CHAPTER 1

CLIMATE AND HEALTH IN GLOBAL CONTEXT

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

INTRODUCTION

It has been widely acknowledged that climate and changes in climatic conditions have wide ranging effects on health (IPCC, 2014b; United States Global Change Research Program, 2016). This chapter reviews connections between climate and health, drawing on the international literature. Global policies and framework responses are also considered. Later chapters focus on the Caribbean.

Article 1 of the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UN, 1992). It is important to note that climate change is *in addition to* natural climate variability and that it is *attributable to human activity*. These two notions are not universally accepted, with some arguing that global warming – for which the evidence is strong – is the result of long-term but natural variation (IPCC, 2014b). In this document, we do not dwell on the disagreements between those who believe and do not believe that climate change exists. Instead, we focus on the health impacts of global warming and other aspects of climate.

It is important to distinguish between *climate* and *weather*. Climate is the description of the long-term pattern of weather in specific areas. Some scientists define climate as the average weather pattern for a particular region and time period, usually taken over 30 years (National Aeronautics and Space Administration, 2018). Climate change entails sustained movement in averages. It is the culmination of a changing pattern of weather events. As such, a single event cannot be solely attributed to climate change, but a scientific approach can enable one to express a single event as likely or more severe because of climate change. Thus, a single weather event, however dramatic in its effects – such as a Category 5 hurricane[1] - does not prove climate change, but evidence as to possible role of human action, via the increase in greenhouse gases (GHGs), in the intensity of tropical cyclones (Emanuel, 2005; Webster, Holland, Curry, & Chang, 2005), leads scientists to state that such events are likely to be as a result of climate change. The contribution of a single weather event to the evidence that climate change is occurring depends on the frequency and severity of such events and whether they, collectively, consistently shift the average pattern in specific ways.

Climate variability includes seasonal cycles of weather patterns such as El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation, and the Pacific Decadal Oscillation; all of which will be affected by climate change (Kelman & West, 2009; McMichael et al., 2003). The ENSO cycle describes climatic fluctuations in temperature between the ocean and the atmosphere in the east-central Equatorial Pacific. ENSO is made up of two cycles – El Niño and La Niña – with El Niño being the warm phase and La Niña being the cold phase. These phases, which usually last between 9-12 months, occurring every two to seven years, can have serious effects. These include changes in wind and precipitation patterns and on economic-earning sectors such as fisheries, including those of the Caribbean (IPCC, 2014b; National Oceanic and Atmospheric Administration, n.d.).

The global land and ocean surface temperature was remarkably high in 2017. Depending on the dataset considered, 2017 ranked as having the second or third highest temperatures since records began in the mid-to-late 1800s at 0.38°–0.48°C above the 1981–2010 average. Notably, as ENSO conditions were neutral throughout much of 2017, it was the warmest year not influenced by El Niño

[1] See Chapter 4 for definition of hurricane strength categories.

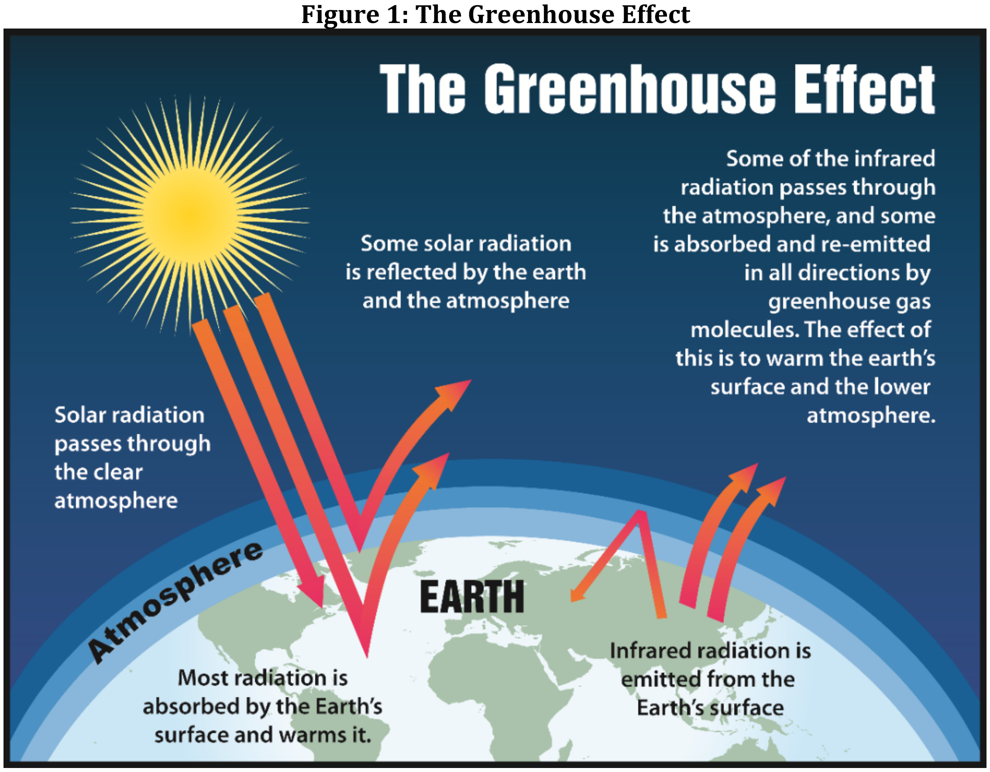
in the instrumental record, as well as being warmer than any year before 2015 (Dunn, Stanitski, Gobron, & Willett, 2018).

This chapter presents analysis of the links between climate and health, as they have been presented in international sources such as scientific literature, multilateral agency documents and websites. We start with a basic review of the scientific evidence for climate change, then examine the impact of climate change and variability on health. We then examine the basis for inter-sectoral linkages and strategies to address the links and outline global policies and frameworks on climate and health.

1.1 Scientific evidence for climate change

The Intergovernmental Panel on Climate Change (IPCC) has described the physical basis for climate change. Global warming – one of the major features of climate change – is caused primarily by increases in GHGs in the earth's atmosphere. The sun's shortwave radiation warms the earth's surface which in turn emits longer-wavelength radiation, some of which passes through the atmosphere. GHG molecules in the atmosphere absorb some of the radiation and re-emit it in all directions, thus increasing the temperature of the atmospheric layer that warms the earth below. Increasing levels of GHGs further increase the earth's surface temperatures (see Figure 1). GHGs consist largely of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CO_2 is produced mainly when fossil fuels such as oil, coal and natural gas are burned. CH_4 and N_2O are also produced by using fossil fuels and by human agricultural practices.

Figure 1: The Greenhouse Effect



Source: US Environmental Protection agency https://www.epa.gov

Ozone in the atmosphere acts to absorb incoming solar radiation, especially the shorter wave, more biologically damaging radiation. With the increased use of various industrial chlorofluorocarbons (CFCs), particularly in refrigerants, insulation and spray cans propellants, these CFCs react with the ozone causing its depletion, which results in an increase in ultraviolet radiation exposure and an increased risk of skin cancers and cataracts. It should be noted that ozone depletion is not strictly part of global climate change but is included here as the increase in CFCs is a global environmental determinant of health that can be attributed to human activity (McMichael et al., 2003; Tucker, 2009).

Since the industrial revolution in the mid-18th century, GHGs have been rising sharply, with global CO_2 concentrations reaching 400 parts per million (ppm) in 2014 (Bala, 2013) and 407 ppm in 2017 (NOAA, 2018). The increase in atmospheric GHGs increases heat in the gaseous atmosphere, solid land surface and liquid ocean, causing global warming (IPCC, 2013; Watts et al., 2015).

The Fifth Assessment Report (AR5) of the IPCC catalogues increases in temperatures in the atmosphere and the ocean, changes in global precipitation cycles, reductions in global snow and ice, a rise in global mean sea level, and changes in weather extremes. Based on comparing the rapidity of warming since the mid-20th century with evidence of long-term fluctuations in global temperatures over thousands of years, the IPCC concludes that it is *extremely likely*[2] that human influence has been the main cause of the observed global warming. The IPCC AR5 clearly outlines the scientific evidence for this global warming on the climate system (IPCC, 2013). Papers about the Caribbean enable comparison of the regional situation with global trends (highlighted in italics below) (Bell, Blake, Landsea, Goldenberg, & Pasch, 2018; T. S. Stephenson et al., 2018; T.S. Stephenson et al., 2014).

- The last three decades have been hotter than all preceding decades since 1850. Between 1880 and 2012, the global average combined land and ocean surface temperature has increased by 0.85^0 C. Between 1983 and 2012 was likely the warmest 30-year period in the last 1400 years in the Northern Hemisphere (medium confidence) (IPCC, 2013). *In the Caribbean, between 1961 and 2010, the annual mean daily maximum temperature has increased by 0.19^{0}C per decade (T.S. Stephenson et al., 2014). Throughout the Caribbean, in 2017, annual maximum surface temperatures, were recorded as some of the highest on record since temperatures started to be recorded. In the latter half of 2017, above-normal surface temperatures (+0.2^0 to +1.0 ^{0} C) were spread across the entire Caribbean region (T. S. Stephenson et al., 2018).*
- There have been changes in extreme weather conditions and climate events since 1950. Globally it is *very likely* that the total number of cold days and nights has decreased, and the number of hot days and nights has increased. In Europe, Asia and Australia, the frequency of heat waves has increased (IPCC, 2013). *In the Caribbean, the occurrence of warm days and nights have increased by 3.31% and 4.07% respectively per decade while that of colder days and nights have decreased by 1.80% and 2.55% (Peterson et al., 2002; T.S. Stephenson et al., 2014).*

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[2] The IPCC AR5 describes the likelihood or probability of some outcome having occurred or occurring in the future in terms of: *virtually certain* (99-100% probability); *extremely likely* (95-100% probability); *very likely* (90-100% probability); *likely* (66-100% probability); *more likely than not* (>50-100% probability); *about as likely as not* (33-66% probability); *unlikely* (0-33% probability); *very unlikely* (0-10% probability); *extremely unlikely* (0-5% probability); and *exceptionally unlikely* (0-1% probability). Italics are used in this Report when referring to these descriptions.

- The 2017 hurricane season was considered an above-normal season and an extremely active season by the National Oceanic and Atmospheric Administration (NOAA). It has 17 named storms of which 10 became hurricanes and 6 became major hurricanes. The average (1981-2010) is 11.8 named storms, 6.4 hurricanes and 2.7 major hurricanes (Bell et al., 2018; Landsea & Franklin, 2013). *A multidecadal trend can be seen across the Caribbean with the intensity and frequency of storms. 1950-1970 was considered a period of high activity with 10 above normal and 5 extremely active seasons. The next period of high activity was 1995 to present (2017) with 15 above normal and 9 extremely active seasons to date. The period in between, 1971-1994 was relatively quiet with only 2 above active seasons and no extremely active seasons (Bell et al., 2018; Goldenberg, Landsea, Mestas-Nuñez, & Gray, 2001).*
- It is *likely* that there are more land regions where there have been more heavy precipitation events. The frequency or intensity of such precipitation events has *likely* (Landsea & Franklin, 2013) increased in North America and Europe (IPCC, 2013). *In the Caribbean, regionally, small increasing trends were observed in annual total precipitation, daily intensity, maximum number of consecutive dry days and heavy rainfall events between 1961 and 2010. While there was no statistically significant increase in annual total precipitation, the intensity of daily rainfall and the heavy rainfall events have been significantly increasing from 1986 to 2010 (T.S. Stephenson et al., 2014). Guyana and Suriname were both affected by extreme flooding in 2005 and 2006; in Guyana 62% of the population was affected (CARPHA, nd)*.
- *In the Caribbean it has also been noted that the number of continuous dry days (CDD), a measure of dry conditions, has been increasing from the mid-1990s to 2010 (T.S. Stephenson et al., 2014). In 2009-2010 and 2014-2016 there were numerous recordings of drought throughout the Caribbean countries, leading to water outages, the rationing of water supplies and agricultural losses (CARPHA, nd; CIMH & FAO, 2016; Farrell, Trotman, & Cox, 2010; Trotman et al., 2017).*
- Greenland and Antarctic ice sheets have been getting smaller, glaciers are shrinking throughout the world and Arctic sea ice and Northern Hemisphere spring snow supply has decreased in extent (*high confidence*[3]) (IPCC, 2013). This is among the factors responsible for sea level rise (SLR): consequences for the Caribbean are explored in Chapter 2.
- Since mid-19th century the rate of SLR has been larger than the mean rate during the previous two millennia (*high confidence*). Between 1901 and 2010, the global mean sea level has risen by 0.19 metres (*very likely*) (IPCC, 2013).
- Ocean acidification (increase in pH) has been caused by the oceans absorbing about 30% of the emitted anthropogenic CO_2 (*high confidence*) (IPCC, 2013, 2014b). This has led to ecological changes in the balance between various marine plant and animal species. Rising sea surface temperatures together with rising ocean acidification can be detrimental to the growth and resilience of corals and coral reefs. Coral reefs play an important role in breaking waves, storing carbon and supporting biodiversity as well as being a source of sand and slowing down beach erosion. (UN-OHRLLS, 2015). They are also important sources of income from tourism. The degradation of coral reefs in the Caribbean is discussed in chapter 2.

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[3] The IPCC AR5 describes each finding in terms of evidence (limited, medium, or robust) and agreement (low, medium and high). Levels of confidence include five qualifiers (*very low, low, medium, high and very high*). Confidence is described as *very low* with low agreement and limited evidence and increases to *very high* with high agreement and robust evidence). Italics are used in this Report when referring to these descriptions.

Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018c) Climate modelling in the Caribbean has resulted in the prediction that global temperature rise of 1.5^{0}C will be accompanied by 0.5^{0}C to 1.5^{0}C temperature rise in the Caribbean region. At these levels of temperature rise, the Caribbean region will be 5%–10% wetter except for the northeast and southeast Caribbean, which will be drier, and there will be increases in annual warm spells of more than 100 days (Taylor et al., 2018). Temperature rise beyond 1.5^{0}C has been judged by some climate scientists to take the planet beyond a "tipping point" of catastrophic and spiralling climatic changes.[4]

Caribbean climate modelling predicts that for the Region, a temperature rise of 2^{0}C would further extend warm spells by up to 70 days, cause a shift to a predominantly drier region (5%–15% less precipitation than present day), and a greater occurrence of droughts (Taylor et al., 2018). The implications for public health are explored in chapters 2 to 4 of the current report. Because of the potential damage to the ecosystem and consequences for the health of the population, CARICOM and other SIDS used the slogan, '1.5 to Stay Alive'. The slogan was accompanied by statements to the effect that for life to be viable in the Caribbean, by the end of the 21st century the atmospheric temperature must not be greater than 1.5^{0}C above pre-industrial levels (Benjamin & Thomas, 2016; Caribbean Development Bank & Caribbean Community Climate Change Centre, 2016; Sealy, 2017).

Global average temperature is expected to rise more than 4^{0}C above pre-industrialised temperatures in the upcoming 85 years approximately (i.e. by 4^{0}C between 1880 and 2100). Increases in temperatures will not be even throughout the world. Scientists predict 2-3^{0}C rises at higher latitudes globally by 2090 and 4-5^{0}C rises in Northern Canada, Greenland and Siberia (Costello et al., 2009). In parts of the Arctic, temperatures may rise as much as 11^{0}C due to polar amplification phenomena[5] by 2100 (Holland & Bitz, 2003; Watts et al., 2015). Mean precipitation will *likely* decrease in many mid-latitude and subtropical dry regions. Extreme precipitation events over mid-latitude and wet tropical regions will *very likely* be more intense and frequent by the end of the 21st century. It is *very likely* that the rate of sea level rise will exceed that observed during the period 1971 to 2010 due to the increased global warming and melting of the glaciers and ice sheets (IPCC, 2013).

[4] To better understand the risk and impacts of global warming of more than 1.5^{0}C above pre-industrial levels, the IPCC was invited to produce a special report; a summary of this report has been released at time of writing (IPCC, 2018b, 2018c).

[5] Polar (Arctic) amplification phenomena occurs when, primarily due to an increase in GHGs, the earth's surface temperatures in the Arctic region increases about twice as fast as those in the mid-latitude zones. The reason for this is believed to be largely due to the melting of bright and reflective ice. This loss produces increased areas of dark ocean which in turn absorb more heat from the Sun than the surface of the ice would have.

Box 1: Representative Concentration Pathways

Climate change projections from the IPCC require information about future emissions or concentrations of greenhouse gases, aerosols and other climate drivers. This information is often expressed as a scenario of human activities. Scenarios used in IPCC have focused on anthropogenic emissions and do not include changes in natural drivers such as solar or volcanic forcing or natural emissions, for example, of CH_4 and N_2O.

For the Fifth Assessment Report (AR5) of IPCC, the scientific community has defined a set of four new scenarios, denoted Representative Concentration Pathways (RCPs, see Glossary). They are identified by their approximate total radiative forcing (see Glossary) in year 2100 relative to 1750: 2.6 W m^{-2} for RCP2.6, 4.5 W m^{-2} for RCP4.5, 6.0 W m^{-2} for RCP6.0, and 8.5 W m^{-2} for RCP8.5.

These 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) . For RCP6.0 and RCP8.5, radiative forcing does not peak by year 2100; for RCP2.6 it peaks and declines; and for RCP4.5 it stabilizes by 2100. Each RCP provides spatially resolved data sets of land use change and sector-based emissions of air pollutants, and it specifies annual GHG concentrations and anthropogenic emissions up to 2100. RCPs are based on a combination of integrated assessment models, simple climate models, atmospheric chemistry and global carbon cycle models. While the RCPs span a wide range of total forcing values, they do not cover the full range of emissions in the literature, particularly for aerosols.

For the Coupled Model Intercomparison Project Phase 5 (CMIP5) results, these values should be understood as indicative only, as the climate forcing resulting from all drivers varies between models due to specific model characteristics and treatment of short-lived climate forcers. Most of the CMIP5 and Earth System Model simulations were performed with prescribed CO_2 concentrations reaching 421 ppm (RCP2.6), 538 ppm (RCP4.5), 670 ppm (RCP6.0), and 936 ppm (RCP 8.5) by the year 2100. Including also the prescribed concentrations of CH_4 and N_2O, the combined CO_2-equivalent concentrations are 475 ppm (RCP2.6), 630 ppm (RCP4.5), 800 ppm (RCP6.0), and 1313 ppm (RCP8.5). For RCP8.5, additional CMIP5 Earth System Model simulations are performed with prescribed CO_2 emissions as provided by the integrated assessment models. For all RCPs, additional calculations were made with updated atmospheric chemistry data and models (including the Atmospheric Chemistry and Climate component of CMIP5) using the RCP prescribed emissions of the chemically reactive gases (CH_4, N_2O, HFCs, NO_x, CO, NMVOC). These simulations enable investigation of uncertainties related to carbon cycle feedbacks and atmospheric chemistry.

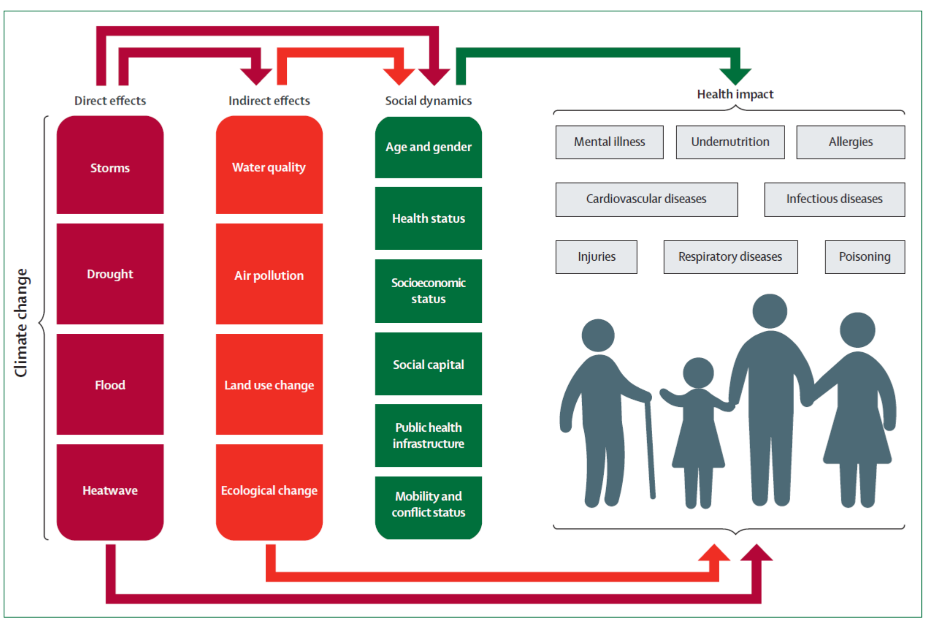
Source: (IPCC, 2013)

1.2 Impact of Climate Change and Variability on Human Health

The links between climatic conditions and health are numerous and complex. The United States Global Change Research Program's (USGCRP) 2016 scientific assessment, the 2015 Lancet Commission on Health and Climate Change and the IPCC AR5 show health impacts being affected by direct and indirect consequences of climate change, mediated by social conditions and dynamics (Figure 2). Climate change itself is affected by social and economic development, technology, and individual and national decisions. Direct effects of climate change include changes in weather patterns such as increased precipitation through storms, floods, hurricanes, drought or heatwaves. Indirect effects are caused through changes in the biosphere, for example rising air pollution and fine particulate matter, as well as ecological change through the distribution of disease vectors. Both outdoor and indoor air quality are affected by changes in climate. Rising levels of CO_2 can potentially increase growth rates of plants which in return release airborne allergens which can travel indoors. Poor air quality can cause an increase in respiratory and cardiovascular diseases.

Socially mediated health impacts occur when climate change interacts with social and human systems. For example, water quality will be affected by public health infrastructure such as sanitation systems. It is also mediated by the characteristics of people. For example, poor water quality is likely to have particularly deleterious effects on senior citizens who are physically frail, people with pre-existing health conditions involving weakened immunity to pathogens, and people living in poverty who are unable to pay for alternative water supplies. These two examples show how social dynamics are interlinked in producing health outcomes (IPCC, 2014a; United States Global Change Research Program, 2016; Watts et al., 2015; WHO, 2015). The Interagency Working Group on Climate Change and Health also highlights the fact that the effects of climate change on health are complex and dynamic since they are mediated by decisions made by individuals and policy makers. Figure 2 demonstrates relationships between direct and indirect effects and social dynamics on health outcomes due to climate change.

Figure 2: The direct and indirect effects of climate change and their impact on health and wellbeing



Source: (Watts et al., 2015)

Socially mediated impacts are linked to social determinants of health. The Commission on the Social Determinants of Health (CSDH) defined the Social Determinants of Health (SDH) as, *"the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life. These forces and systems include economic policies and systems, development agendas, social norms, social policies and political systems"* (WHO, 2017). A concern with the distribution of resources and power is at the heart of the social determinants of health approach. Thus, issues such as poverty, income inequality, gender and racial equity, and access to health care are of concern. As regards climate change, low income countries and SIDS, and sub-populations such as the poor and marginalised, people with disabilities, the elderly, women and young children are disproportionally affected by the health effects of climate change (IPCC, 2014a; McMichael et al., 2003; United States Global Change Research Program, 2016; Watts et al., 2015; WHO, 2015). Risks are not evenly distributed throughout the world and within national populations. Chapter 2 examines the vulnerability of the Caribbean and specific groups of people within the region.

Climate affects health not only through slow onset impacts but also through sudden and acute, highly visible impacts. The latter include extreme weather events such as storms, hurricanes and more severe heat waves. Such events have the potential to destroy key infrastructure such as health and accommodation facilities. Climate change also has the potential to limit national and global development goals through, for example, malnutrition caused by extreme weather conditions. In the Caribbean the intensity of severe storms and hurricanes has the potential to severely impact on national development goals (see Chapter 4). Exposure to toxic contaminants from climate change adaptation methods, such as the use of pesticides in agricultural and fisheries industries to increase food production and control disease vectors, respectively, can also adversely affect human health (Haines, RS, Campbell-Lendrum, & Corvalan, 2006; Portier CJ et al., 2010; United States Global Change Research Program, 2016). The strength of national health systems, their ability to absorb the impacts of climate change, and manage and adapt to the climate-sensitive health risks, will determine the health outcomes (IPCC, 2014a; Portier CJ et al., 2010; Watts et al., 2015).

Some of the human health categories that have been identified as likely to be affected by climate change include asthma, respiratory allergies and airway diseases, cancer, cardiovascular disease and stroke, foodborne diseases and nutrition, heat-related morbidity and mortality, human developmental effects, mental health and stress related disorders, neurological diseases and disorders, vector-borne and zoonotic diseases, waterborne diseases and weather-related morbidity and mortality. Note that these categories have been listed alphabetically and in no specific order of prioritization (IPCC, 2014a; McMichael et al., 2003; Portier CJ et al., 2010; United States Global Change Research Program, 2016; Watts et al., 2015; WHO, 2015). Evidence for links between climate and these health categories in the Caribbean is explored in Chapters 3 and 4. Table 1 summarises some of the most important health risks and also gives a confidence rating as to the likelihood of the impact as designated by the IPCC AR5 (IPCC, 2014a; WHO, 2015).

Table 1: Summary of the main expected health impacts of climate variability and climate change globally by the middle of the current century

	Exposures affected by climate change	Health risks and associated disease conditions	Health Impact	Confidence rating
Direct effects	Increased numbers of warm days and nights; increase in frequency and intensity of heat waves; increased fire risk in low rainfall conditions	Excess heat-related mortality; increased incidence of heat exhaustion and heat stroke, particularly for outdoor labourers, athletes, elderly; exacerbated circulatory, cardiovascular, respiratory, and kidney diseases; increased premature mortality related to ozone, and air pollution produced by fires, particularly during heat waves.	Greater risk of injury, disease, and death due to more intense heat waves and fires.	Very high
	Decreased numbers of cold days and nights	Lower cold-related mortality, reduced cardiovascular, and respiratory disease, particularly for the elderly in cold and temperate climates	Modest improvements in cold-related mortality and morbidity	Low
Effects mediated through natural systems	Higher temperatures and humidity, changing and increasingly variable precipitation, higher sea surface and freshwater temperatures	Accelerated microbial growth, survival, persistence, transmission, virulence of pathogens; shifting geographic and seasonal distributions of e.g. cholera, schistosomiasis, and harmful algal blooms; increased air pollution and aerosolized marine toxins; increased dust; lack of water for hygiene; flood damage to water and sanitation infrastructure, and contamination of water sources through overflow.	Increased risks of food- and water-borne diseases.	Very high
	Higher temperatures and humidity, changing and increasingly variable precipitation	Accelerated parasite replication and increased biting rates; prolonged transmission seasons; re-emergence of formerly prevalent diseases; changing distribution and abundance of disease vectors; reduced effectiveness of vector control interventions.	Increased risks of vector-borne diseases	Medium
Effects heavily mediated through human systems	Higher temperatures and changes in precipitation	Lower food production in tropics; lower access to food due to reduced supply and higher prices; combined effects of undernutrition and infectious diseases; chronic effects of stunting and wasting in children.	Increased risk of undernutrition resulting from diminished food production in poor regions.	High
	Higher temperatures and humidity	Outdoor and unprotected workers obliged to work in physiologically unsafe conditions, or to lose income or livelihood opportunities	Consequences for health of lost work capacity and reduced labour productivity in vulnerable populations	High

Source (WHO, 2015, p. 8)

In addition to the health impacts as described in Table 1 , the IPCC AR5 has identified key 'reasons for concern' within various sectors and regions (IPCC, 2014a; WHO, 2015). For the health sector these include:

- Risk of death, injury, or disrupted livelihoods in low-lying coastal zones and SIDS due to storm surges, coastal flooding and sea level rise.
- Risk of severe ill-health, mass displacement and disrupted livelihoods for large urban populations due to inland flooding in some regions.
- Systemic risks due to extreme weather events including storms or floods leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services. For example, a breakdown in infrastructure for drinking water and wastewater can lead to contamination of drinking water for human consumption by water-related bacteria, harmful algae, chemicals and other toxins leading to an increase in water-related illnesses (United States Global Change Research Program, 2016).
- Risk of food insecurity, volatile food prices and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings.
- Loss of livelihoods and income, particularly for farmers, due to insufficient access to drinking and irrigation water and reduced agricultural productivity; and for fishing communities due to loss of marine and coastal ecosystems through the goods, functions and services they provide. This will lead to overall reduction in economic growth, the exacerbation of poverty and increased mental health and stress-related disorders.
- Reversal of global health progress, including the achievements of the Millennium Development Goals and the objectives of the Sustainable Development Goals.

1.3 Inter-sectoral Linkages and Cross Sectoral Strategies to Address Health Outcomes of Climate Change and Variability

In order to limit the negative impacts of climate change on human health it is necessary to reduce the vulnerability of health systems and the populations at risk and ensure that individuals, societies and governments have the tools to manage and/or adapt to the impacts. The health sector has a large part to play in climate change adaptation and resilience, but conditions and actions in other sectors also affect health; so-called health-determining sectors, such as water, electricity, sanitation, agriculture and sectors making a significant contribution to the economy, such as tourism. Thus, effective adaptation to protect and promote health must be implemented across multiple sectors, where numerous ways to overcome barriers to achieve co-benefits are identified and vulnerable populations and regions are targeted (Shumake-Guillemot, Villalobos-Prats, & Campbell-Lendrum, 2015; Watts et al., 2015).

Box 2: Some concepts related to changes in the climate

Vulnerability is defined as propensity or predisposition to be adversely affected. It is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and it adaptive capacity (IPCC, 2014b; UNFCCC, 2014).

Adaptation is defined as the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014b).

Resilience is defined as the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure (IPCC, 2014b).

Mitigation is defined as a human intervention to reduce the sources or enhance the sinks (see Glossary) of GHGs (IPCC, 2014b).

Adaptation to direct health impacts of climate change, especially extreme events such as hurricanes, includes the introduction of Early Warning Systems (EWS), effective contingency planning and the identification of vulnerable populations and exposed communities. Public health agencies need to upgrade emergency programmes and include the forecasting and preparedness of anticipated health risks from extreme weather events.

The impacts of extreme weather may include flooding, which can cause contamination of fresh drinking water and increased morbidity and mortality. Other health impacts include mental stress due to injury of self and significant others, damage and loss to property and possible migration. Adaptive methods for flooding can be either structural or non-structural. Structural measures can include the building of sea walls, dams and floodways to keep people and their property safe. Non-structural measures seek to reduce effects of flood damage through flood insurance zoning laws, emergency preparedness, EWS and post-flood recovery (Watts et al., 2015; WHO, 2009).

The frequency, intensity and duration of extremely hot days and nights and heatwaves are set to increase with climate change. These effects are predicted to be amplified by the urban heat-island effect, which occurs when buildings and paved surfaces retain heat compared to reflective, shading surfaces and those covered with vegetation. Adaptive measures within the public health system include training of health-care workers and implementing integrated heatwave EWS. Other measures include increasing green spaces and improving the design of public spaces and infrastructure to be more climate-responsive; these measures include sectors other than public health such as urban planning and water utility. In addition, communities must also be strengthened to improve resilience, focusing on the most vulnerable to heat stress. Europe, the United States, Asia, and Australia have introduced warning systems for heat waves. Components of effective heat wave and health warning systems include identifying weather situations that adversely affect human health, monitoring weather forecasts, communicating heat wave and prevention responses, targeting notifications to vulnerable populations, and evaluating and revising the system to increase effectiveness in a changing climate. As noted there are many opportunities to increase resilience to extreme weather events outside of the health sector; these can also provide co-benefits (IPCC, 2014a; United States Global Change Research Program, 2016; Watts et al., 2015).

Adaptation to indirect health impacts are challenging due to the complex causal pathways between the increased risk, the environment in which it is taking place and health impact which may lead to unexpected results. One of the main indirect health impacts of climate change is food insecurity as ecosystem changes affect agriculture and fisheries. Adaptation methods to reduce food insecurity include better management of ecosystems and ecosystem restoration through, for example, the preservation of mangrove forests for those who are dependent on the mangroves and adjacent marine ecosystems. This involves collaboration with farmer networks and sustainable farmer markets. This will not only decrease food insecurity but will achieve other social goals. Examples of mangrove restoration and rehabilitation has occurred in several locations (e.g., Vietnam, Djibouti, and Brazil) to reduce coastal flooding risks and protect shorelines from storm surge.

Restored mangroves have been shown to attenuate wave height and thus reduce wave damage and erosion. They protect aquaculture industry from storm damage and reduce saltwater intrusion (IPCC, 2014a). Other adaptation strategies include investments in agricultural research and human capital, use of innovative crop management and insurance methods, increased investments in rural and water infrastructure and enhanced international collaboration for financial support, emergency food and grain reserves, capacity building in emergency responses to food crises etc. Such strategies can also increase household incomes and reduce gender inequality (von Braun et al., 2008; Watts et al., 2015; WHO, 2009).

Climate-related migration within and between countries can occur as a result of an emergency situation, such as a sudden devastating hurricane, or, as climatic conditions worsen, people seek new areas to live and work. Migration can further affect health through increased spread of communicable diseases and malnutrition resulting from overcrowding, lack of safe water, food and shelter. Adaptive measures to reduce international migration due to climate change include introducing measures to reduce climate change and land degradation processes in the home country; EWS for impending extreme weather events and integrated water management systems which will reduce flooding and ensure safe drinking water; and rehabilitation of degrading coastal and territorial ecosystems (Watts et al., 2015; WHO, 2009).

Changes in demographics, climate, human relations, land use and biodiversity resulting from climate change are predicted to lead to changes in disease patterns. For example, an increase in vector-borne disease risks is likely due to increased precipitation, changing temperatures and rising sea levels. Adaptation measures towards infectious disease risks include developing EWS based on modelling health impacts of climate variability (Lowe et al., 2018), investing in public health, adopting the One Health approach[6] and strengthening surveillance and monitoring capacity in countries to ensure relevant data on health climate risks or vulnerabilities is available. These measures will not only reduce the health impacts of climate change but will also result in building capacity in public health, ensuring that emerging infectious diseases are well managed through effective and collaborative national agriculture and health systems (Watts et al., 2015; WHO, 2009, 2015).

Climate change also increases the likelihood of respiratory diseases, such as asthma, airway diseases and respiratory allergies. Asthma can be triggered by air pollutants, allergens, stress and other

[6] One Health is an approach that, "understands that humans, animals and ecosystems are interconnected and involves applying a coordinated, collaborative, multidisciplinary and cross-sectoral approach to address potential or existing risks that originate at the animal-human-ecosystems interface" (One Health Global Network, nd).

environmental variables while respiratory allergies tend to be seasonal and linked to increases in climate-sensitive components. Mitigation measures include introduction of policies to reduce GHGs into the atmosphere by reducing vehicle use and encouraging alternate transportation mechanisms such as bicycling and walking. Such measures also have the co-benefits of increasing exercise and reducing obesity thus increasing cardiovascular fitness. However, it must be noted that just by being outside there is the risk of more exposure to air pollutants (Portier CJ et al., 2010).

1.4 GLOBAL POLICIES AND FRAMEWORK RESPONSES

There have been several major international global policies and frameworks in response to climate change since the first World Climate Conference in 1979. This first conference noted the variability in global climate over the past millennia and its potential impact on all areas of human life. The meeting was attended mainly by scientists who, arguing that this change was largely due to human action, urged governments "to work together to preserve the fertility of the soils; to avoid misuse of the world's water resources, forests and rangelands; to arrest desertification; and to lessen pollution of the atmosphere and the oceans" (UN, 1979).

The Rio Earth Summit (1992) joined countries through an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC)[7], to solidify international cooperation to combat climate change and its impacts. This framework came into force in 1994 and the first Conference of Parties (COP) took place in Berlin in 1995. To date 197 countries (Parties to the Convention) have ratified the UNFCCC (UNFCCC, nd-a). At the Rio Earth Summit, the countries adopted a non-binding action plan for sustainable development, Agenda 21 (United Nations Sustainable Development, 1992).

To strengthen the global response to climate change, in 1997 the Kyoto Protocol was formally adopted by governments and entered into force in 2005. The Kyoto Protocol sets binding targets for the reduction of GHG emissions by developed countries, as they are responsible for the largest share of current and historical GHG emissions. The first commitment period was 2008-2012. The second commitment period (2013-2020) was agreed via the Doha Amendment in 2012 (UNFCCC, nd-a, nd-b).

The International Health Regulations (IHR) 2005 is a legal framework, agreed by all WHO Member States, "*…to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public health risks, and which avoid unnecessary interference with international traffic and trade*" (WHO, 2005, p. 1). The WHO Member States were tasked to assess their 13 national public health core capacities and develop a plan to achieve them. Core capacities are as follows (WHO, 2005):

A. Surveillance and response
    a. National legislation, policy and financing
    b. Coordination and communication
    c. Surveillance
    d. Response

[7] The UNFCCC is also the name of the organisation set up to support the work of the Convention itself (UNFCCC, nd-a).

e. Preparedness
f. Risk communication
g. Human resources capacity
h. Laboratory diagnostic and confirmation capacity

B. Development of capacities at Points of Entry
C. Potential health hazards
    a. Zoonotic events
    b. Food safety
    c. Chemical events
    d. Radiological and nuclear events

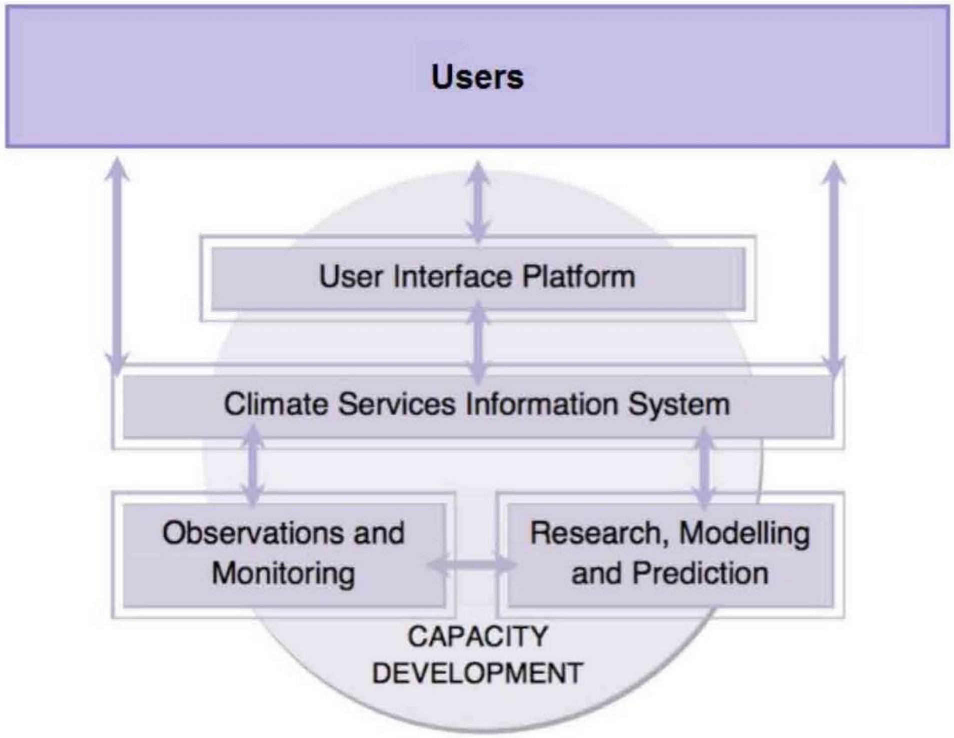
Despite extensions being given to WHO Member States including CMS, as of 2016, CMS were still not fully compliant with regards to having achieved IHR 2005 core capacities (Caribbean Public Health Agency, Allen, & West, 2017). Ensuring that the core capacities are implemented is important as they respond to adaptation and mitigation aspects of climate and health and have been linked to various international (for example, Lancet Countdown 2017 – see below) and regional strategies (for example, Caribbean Cooperation in Health IV). Responses to health security issues associated with climate change in the Caribbean will be further detailed and discussed in Chapter 5.

In 2009 at the World Climate Conference-3, in Geneva, it was proposed that a Global Framework for Climate Services (GFCS) should be established, *"to strengthen production, availability, delivery and application of science-based climate prediction and services"* (World Climate Conference 3, 2009, p. 1). The goal of GFCS is to enable accurate and timely science-based climate information to be available to manage climate risks and opportunities arising out of climate variability and change; *"climate services [will] provide climate information to help individuals and organisations make climate smart decisions"* (GFCS, nd). Policymakers, planners, investors and vulnerable populations require such climate information in user friendly formats so that they can prepare for expected trends and changes in the weather. Such information can be gathered from national and international climate organisations on temperature, rainfall, wind, soil, moisture and ocean conditions. Long-term historical averages of these variables are also needed. Such data can also be combined with non-climate information such as agricultural production, health trends, population distributions in high-risk areas, roads and infrastructure, so that the user can tailor his needs to suit changes in climate patterns. The aim is to be prepared for new climate conditions thus enabling the user to adapt to the impact on water supplies, health risks, extreme events etc (GFCS, 2018). The GFCS has five overarching goals (GFCS, 2014, p. iv):

1. Reducing the vulnerability of society to climate-related hazards through better provision of climate information;
2. Advancing the key global development goals through better provision of climate information;
3. Mainstreaming the use of climate information in decision-making
4. Strengthening the engagement of providers and users of climate services; and
5. Maximising the utility of existing climate service infrastructure

The GFCS encompasses five components or pillars (see Figure 3) to ensure that the climate services are delivered as effectively as possible. Note that there will be some overlap of functions of each pillar (GFCS, 2014).

Figure 3: Schematic representation of the five pillars of the Global Framework for Climate Services



Source: (GFCS, 2014)

The GFCS works at the international, regional and national levels to ensure effective collaboration at all levels and delivers critical climate services and products to climate sensitive sectors: agriculture and food security, disaster risk management, energy, health and water (CRCC, 2018; GFCS, 2016). The GFCS will be discussed further in Chapter 5, under the description of the international project – Implementing the Global Framework for Climate Services (GFCS) at Regional and National Scales which was implemented by the Caribbean Regional Climate Centre (CRCC).

On 12 December 2015, the Paris Agreement was adopted by the COP and this entered into force on 4 November 2016. The aim of the Paris Agreement is to strengthen the global response to the threat of climate change, to keep the global temperature rise in the 21st century well below 2⁰C above pre-industrial levels. Parties agreed to pursue efforts to limit the temperature increase to 1.5⁰C as this difference of 0.5⁰C would substantially limit the impacts of climate change[8]. The agreement also aims to strengthen the ability of countries to deal with the impacts of climate change. In order to do this, appropriate financial flows, a new technology framework and an enhanced capacity-building framework were to be put in place (UN, 2015; UNFCCC, nd-a, nd-b).

In order to provide policymakers with regular scientific evidence of climate change, its impacts and future risks, and options for adaptation and mitigation, the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) set up the IPCC in 1988. It

[8] To better understand the risk and impacts of global warming of 1.5⁰C above pre-industrial levels, the IPCC was invited to produce a special report; this report has been published in summary form at time of writing (IPCC, 2018b, 2018c).

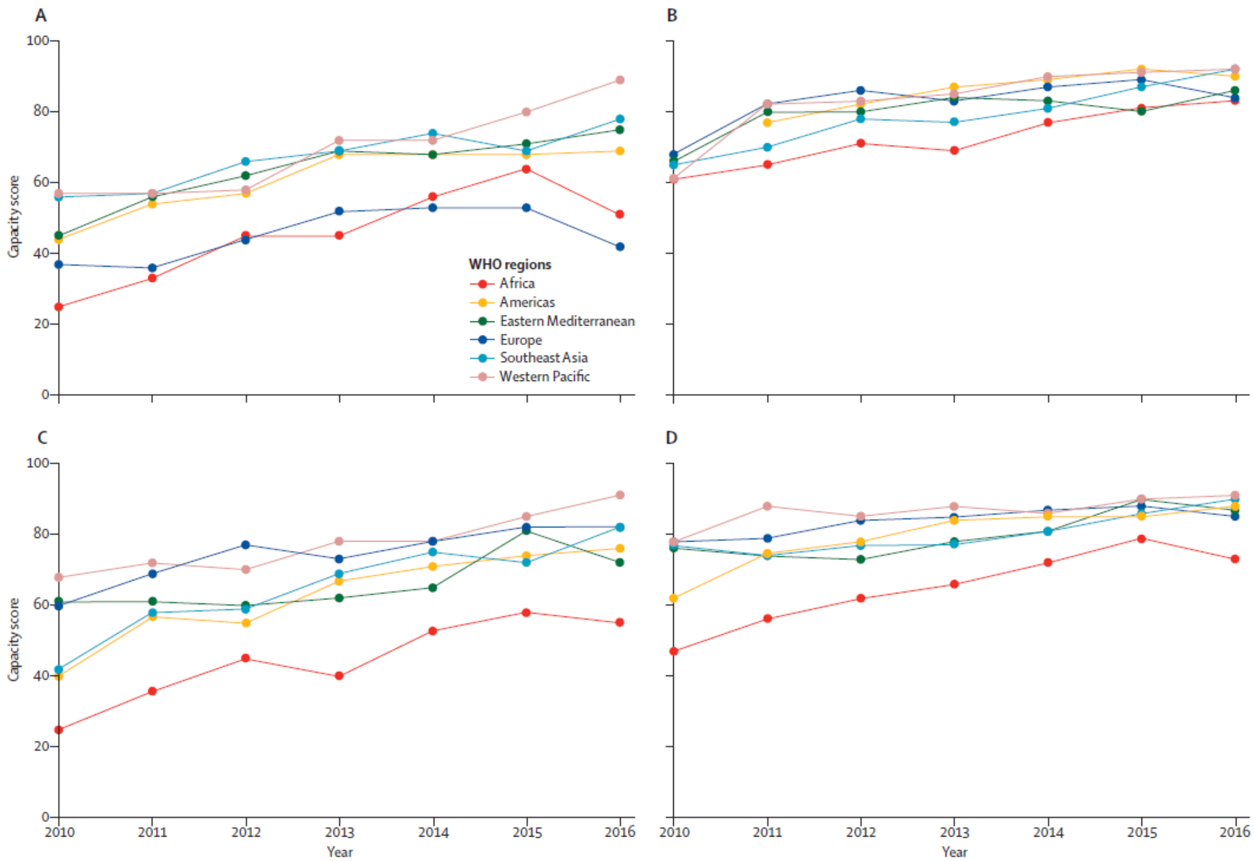
conducts research through worldwide reviews and compiles special reports and technical papers. In addition, it issues regular Assessment Reports (ARs). To date it has issued five ARs; the latest, AR5, issued in 2014. The findings of the IPCC represent global scientific consensus and are apolitical in nature. The IPCC is now recognised as the leading international body for assessing climate change and the ARs are used by the UNFCCC to set international policy (IPCC, 2018a).

There have been various global collaborations by the Lancet Commission to examine health effects of climate change, policy responses to health and climate change, and the tracking of progress on health and climate change in the implementation of international policies (Costello et al., 2009; Watts et al., 2015; Watts et al., 2017). In 2009, a multidisciplinary Lancet Commission on Managing the Health Effects of Climate Change described climate change as, "the biggest global health threat of the 21st century" (Costello et al., 2009). Later, in 2015, University College London (UCL) – Lancet Commission on Health and Climate Change indicated that, "tackling climate change could be the greatest global health opportunity of the 21st century" (Watts et al., 2015, p. 1861). The Lancet Countdown builds on the success of the 2015 Lancet Commission and is an international research collaboration, dedicated to tracking, using a series of indicators, the world's response to climate change, and the health benefits that emerge from this transition. The Countdown's 2017 report looks at indicators around climate change impacts, exposures and vulnerability; planning for adaptation and resilience; mitigation actions and health co-benefits; economics and finance and public and political engagement (Watts et al., 2017). There are five key messages from the 2017 Lancet Countdown (Watts et al., 2017, p. 1).

1. Human symptoms of climate change are unequivocal and potentially irreversible; they will affect the health of all people around the world, especially vulnerable populations including children and the elderly, and those living in SIDS and other low-lying areas.
2. Human lives and livelihoods have been jeopardized by the late response to climate change. There has been limited progress towards adaptation and in some instances, changes have gone in the wrong direction, resulting in an increase in GHG emissions and the resultant increase in global temperatures.
3. Health professionals must be incorporated in the decision-making processes in order to advance progress on climate change. There is a huge opportunity for health professionals to act as advocates of reducing the risks and impacts that climate change has on health, as well as highlighting the co-benefits of adaptation. Actions on climate change by health professionals, especially if directed towards the policy makers, can result in better programmes which will benefit human health and wellbeing.
4. Progress towards the aforementioned indicators has been slow, but there has been an accelerated progress over the last 5 years and in 2017, sectors critical to public health have seen a move towards a low-carbon world. This progress has tracked the ten recommendations made to governments in the 2015 Lancet Commission (Watts et al., 2015). For example, in the area of clean fuel use, the cost of electric vehicles is expected to match that of non-electric vehicles in 2018. There are also now 9.8 million people employed in the renewable energy sector; more than 1 million more people than in the fossil fuel extraction sector. This together with the 2015 Paris Agreement shows a global commitment towards reducing the impacts of climate change.

An example of one of the Lancet Countdown's indicators is Indicator 2.3: 'detection and early warning of, preparedness for, and response to health emergencies.' It has been suggested that because of the focus on ensuring the implementation of the IHR 2005 country core capacities (including disease surveillance and early detection, multihazard public health emergency preparedness and response, and human capacity), national capacities to achieve this indicator has increased dramatically from 2010 to 2016 throughout the world (see Figure 4).

Figure 4: International Health Regulations capacity scores by global region, 2010-16



A: Human resources capacity score; B: Surveillance capacity score; C: Preparedness score; D: Response capacity score

Source: (Watts et al., 2017)

The IHR capacity scores can serve as a proxy of the national health system adaptive capacity and system resilience as they measure the extent to which health systems are able to detect, prepare for and respond to public health emergencies, some of which are climate sensitive. For example, under IHR 2005, the human resources available to implement the IHR core capacities can be used as a proxy for specific capacity for health adaptation to climate change. The surveillance capacity can be used a proxy for the health system's ability to predict and identify outbreaks of climate sensitive diseases such as vector and water borne diseases and food related outbreaks.

The preparedness capacity reflects the presence and implementation of a Multihazard National Public Health Emergency Preparedness and Response Plan. Finally, the response capacity can be used as a proxy for the health system to effectively mobilise a response when a disaster has occurred, such as a hurricane (Watts et al., 2017).

In 2015, the UN formulated 17 goals and 169 targets which seek to eradicate poverty and eliminate inequalities between people within and between countries by 2030 in the form of the Sustainable Development Goals (SDGs). Central to achieving these goals is a global commitment to, "address decisively the threat posed by climate change and environmental degradation [and achieve] cooperation aimed at accelerating the reduction of global GHGs and addressing adaptation to the adverse impacts of climate change." (UNDP, 2015, p. 13). This is expressed through SDG 13 - "Take urgent action to combat climate change and its impacts" - and its six targets (UNDP, 2015, p. 27). It is important to note that climate change has the potential to impact on many of the other SDGs, which are listed below. Addressing climate change is thus critical to human development. Impacts on poverty, hunger etc. are explored at various points in this report, while the central interest is in links between health (SDG 3) and SDG13. We discuss links between climate change and other development goals in the concluding chapter of this report.

Table 2: United Nations Sustainable Development Goals

Goal	
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: https://sustainabledevelopment.un.org/

The Caribbean Cooperation in Health IV 2016-2025 (CCH IV), *Focusing on regional Public Goods for Sustainable Development* (CCHIV), has as its overarching vision that, "Caribbean people will be happier, healthier and more productive, each respected for his/her individuality and creativity and living more harmoniously within cleaner, greener environments." (CARICOM, 2016, p. 12). Strategic objective 2 of the CCHIV, has as its outcome, "regional health security improved through reduction of environmental and occupational threats and through building a disaster resilient health sector, with an emphasis on vulnerable populations" (CARICOM, 2016, p. 13). This regional strategic outcome ties in with SDG 13 and its first target 13.1 to, "strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries" (UNDP, 2015, p. 27). CCH IV will be examined in more detail in Chapter 5.

CONCLUSION

There is a large body of evidence that details changes in climatic conditions, with much of this evidence attributing these changes to human activity. Increases in GHGs are widely accepted as causes of increases in atmospheric and oceanic temperatures, changes in global precipitation cycles, reduction in global snow and ice, rises in global mean sea levels and changes in extreme weather events. Some examples of climatic change in the Caribbean have been noted. For example, there has been an annual mean daily maximum temperature increase of 0.19^{0}C per decade from 1961 to 2010; the occurrence of warm days and nights have increased by 3.31% and 4.07% respectively per decade; and the intensity of daily rainfall and heavy rainfall events have significantly increased from 1986 to 2010. The year 2017 was considered an above normal and extremely active season with 17 named storms. The slogan '1.5 to Stay Alive' is used by CARICOM and other SIDS to highlight the importance, and potentially catastrophic events that may occur in the Caribbean region as a result of climate change.

The links between climate and health are numerous and complex and include direct (e.g. floods, heatwaves) and indirect effects (e.g. water quality and air pollution) and the interaction of these effects with social dynamics (e.g. age and public health infrastructure). Social determinants of health such as income and gender inequality also mediate the impacts. Some of the health outcomes include respiratory diseases, foodborne diseases and nutrition, heat-related morbidity and mortality, vector-borne and zoonotic diseases, waterborne diseases and weather-related morbidity and mortality.

It is important to note that in order to reduce vulnerability of health systems and populations at risk to the impacts of climate, national governments must include not only the health sector but take a multi-sectoral approach to adaptation and building resilience to the negative effects of climate change and variability, building on international agreements and partnerships. There have been several international and global policies and frameworks in response to climate change and variability including the Kyoto Protocol (1997) and the Paris Agreement (2015). Leading international governmental bodies on climate change include the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change while the Lancet Commission on Health and Climate is a leading collaboration that looks specifically at the effects of climate trends and their impact on health. The Global Framework on Climate Services (GFCS) is a partnership between governments and organisations which seeks to provide climate data and information to decision-makers at all levels in five priority areas – agriculture and food security, disaster risk reduction, energy, health and water (GFCS, 2018). (Also see Chapter 5). In the next chapter we outline specific challenges for SIDS and low-lying areas, as a background to the climate and health challenges and options facing the Caribbean.

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