane Wilma on Jamaica." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/Hurricane%20Wilma.pdf.

Planning Institute of Jamaica. 2007. "Assessment of the Socio-Economic and Environmental impact of Hurricane Dean on Jamaica." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/Hurricane%20Dean.pdf.

Planning Institute of Jamaica. 2008. "Assessment of the Socio-Economic and Environmental Impact of Tropical Storm Gustav on Jamaica." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/Tropical%20Storm%20Gustav.pdf.

Planning Institute of Jamaica. 2010a. *Economic and Social Survey Jamaica 2009*. Kingston, Jamaica: PIOJ.

Planning Institute of Jamaica. 2010b. "Jamaica Macro Socio-Economic and Environmental Assessment of the Damage and Loss Caused by Tropical Depression No. 16/Tropical Storm Nicole." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/Tropical%20Storm%20Nicole_Impact%20Assessment_Final.pdf.

Planning Institute of Jamaica. 2013. "Jamaica Macro Socio-Economic and Environmental Assessment of the Damage and Loss Caused by Hurricane Sandy." http://www.pioj.gov.jm/Portals/0/Sustainable_Development/Final%20%20DaLA%20Report%20Hurricane%20Sandy_Update.pdf.

Pulwarty, R.S., L.A. Nurse and U.O. Trotz. 2010. "Caribbean Islands in a Changing Climate." *Environment: Science and Policy for Sustainable Development* 52(6): 16–27.

Rahmstorf, S. 2007. "A Semi-Empirical Approach to Projecting Future Sea-Level Rise." *Science* 315: 368–70.

Rignot, E. and P. Kanagaratnam. 2006. "Changes in the Velocity Structure of the Greenland Ice Sheet." *Science* 311(5763): 986–90.

Robinson, E., S.A. Khan, R. Coutou and M. Johnson. 2012. "Shoreline Changes and Sea-Level Rise at Long Bay, Negril, Western Jamaica." *Caribbean Journal of Earth Science* 43: 35–49.

Simpson, M.C., D. Scott, M. New et al. 2009. *An Overview of Modelling Climate Change Impacts in the Caribbean Region with Contribution from the Pacific Islands*. Barbados, West Indies: United Nations Development Programme (UNDP).

Simpson, M.C., D. Scott, M. Harrison et al. 2010. *Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean* (Full Document). Barbados, West Indies: United Nations Development Programme (UNDP).

Stahle, D.W., R.D. Arrigo, P.J. Krusic et al. 1998. "Experimental Dendroclimatic Reconstruction of the Southern Oscillation." *Bulletin of the American Meteorological Society* 79: 2137–152.

Stephenson, T.S. et al. 2014. "Changes in Extreme Temperature and Precipitation in the Caribbean Region, 1961–2010." *International Journal of Climatology*. doi:10.1002/joc.3889.

Studds, C. and P.P. Marra. 2007. "Linking Fluctuations in Rainfall to Non-Breeding Season Performance in a Long-Distance Migratory Bird." *Climate Research* 35: 115–22.

Taylor, M.A., D.B. Enfield and A.A. Chen. 2002. "The Influence of the Tropical Atlantic vs. the Tropical Pacific on Caribbean Rainfall." *Journal of Geophysical Research* 107(C9): 3127. doi:10.1029/2001JC001097.

Taylor, M.A., T.S. Stephenson, A.A. Chen and K. Stephenson. 2012. "Climate Change and the Caribbean: Review and Response." *Caribbean Studies* 40(2): 169–200.

Taylor, Michael A., Abel Centella, John Charlery, Arnoldo Bezanilla, Jayaka Campbell, Israel Borrajero, Tannecia Stephenson and Riad Nurmohamed. 2013. "The PRECIS Caribbean Story: Lessons and Legacies." *Bulletin of the American Meteorological Society* 94: 1065–073. doi: http://dx.doi.org/10.1175/BAMS-D-11-00235.1

Torres, R.R. and M.N. Tsimplis. 2013. "Sea-Level Trends and Interannual Variability in the Caribbean Sea." *Journal of Geophysical Research: Oceans* 118: 2934–947. doi:10.1002/jgrc.20229.

Trotman, R. and D. Farrell. 2010. "Drought Impacts and Early Warning in the Caribbean: The Drought of 2009-2010." Presented at the Technical Cooperation Workshop for Development of the Caribbean Regional Cooperation Programme in Multi-Hazard Warning System, 2–5 November 2010. https://www.wmo.int/pages/prog/drr/events/Barbados/Pres/4-CIMH-Drought.pdf.

UNDP News Centre. 2012. "Hurricane Sandy Kills around 80 in the Caribbean, 1.8 million Affected in Haiti." http://www.undp.org/content/undp/en/home/presscenter/articles/2012/11/02/hurricane-sandy-kills-around-80-in-the-caribbean-1-8-million-affected-in-haiti/.

UNEP. 2008. *Climate Change in the Caribbean and the Challenge of Adaptation*. Panama City, Panama: UNEP Regional Office for Latin American and the Caribbean. http://www.pnuma.org/deat1/pdf/Climate_Change_in_the_Caribbean_Final_LOW20oct.pdf .

USACE. 2001. "Water Resources Assessment of Jamaica." Report of the Mobile District & Topographic Engineering Center, United States Army Corps of Engineers.

USACE. 2004a. "Water Resources Assessment of the Bahamas." Report of the Mobile District & Topographic Engineering Center, United States Army Corps of Engineers.

USACE. 2004b. “Water Resources Assessment of Dominica, Antigua, Barbuda, St. Kitts and Nevis.” Report of the Mobile District & Topographic Engineering Center, United States Army Corps of Engineers.

van Vuuren, D.P., J. Edmonds, M.L.T. Kainuma et al. 2011. “Representative Concentration Pathways: An Overview.” *Climatic Change* 109: 5–31. doi:10.1007/s10584-011-0148-z.

Webster, P.J., G.J. Holland, J.A. Curry and H.R. Chang. 2005. “Changes in Tropical Cyclone Number, Duration and Intensity in a Warming Environment.” *Science* 309: 1844–846.

Wilby, R.L., C.W. Dawson and E.M. Barrow. 2002. “SDSM – A Decision Support Tool for the Assessment of Regional Climate Change Impacts.” *Environmental Modelling & Software* 17: 147–59.

Wilkinson, C. and D. Souter. 2008. *Status of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005*. Townsville: Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre.

World Bank. 2014. “Eastern Caribbean Islands Rebuilding from Flash Floods.” Press Release. March 21. http://www.worldbank.org/en/news/press-release/2014/03/21/eastern-caribbean-islands-rebuilding-from-flash-floods.

World Resources Institute. Climate Analysis Indicator Tool 2.0 (CAIT 2.0). http://cait2.wri.org/wri/Country%20GHG%20Emissions?indicator[]=Total%20GHG%20Emissions%20Excluding%20LandUse%20Change%20and%20Forestry&indicator[]=Total%20GHG%20Emissions%20Including%20Land-Use%20Change%20and%20Forestry&year[]=2011&chartType=geo.

World Travel and Tourism Council (WTTC). 2008. “WTTC Supports CARICOM Prioritization on Tourism.” *PR Newswire-Hispanic PR Wire*. March 13. www.hispanicprwire.com/news.php?l=in&id=10940.

World Travel and Tourism Council. 2014. “The Economic Impact of Travel and Tourism 2014: Jamaica.”

Appendix – Impact Tables

Adapted from The State of the Climate Jamaica, CSGM (2012).

Table 1

Impact of Climate Change on Freshwater Resources

	Climate Change Variables and Extreme events	Impacts
CLIMATE CHANGE ON FRESHWATER RESOURCES	Sea Level Rise	Groundwater quality continues to be and will be further affected by the proximity of some basins to the coast (4, p. 74).[8] Sea water intrusion has resulted in the loss of 100 million cubic metres of groundwater (10% of local supply) annually (4, p. 74).
	Heavy Rainfall / Storms	Some water catchment areas are prone to flooding and exposed to the risk of debris and sediment flows (4, p. 67). Heavy rains contaminate watersheds by transporting human and animal faecal products and other wastes into groundwater (1, p. 25). Heavy rainfall also affects the health and sanitation of some communities without proper toilet facilities (water closets). Flooded pit latrines release waste directly into the rivers. This solid waste then threatens the health of people in the communities and especially the health of children who use the river for bathing purposes. This has led to an increase in diseases associated with water sanitation and poor hygiene practices (6, p. 15).
	Droughts	Drought affects sanitation due to lack of water for hygiene purposes, thereby affecting the transmission of disease (3, p. 30). Scarcity of freshwater sources could limit Jamaica's social and economic development. It could affect local sectors which include agriculture and domestic usage which account for 75% and 17% respectively of local water demand (3, p. 29). Irrigated agriculture depends on 85% of local water supply (4, p. 83). Water shortage: Loss of food production would create food shortage and a necessity for food importation. Hunger and malnutrition may increase (2, p. 12).
	Increasing Temperature	Rising temperature will lead to more evaporation (4, p. 30). Evaporation leads to a greater pathogen density in the water and this could result in a lack of potable water (2, p. 12).
	Additional Information: 84% of Jamaica's exploitable water comes from groundwater sources and its availability is subject to climatic conditions. (3, p. 29)	

8 The bracketed numbers refer the reader to the research document (including page number) which makes the point. The research documents used in the compilation of these tables are numbered and listed at the end of this section.

Table 2
Impact of Climate Change on Tourism Sector

	Climate Change Variables/ Extreme Events	Impacts
TOURISM	Sea Level Rise	Beaches respond to sea-level rise by retreating inland at approximately 100 times the rate of sea-level rise (7, p. 13).
	Increasing Temperature	Temperature extremes can lead to increased incidence of heat stress and other heat-related illnesses. In extreme cases it can become fatal. Heat stress remains a concern with higher temperatures for tourists and outdoor workers (1, p. 18). Heat storage of built structures leads to 'heat island effect' (1, p. 18). This leads to additional operating costs for cooling aids (5, p. 87). Sea surface temperature increases of at least 1.0°C will lead to coral reef bleaching (7, p. 14). (NB: No base temperature was given for the 1 degree rise). These reefs contribute to Jamaica's tourism product through diving and fishing tours. They are also critical sources of beach sand (9, p. 6).
	Heavy Rainfall	Adverse rainfall/weather conditions could lead to cancellation of reservations or displacement of visitors, which would incur massive losses in revenue (3, p. 29).
	Hurricanes/ Storms	Increased infrastructural damage, additional emergency preparedness requirements and business interruption, including in the tourist industry, due to floods, coastal inundation and extreme events (5, p. 87). Tropical storms and hurricanes appear to be the dominant factor influencing beach erosion (7, p. 14).
	Additional Information: Aviation emissions are now included in global GHG pollution. This means that the aviation industry (like the EU) cap and trade emissions reductions programmes now make long distance travelling environmentally unfriendly and expensive. As a result, tourists will have to spend more on tickets to visit island destinations (3, p. 52). Visitor numbers may decrease because of increased travel costs. Arrivals in Jamaica are reported to decline from 1.3% -3.7% (3, p. 53). This reduces discretionary income of tourists which would affect tourism negatively (5, p. 88).	

Table 3

Sea Level Rise and Storm Surge Impact on Coastal Infrastructure and Settlement

SEA LEVEL RISE AND STORM SURGE IMPACTS ON COASTAL INFRASTRUCTURE AND SETTLEME NTS	**Impacts**
	Storm surges associated with hurricanes and tropical storms can lead to the inundation of low-lying coastal areas by high tides with coastal swells (4, p. 67). Permanent inundation could occur in some areas (2, p. 391). A large percentage of Jamaica's population (25%) is concentrated near to the coastline, thus a rise in sea level will cause a displacement of coastal settlements (2, p. 391).
	Critical infrastructure like port facilities, tourism centres and dense population centres are located within Jamaica's coastal zone. The coastal zone of Jamaica is thus very susceptible to sea-level rise, which would cause increased beach erosion rates and higher incidence of coastal flooding (2, p. 391). Sea-level rise and storm surges will affect critical infrastructure economically since it is reported that 90% of GDP is produced within the coastal zone (2, p. 391).
	Sea-level rise is also expected to exacerbate coastal erosion, resulting in damage or increased loss of coastal ecosystems, threatening property and infrastructure located in coastal areas and resulting in salt water intrusion of underground coastal aquifers (5, p. 43). Damage to road networks and bridges during the passage of hurricane Nicole resulted in losses totalling J$14 billion dollars (16). Coastal erosion along the Palisadoes Spit has caused flooding and deposited sand and debris on the road access to the Norman Manley International Airport, rendering it impassable (3, p. 36).
	Additional Information: The First National Communication indicated that the IPCC in 1990 estimated that the cost to protect Jamaica from one metre of sea-level rise would be US$462 million (2, p. 391). Continued coastal development is very likely to exacerbate risk of loss of life and property due to storms and sea-level rise (9, p. 2).

Table 4

Impact of Climate Change on Community Livelihoods

	Climate Change Variables/ Extreme Events	Impacts
COMMUNITY LIVELIHOODS	Increasing Temperature	The majority of Jamaica's coastal communities depend on coastal resources for their livelihood. In particular reef fisheries are of major importance in the Jamaican food chain as the island's fringing reefs provide a livelihood for artisanal fisheries. Coral reefs are already facing impacts from climate change, which are thereby affecting reef fisheries (3, p. 34). Temperature increases could lead to the spread of dengue fever and other vector-borne diseases (2, p. 12). Households inhabited by disabled or ill members are considered more vulnerable since this affects the number of people available for productive labour and puts a strain on household resources (8, p. 43).
	Droughts, Storms and Hurricanes	Crop loss and flooding which are some of the effects of extreme weather conditions also affect farming communities, which are largely vulnerable to climatic variability (5, p. 61). Increased flooding will lead to inundation of production fields (5, p. 27). Rainfall extremes (drought, floods) are associated with the spread of waterborne diseases due to a lack of potable water and sanitation issues (6, p. 15) possibly leading to lack of productivity.
	Additional Information: Pollution from sewage and agricultural runoff as well as unsustainable activity (like over-harvesting of fish) also damage Jamaica's reef systems, negatively affecting marine life and contributing to declining fish stocks (3, p. 36). Flooding is also caused by poor land use practices in watershed areas (4, p. 67). Some farmers reduce forest cover, which aggravates the impact of extreme events like drought (6, p. 19). Hunger and malnutrition could affect local populations due to a reduction in food production as a result of drought conditions (1, p. 18). Increasing sea surface temperature will heighten storm surges which will create more damaging flood conditions to coastal zones and low-lying areas. These changes are likely to affect goods and services produced within the coastal zone (5, p. 45).	

Table 5

Climate Change Impact Related to Development

	Climate Change Variable/Extreme Events	Impact
DEVELOPMENTAL ISSUES	Storm Surges Sea Level Rise	Increased incidence of sea-level rise and storm surges could lead to displacement of 25% of Jamaicans who inhabit coastal areas (2, p. 391). Areas like Portmore, which is a drained low-lying coastal area (170,000 pop.) would be at risk from flooding (4, p. 67). Inundation of coastal areas, settlements, loss of life and property are also features of continual coastal development which exacerbate risks from these events (9, p. 2). Coastal erosion could destroy economically critical infrastructure (ports, tourism centres, airports, road networks, since 90% of Jamaica's GDP is earned along the coastal zone (2, p. 390). This could result in massive economic losses for the country (3, p. 29).
	Increasing Temperature	Increasing temperature has the potential to threaten social and economic development in the country. This is due to the correlation among body temperature, work performance and alertness (14, p.1). This has implications for outdoor workers, indoor workers and students in classrooms without cooling aids. Higher temperatures can lead to low productivity. This is due to the fact that heat exposure can affect physical and mental capacity and lead to heat exhaustion or heat stroke in extreme cases. In particular, there is the potential threat of the effect of increasing atmospheric temperature on youth and their educational development. Reading speed, reading comprehension and multiplication performance of schoolchildren could be affected by temperatures of 27°C–30°C (15, p. 1). (NB. Such temperatures are achieved in Jamaica regardless of climate change).
	Storms, Hurricanes, Droughts, Tropical Cyclones, Floods	With a rise in the occurrence of extreme events, fresh water may be less available or it may be contaminated which will increase susceptibility, especially of some remote and rural communities, to infectious diseases that have minimal public health care infrastructure (3, p. 35). Improper land use/development in watershed/flood-prone areas increases vulnerability to landslides and floods (4, p. 67). Deterioration in social and economic circumstances might arise from adverse effects of climate change on patterns of employment, population mobility, wealth distribution and limited resettlement prospects (3, p. 35).

	Storms, Hurricanes, Droughts, Tropical Cyclones	Insurance sector: Weather and climate are "core business" for the insurance industry. Insurers underwrite weather-related catastrophes by calculating and pricing risks and then meeting claims when they arise. Therefore, an unpredictable climate has the potential to reduce the sector's capacity to calculate and price this weather-related risk (18, p. 1). The role of insurance in underwriting weather-related risk is an important component of the national economy. Any reduction in the industry's ability to underwrite weather-related risk will have serious ramifications for vulnerable countries (like Jamaica) where climate and weather risk is greatest (18, p. 1). The unpredictability of climate change is forcing insurers to develop adaptation strategies which include putting a price on current and future risks (19). Banking sector: Banks will be affected by climate change mostly indirectly to the extent that general economic activity is affected (20, p. 11). It is estimated that up to 5% of market capitalization could be at risk from the consequences of climate change (20, p. 11). The effects of climate change on banking companies would be direct (for example, through extreme events that put facilities at risk or indirect (through imposed regulations or shifts in social preferences) (20, p. 11).
	Additional Information: Population growth in coastal areas increases demand for land. This involves the removal of coastal vegetation and many natural barriers, which increase risks to these events (that is, storm surges and sea level rise) (9, p. 9). Poor land use practices also exacerbate the impact of flooding (3, p. 29). Impact by mid-level scenario of sea-level rise would cost the CARICOM countries (including Jamaica) in 2050, US$60.7 billion (12). During a hurricane or a storm, rainfall exceeds aquifer capacity, causing damage to infrastructure like bridges and roads (3, p. 30).	

Sources of Information Referenced in Tables

1. W. Bailey, A.A. Chen and M.A. Taylor, *Review of Health Effects of Climate Variability and Climate Change in the Caribbean* (Mona, Jamaica: University of the West Indies, Climate Studies Group Mona, in association with the Caribbean Environment and Health Institute for the Mainstreaming Adaptation to Climate Change Project of the Caribbean Community Climate Change Centre (CCCCC), 2009).

2. Government of Jamaica, "Second National Communication of Jamaica to the United Nations Framework Convention Climate Change" (Kingston, Jamaica: National Meteorological Service, 2011).

3. CARIBSAVE, "CARIBSAVE Final Report: Negril, Jamaica" (2009), accessed 24 April 2012, www.caribsave.org.

4. Environmental Solutions Limited, "Development of a National Water Sector Adaptation Strategy to Address Climate Change in Jamaica," Prepared by Environmental Solutions Limited, Jamaica, for the Mainstreaming Adaptation to Climate Change Project of the Caribbean Community Climate Change Centre (CCCCC), 2009).

5. UN ECLAC, "UN ECLAC Summary Report: The Economics of Climate Change in the Caribbean" (2011).

6. L. Vassell, "UNDP Case Study on the Impact of Climate Change on Water and Sanitation in Jamaica" (2009), accessed 24 April 2012 from http://www.undp.org.cu/crmi/docs/crmi-gttfcstjamaica-bp-2009-en.pdf.

7. CANARI, "CANARI Technical Report 386: The Impacts of Climate Change on Biodiversity in Caribbean Islands; What we Know, What we Need to Know and Building Capacity for Effective Adaptation," (2009), accessed 24 April 2012, http://www.canari.org/CANARI%20Tech%20Report%20386.pdf.

8. A.A. Chen, D.D. Chadee and S.C. Rawlins (eds.), *Climate Change Impact on Dengue: The Caribbean Experience* (Mona, Jamaica: University of the West Indies, Climate Studies Group, Mona, 2006).

9. A. Richards, "Development Trends in Jamaica's Coastal Area and the Implications for Climate Change" (2008), accessed 24 April 2012, http://www.pioj.gov.jm/portals/0/sustainable_development/jamaica_climate_change_paper.pdf.

10. CARICOM, "CARICOM Regional Food and Nutrition Security Policy" (2010), accessed 24 April 2012, http://www.caricom.org/jsp/community_organs/regional_food_nutrition_security_policy_oct2010.pdf .

11. L. Dunn, "What is Gender Analysis? Presentation to the Third Caribbean Conference on Comprehensive Disaster Management, CDM – A Catalyst for Change," (Barbados, 2008).

12. A. Chen, "Impacts of Climate Change on Renewable Energy Systems," presented to the Renewable Energy Forum, St. Thomas, U.S. Virgin Islands (2011).

13. PIOJ, *Economic and Social Survey* (Kingston: Planning Institute of Jamaica, 2010).

14. K.P. Wright, Jr., J.T. Hull and C.A. Czeisler, "Relationship between Alertness, Performance and Body Temperature in Humans," *American Journal of Physiology* 283(6) (2002), accessed 23 April 2012, http://ajpregu.physiology.org/content/283/6/R1370.full.pdf+html. DOI: 10.1152/ajpregu.00205.2002.

15. L.N. Dapi, J. Roacklo and G. Nguefack-Tsague, "Heat Impact on Schoolchildren in Cameroon, Africa: Potential Health Threat from Climate Change," (2010), accessed 24 March 2012, http://www.globalhealthaction.net/index.php/gha/article/view/5610/6410.

16. Wikipedia, Ocean Thermal Energy Conversion, accessed 25 April 2012, http://en.wikipedia.org/wiki/Ocean_thermal_energy_conversion.

17. Engineering Toolbox, Wind Power (2012), accessed 25 April 2012, http://www.engineeringtoolbox.com/wind-power-d_1214.html.

18. T. Coleman, "The Impact of Climate Change on Insurance against Catastrophes," (2003), accessed 26 April 2012, http://stephenschneider.stanford.edu/Publications/PDF_Papers/IAG-Climate_Change_Paper.pdf.

19. Caribbean Catastrophe Risk Insurance Facility, "Climate Change and Insurance in the Caribbean," accessed 26 April 2012, http://www.ccrif.org/sites/default/files/publications/Flyer-ClimateChangeInsuranceCaribbean.pdf.

20. B. Furrer, M. Swoboda and V.H. Hoffmann, *Banking and Climate Change: Opportunities and Risks, An Analysis of Climate Strategies in more than 100 Banks Worldwide* (2009) http://ec.europa.eu/enterprise/policies/sustainable-business/corporate-social-responsibility/reporting-disclosure/swedish-presidency/files/surveys_and_reports/banking_and_climate_change_-_sam_group_en.pdf.