Chapter 2

From Science to Science-based: Using State-of-the-Art Climate Information to Strengthen DRR in Small Island States

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Abstract

While weather and climate-related hazards have historically taken a toll on Caribbean small islands, the impacts of recent storms have prompted urgent dialogue on updating and improving the way the region understands, prepares for and responds to disasters. As the region convenes on issues related to boosting environmental governance, developing key technology systems and building resilient infrastructure, it is imperative that consideration be offered to the potential of using climate information, most of which is freely available, for the effective strengthening of disaster risk reduction (DRR). Enhanced awareness and use of a wide range of weather- and climate-related information can empower small states with data to make appropriate and impactful decisions towards advanced disaster preparedness, disaster risk reduction and future resilience.

In attempting to understand the divide between science/research and policy/use in disaster risk reduction in small states, this chapter aims to underscore the potential value and utility of climate information. We define climate information, review its nature and utility globally, and discuss the variability in verified climate information for highly climate-vulnerable but data-poor countries. Such a chapter has the potential to engage the science-policy dialogue of encouraging the development and use of climate information, especially at this time when governments and various agencies are interested in building and fostering resilience following recent disasters and impacts, and within the context of a region whose vulnerability will increase with climate change.

2.1 Introduction

Between 1900 and 2018, the insular Caribbean was affected by at least 599 natural hazard-based declared disasters (EM-DAT 2018). Of these, 543 were weather-related events (storms, floods, landslides and drought), contributing to some US$135 billion in estimated damages and affecting more than 51 million people within the region. Despite a potential reporting bias, it is a concern that more than half of these events occurred within the past 20 years alone. The increasing density of population and infrastructure in this period, especially along coastal areas, has amplified the region's exposure to climate-related hazards, including impacts on people and damages to infrastructure. While the projected effects of climate change on temperature and precipitation changes, as well as sea-level rise, within the region are already alarming (Nurse et al. 2014), scientific experts have recently forewarned of the worsening impacts of climate change (IPCC 2018), manifested for instance by a likely coupling with increased intensities of tropical storms (Fountain 2018).

Responding to the many events within the recent past, Caribbean agencies in the areas of meteorology, water resources and disaster risk management seem committed to build resilience within the region to reduce its vulnerability to weather-related disasters. It is timely, then, that this study seeks to ensure that within these efforts must be the focus on building capacity for the understanding, development, effective use, dissemination and interpretation of climate information. However, while climate sciences have made enormous progress in recent decades, only a few key findings 'trickled down' into operational disaster risk reduction (DRR) programmes, leaving decision-makers wondering about 'acceptable uncertainties' in forecasts (Coughlan de Perez et al. 2015), the benefits of early action compared to the costs of inaction, or the links between socioeconomic vulnerabilities/coping capacities in the face of chronic climatic threats.

In attempting to understand the divide between science/research and policy/use in disaster risk reduction in small states, this chapter aims to underscore the potential utility and added-value of climate data/information/services, as well as to identify current limitations. We define climate information, review its nature and utility globally, and discuss the variability in verified climate information for highly climate-vulnerable but data-poor countries. In a case study, we focus on available information for Jamaica. Like many other island regions, Jamaica is highly vulnerable to the impacts of climate change, variability and related extreme events. While significant efforts are currently underway to improve the availability of climate data through the installation of automatic weather stations, there are still gaps in terms of a long time series of ground-truthed weather station data for all of the island. Satellite and modelled data have the potential to complement and partly replace in-situ observations (Dinku et al. 2018) but different factors (such as island location and topography) result in highly heterogeneous validation results, leading to uncertainties regarding their operational added-value. Hence, identifying the strengths and weaknesses or specific climate datasets, their usefulness to track and forecast extreme events, their integration into existing decision-making workflows and links to socioeconomic conditions (e.g. changes in livelihoods) are a necessary step towards advanced disaster risk reduction in Jamaica and the wider Caribbean.

Noting that climate data and, ideally, resulting actionable climate knowledge are but one key component that should be developed and better utilised within the context of disaster resilience within the region, we also discuss the requirements that are needed to enhance its use. We attempt to describe advanced visualisation techniques, metalevel studies that summarise the applicability of climate data in particular regions (including calibration and validation studies), and operational projects that use 'high-level' climate data (i.e. the opposite of raw data) to develop or improve climate services or related applications (such as financial instruments/parametric insurance). This discussion also includes the role of improved dialogue between key agencies within countries, regional counterparts and also international agencies.

This study aims to broaden the discussion of DRR and building resilience by preparing countries for advanced risk management using available data and information products. These discussions are complementary to the concerns of environmental governance, technology, resilient infrastructure and stimulated investments, and can enhance such directives and actions. As they rebuild, it is important to empower small states with applicable and actionable data and information to make appropriate and impactful decisions that minimise disaster impacts and increase resilience to future risk.

2.2 The Caribbean: Vulnerability and disasters in context

While countries categorised as small island developing states (SIDS), such as many of those in the Caribbean region, exhibit heterogeneous vulnerability profiles, it is widely accepted that there are several common characteristics that are likely to increase their vulnerability and pose a risk to sustainable development (UNFCCC 2005). Such challenges may be due to geographic factors such as location, remoteness, small land masses, geomorphological structures and exposure to natural hazards, as well as socioeconomic features, including small economic sizes and populations, dependence on primary industries, and yet-developing economic and governance systems (e.g. see Kruczkiewicz et al. 2018). The concept of this particular vulnerability as experienced by SIDS has been well-discussed by many (e.g. see Briguglio 1995; Pelling and Uitto 2001; Briguglio et al. 2006; Lewis-Bynoe 2014, 2016) and has also been challenged for increased perspective (e.g. see Barnett and Waters 2016). The complexity of this inherent vulnerability is specifically highlighted in times of disasters. The susceptibility of Caribbean islands to a variety of natural hazards, coupled with the increasing exposure of Caribbean societies (due to increasing population sizes and relative number of persons living on or near coastal/low-lying areas or otherwise hazard-prone locations) and ecological systems further increases the risk of severe disaster impacts.

Some economic literature has offered insights into the relative disproportionate nature of disaster impacts on small islands. Kahn (2005) finds that even though developed countries experienced disasters of similar frequency and severity, there were less disaster-related deaths in these countries. As well, disaster impact may also be lower in situations of stable political systems or improved institutional conditions (Kahn 2005; Toya and Skidmore 2007). In terms of the connection between disasters and development, many recent studies suggest that disasters may play a role in observable adverse macroeconomic impacts, leading to negative long-term growth and development consequences (e.g. see Hsiang and Jina 2014), particularly in low-income countries (Benson and Clay 2004; Zapata and Madrigal 2009; Strobl 2012).

While these studies have been generally global in nature or wider in scope, region-specific socioeconomic research has only recently begun to focus on the impact of weather, climate and disasters within the macroeconomic context. Of interest, Strobl

(2012) looks at the particular impacts of hurricanes on macroeconomic outcomes in the wider Central American and Caribbean region, finding an inverse relationship between average damages caused by hurricanes and economic output. Moore et al. (2016) perform general equilibrium framework model simulations which suggest that not only do output losses due to hurricanes have economy-wide effects, but rural regions may suffer most. Recent satellite-based night time light observations before and after hurricane Maria struck Puerto Rico confirm these findings (NASA 2018).

The number of research papers looking at the socioeconomic nature of disasters within the Caribbean is limited, especially given the frequency and impact (both monetary and on persons) of these events. As shown in Table 2.1, which summarises data for the Caribbean over the period 1900 to 2018 using data from the EM-DAT disaster database,[1] while more than 80 per cent of the disasters reported were natural hazard-based, these events have led to more than 99 per cent of the damages and impacts on people. Of these reported disasters, approximately 75 per cent are due

Table 2.1 Disasters in the Caribbean, 1900–2018

Disaster group	Disaster type	Occurrence	Total deaths	Total affected	Total damages (million US$)
Hydrological	Flood	151	6,368	7,494,812	992.68
	Landslide	7	443	2,435	–
Meteorological	Storm	353	31,482	35,848,533	133,831.75
Climatological	Drought	29	–	8,331,762	283.64
	Wildfire	5	–	–	1.00
Biological	Epidemic	30	7,594	749,291	-
Geophysical	Earthquake	15	223,988	3,837,599	8,075.00
	Mass movement (dry)	1	40	–	–
	Volcanic Activity	10	31,599	110,403	8.00
Technological	Industrial Accident	8	59	5,290	22.40
	Miscellaneous Accident	24	657	524,518	50.30
	Transport Accident	98	6,397	2,532	–
ALL DISASTERS TOTAL		**731**	**308,627**	**56,907,175**	**143,264.77**
Subtotal hyd/met/clim disaster groups		545	38,293	51,677,542	135,109.07
% of all disaster total		74.6%	12.4%	90.8%	94.3%

Source: Data compiled from EM-DAT database (update as at: 29 January 2019), available at: www.emdat.be

Note: 'Subtotal hyd/met/clim disaster groups' is the total of the hydrological, meteorological and climatological disaster groups.

primarily to events such as floods, landslides, storms, droughts and wildfires – in other words, most of the disasters in the Caribbean are largely due to weather and climate events. These events have led to an estimated death toll of more than 38,000 people, generally affected more than 51.6 million people, and resulted in economic damages upwards of US$135 billion. Between 2014 and 2018, storms, floods and droughts have contributed the most to those affected by disasters, as well as economic damages. In 2017 alone, 26 storm disaster events throughout the Caribbean affected 11 million people and led to US$93.4 billion in damages. These numbers are particularly concerning because SIDS are among the least responsible of all nations for climate change, but suffer strongly from its adverse effects (UNFCCC 2005).

The frequency and compound nature of such disaster events and their impacts on people and economies reinforce the local vulnerability and viability for development and resilience. Furthermore, the projected effects of climate change and variability certainly add to this vulnerability dimension. For Caribbean small islands, the Intergovernmental Panel on Climate Change's (IPCC's) 5th Assessment Report indicates that under the Representative Concentration Pathway 4.5 Scenario, the annual projected change for 2081–2100, relative to 1986–2005, is a likely 1.4°C average increase in temperature, 5 per cent decline in rainfall and 0.5–0.6 metre sea level rise (IPCC 2014). Inter-annual climate phenomena, such as the El Niño-Southern Oscillation (ENSO), have also affected the frequency and severity of rainfall and extreme events, including droughts, storms and floods.

It is worth noting that the Climate Studies Group at the University of the West Indies, Mona, Jamaica, has been prolific in research to better understand the historical observations and future climate projections using regional climate models, such as that of the Hadley Centre Providing Regional Climates for Impacts Studies. In addition, their research has opened an understanding of a regional system of Caribbean climate drivers, which include the Atlantic warm pool (AWP), the Caribbean low-level jet (CLLJ), and the Atlantic multidecadal oscillation (AMO) signal of the North Atlantic surface sea temperatures (for example, see Peterson et al. 2002; Campbell et al. 2011; Taylor et al. 2011; Taylor et al. 2012; Karmalkar et al. 2013; Stephenson et al. 2014). Also of interest is the continuing work regarding simulations estimating when ongoing warming might exceed the bounds of historical climate variability, such as Camilo et al. (2013) wherein it is discussed that '[u]nprecedented 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'.

Development agencies have long advocated that minimising such disaster impact is likely plausible through an emphasis on strategies focused on risk reduction, resilience and building adaptive capacity (e.g. see Mochizuki et al. 2014); such a focus may in tandem play a role in fostering and sustaining livelihoods, economic development and growth (e.g. World Bank 2013). As offered by the United Nations International Strategy for Disaster Reduction (UNISDR), disaster risk reduction policies may include 'reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events' (UNISDR n.d.). In this regard, utilising available information and data about the weather/climate, as well as how the weather/climate has historically affected countries and the changing nature of this in the future, and designing strategies to best incorporate and communicate such information, could be a pivotal way to improve society's response and resilience to climate change and variability, including hazards relating to extreme weather and climate events.

2.3 Understanding weather and climate information

As per Singh et al. (2018), scientific weather and climate information 'refers to processed data, products and/or evidence-based knowledge about the atmosphere-ocean system across short (hours to days) and long (seasons to decades) timescales'. Generally, it refers to data describing historical, current and future climate conditions, including hydrometeorological ('hydromet') variables, either from ground-based observations, satellites or models that improve our understanding of interaction between natural and human systems. For instance, on a global climate scale, climate information products may include 'global emission scenarios and climate model outputs to information about local impacts and vulnerability to climate change', incorporating 'meteorological, hydrological, oceanographic, terrestrial (collectively, the Essential Climate Variables, or ECVs)', and socioeconomic and other data (see Adaptation Community n.d.). The focus on the use of the term 'information' vis-à-vis solely data 'implies that it has meaning and relevance within a given context', and as such climate information can be used to assist agencies and governments key data in informing short-, medium- and long-term decisions relating to priority topics within the region (Singh et al. 2018).

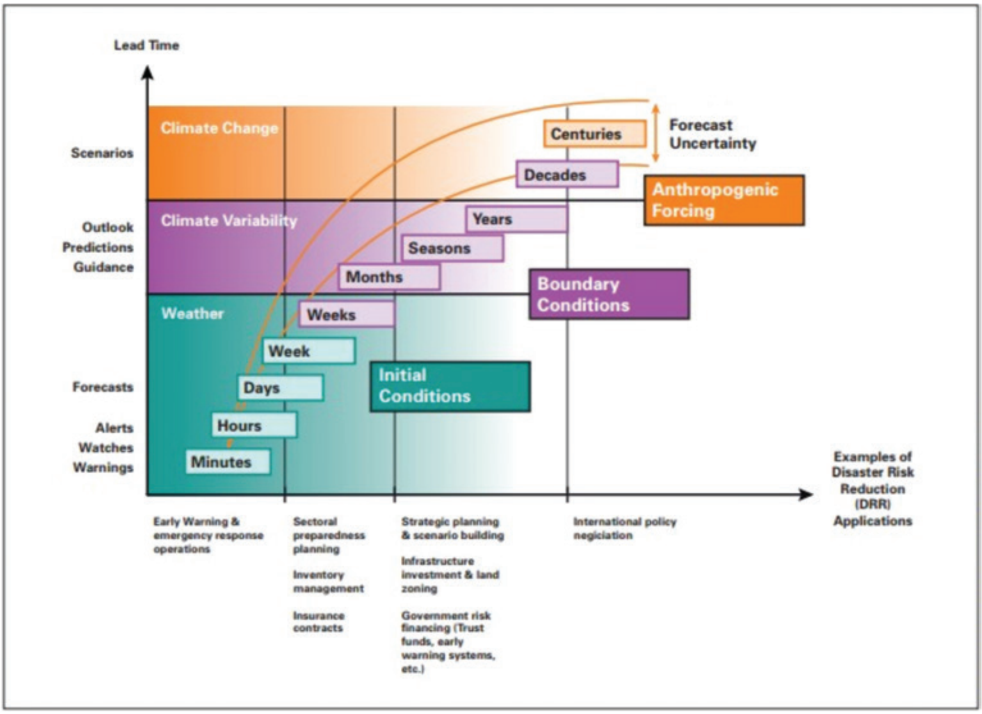
Short-term weather and climate information, on the timescale of days to weeks, can include observed and forecasted rainfall and temperature, alongside early warning of extreme events such as floods, dry spells or droughts, if auxiliary data, such as updated socioeconomic vulnerability profiles or digital elevation models, are available. Key short-term discussions based on this data could refer to disaster risk management decisions on how to protect people and infrastructure from impending events, and concerns of risk communication to and response within the most vulnerable areas. Also, the development and revision of targeted contingency plans and the triggering of advanced financial instruments, such as parametric insurance, fall into this category.

While medium-term decisions can include stocking of essential supplies or the revision of evacuation plans, water resource management may respond to sub-seasonal (two weeks to two months) timescales. Seasonal (>two months) information can be used to inform decisions about investments in irrigation and drainage systems, possible relocation of vulnerable persons to safer areas, and other decisions to improve the overall resilience of an area and population to hazardous events. However, independently of the timescale, decisions need to be based on data that are adapted to the decision-making context, as well as the decision-maker's expertise, objectives and willingness to use climate information.

At the global level, the advancement in scientific investigation and knowledge about past climatic conditions and encouragement of data acquisition and analysis of current data have offered improvements in scope about how we understand and make projections about future climatic conditions. Climate information thus plays a vital role in the development and process of climate services, which 'involve the production, translation, transfer, and use of climate knowledge and information in climate-informed decision making and climate-smart policy and planning' (Hewitt et al. 2012). In general, the 'aim of climate services is to provide people and organisations with timely, tailored climate-related knowledge and information that they can use to reduce climate-related losses and enhance benefits, including the protection of lives, livelihoods, and property' (Vaughan and Dessai 2014). **Figure 2.1** highlights a variety of climate information options at different lead times, together with relevant climate services and risk management applications.

While climate services projects and partnerships are evident across the globe covering a broad range of thematic areas, the World Meteorological Organisation's Global Framework on Climate Services (GFCS) specifically focuses on five priority topics: Agriculture and Food Security, Disaster Risk Reduction, Energy, Health and Water (see: https://www.wmo.int/gfcs/projects- map for a map of projects). As described by the GFCS, the focus on climate services that specifically relate to disaster risk reduction encourages the utilisation of quantitative risk-based climate information, which can assist countries to 'develop risk management strategies using early warning

Figure 2.1 Summary of climate information and climate services



Source: WMO Disaster Risk Reduction Programme, available at: https://www.wmo.int/pages/prog/drr/documents/Climate_DRR-FactSheet_EN.pdf

Figure 2.2 Idealised overview of climate information products and providers

Climate Information Products	Climate Information Providers						
	Meteorological services	Research institutes	Global web-based climate information portals	Consultancy firms	Insurance companies/ private enterprises	Government departments (excl. meteoro-logical services)	WMO
Raw data on Essential Climate Variables	X		X			X	X
Emission scenarios		X	X				
Global models	X	X	X				
Downscaled/regional models	X	X	X	X	X		X
Seasonal and decadal forecasts and predic-tions	X	X	X				X
Impact, risk and vulnerability assess-ments		X	X	X	X	X	
Local knowledge/ historical records		X	X	X	X	X	

Source: Adaptation Community 2013.

systems to reduce casualties; medium and long-term sectoral planning (such as land zoning, infrastructure development, water resource management, and agricultural planning) to reduce economic losses and build livelihood resilience; and weather index insurance (WII) and risk financing mechanisms to transfer the financial impact of disasters' (GFCS 2018).

In the growing field of climate information, there are now a variety of actors producing and encouraging the use of a variety of types of climate information, which is further supported by a variety of agencies, including national research institutes, National Meteorological and Hydrological Services (NMHSs), and global and regional information platforms (Adaptation Community 2013). For example, it is noted that more and more governments are customising climate information for specific users towards more targeted local decision-making, utilising their experiences with weather forecasting (ibid). **Figure 2.2** highlights some climate information products and the providers that may be associated with them.

In this context, it is essential to note that there is sometimes a mismatch of what providers may consider as important compared to the needs of climate information users. As such, it is important for users/decision-makers to be actively aware of the availability, relevance and levels of uncertainty of climate information, and how such data may be used appropriately in the context of given priorities and needs.

2.4 The availability and utility of climate information for DRR: Jamaica case study

Evidence from climate services projects and programmes highlights that 'in order to make a well-informed adaptation decision, decision-makers and their advisors have to make use of climate information' (Adaptation Community 2013). For islands in the Caribbean, which have historically been affected by natural hazard threats, noting the relevance and utility of using climate information to better understand and prepare for such threats may be a key step towards improving disaster risk resilience. While climate services projects have existed within the Caribbean, the authors of this chapter suggest that climate information is currently not being used to its fullest potential within the region, especially within the context of disaster risk reduction and resilience. In this regard, utilising available information and data about the weather/climate, as well as how the weather/climate has historically affected countries and the changing nature of this in the future, and designing strategies to best incorporate and communicate such information, could be a proactive pivotal way to improve society's response and resilience to climate change and variability, including hazards relating to extreme weather and climate events.

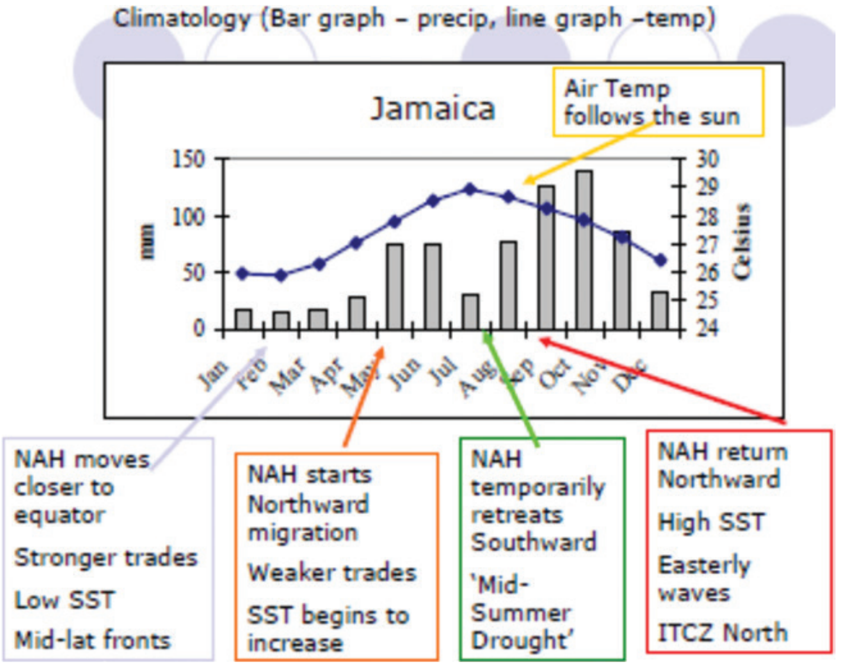
To offer context to how climate information can be used within the Caribbean region, we will review the availability and utility of information for the island of Jamaica, to underscore how such data could be beneficial for disaster risk resilience. Jamaica, like other small states, is highly vulnerable to the impacts of climate change, variability and related extreme events, and has been making strides towards policy and implementation of action to address pressing challenges (see Climate Change Policy Framework for Jamaica, GOJ 2015). Additionally, while there have been significant efforts to improve the availability of climate data through the installation of automatic weather stations, there are still gaps in terms of a long time series of observational weather station data for all of the island. Satellite and modelled data have the potential to complement and partly replace in-situ observations, but different factors (such as island location and topography) impede the clear identification and communication of these datasets' strengths, limitations and resulting uncertainties regarding their operational added-value.

2.4.1 The physical and human geography of Jamaica

The island of Jamaica is situated in the western Greater Antilles region within the archipelago of Caribbean islands, to the southeast of Cuba and west of Haiti. Its land area of approximately 10,911 km^2 (4,213 square miles) was originally evolved from volcanic formation, with thick limestone layers present due to periods of submersion. In terms of topography, there are three landform regions: the eastern mountains, the central valleys and plateaus, and the coastal plains. Within the eastern mountains are the highest areas of the island, the Blue Mountains, which peak at 2,256 metres (7,402 feet) and which rise dramatically from the coastal areas, creating one of the steepest general gradients in the world (see Hamilton 2005). Almost two-thirds of the island is considered to be limestone plateau – karst landscape (including sinkholes, caves and caverns) is thus present and typified well within the Cockpit Country area to the west of the mountains. The coastal areas differ across the island – most of the large stretches of coastal plains can be found in the southwest of the country and, in general, most of the best beaches can be found along the western coastline.

The *State of the Jamaican Climate 2012* report, as prepared by the Climate Studies Group of the University of the West Indies, Mona Campus, shares that the surface

Figure 2.3 Rainfall (bar) and temperature (line) climatologies for Jamaica

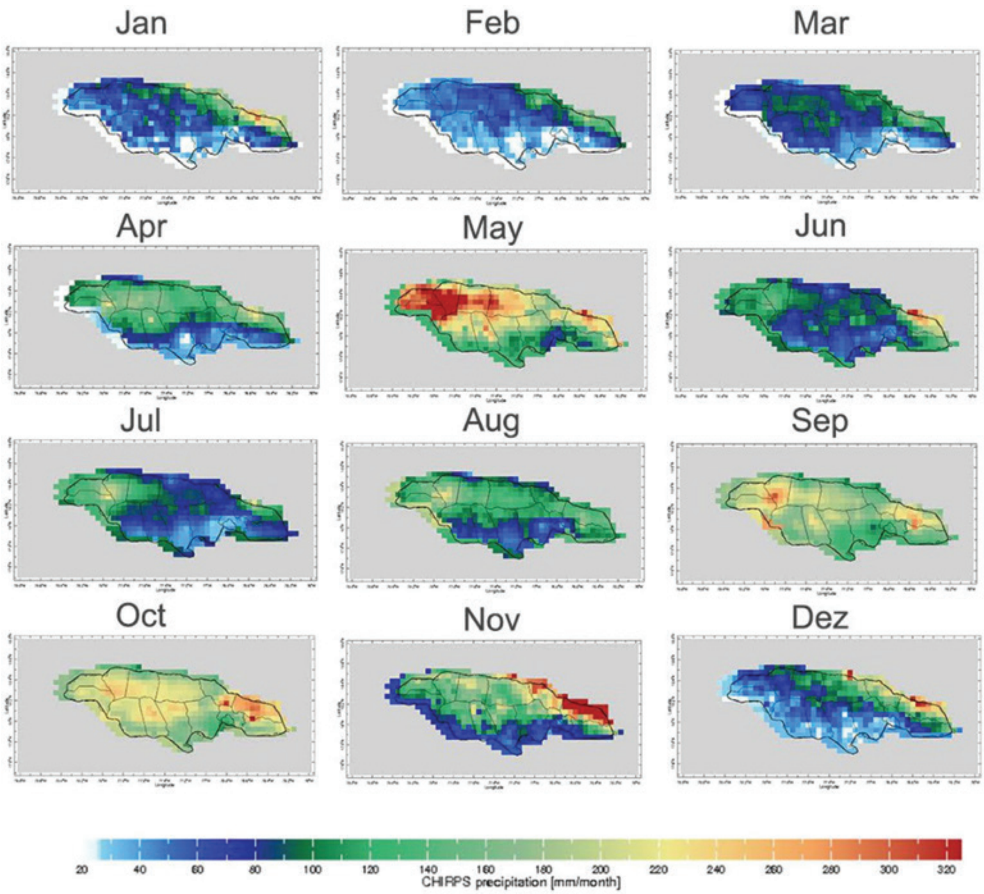


Source: Climate Studies Group, Mona 2012.
Note: NAH = North Atlantic High Pressure system; SST = sea surface temperature; ITCZ = Inter-Tropical Convergence Zone.

temperature in Jamaica is largely controlled by the variation of solar insolation, as shown in Figure 2.3. While there is some precipitation variation from year to year, there is an evident bimodal rainfall pattern on the island consisting of two peak periods of higher rainfall and corresponding periods of lower rainfall amounts (Climate Studies Group 2012). We can get a more detailed picture of this by compiling the mean monthly rainfall over the 35-year period, 1983–2018, using a free satellite precipitation dataset, the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) from the University of California Santa Barbara. As shown in Figure 2.4, there are two peaks, in October and May, with rainfall amounts at their lowest during February and March. There is also a second, but brief, drier period in July (often referred to as a midsummer drought; other Caribbean islands experience a similar Indian Summer or *Petit Carême*, though at different times of the year).

Such a physical environment should be considered alongside the context of the country's socioeconomic reality. Traditionally an agriculture-based economy, with sugar, bananas and tobacco as historical main draws of the labour force, Jamaica now receives most of its revenue from tourism and remittances. In 2018, the World Travel and Tourism Council ranked Jamaica as number 19 in the world in terms of contribution of tourism to gross domestic product (GDP) based on relative economy size: tourism directly contributed[2] to 10.3 per cent of GDP in 2017 (32.9% in terms of total direct and indirect contributions[3]) and directly supported 9.2 per cent of total

Figure 2.4 Mean monthly rainfall distribution map for Jamaica, 1983–2018



Source: Authors' compilation using a free satellite precipitation dataset, Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) from the University of California Santa Barbara, averaged by month over the period 1983–2018. For more information, see: http://chg.geog.ucsb.edu/data/chirps/

employment (29.8% of wider travel and tourism employment) (WTTC 2018). These, alongside visitor exports and investments in travel and tourism, were forecasted to grow in 2018 as well as over the next ten years.

While severe floods and other adverse weather events took a toll on Jamaica's economic health during the first half of 2017, expansion in the mining and quarrying sector (due to the continued focus and development of the country's bauxite-alumina industry), as well the aforementioned good performance in the tourism sector, stimulated economic rebound and growth of about 1.7 per cent in the first half of 2018 (World Bank 2018). The World Bank also reports that there has been a decline in the poverty rate, from 21.1 per cent in 2015 to 17.1 per cent in 2016 (with projected future decline), declines in overall and youth unemployment (at 25.8%, youth unemployment is at its lowest rate since 2007), as well as growth in total employment.

Despite these positive changes, it must be considered that with a population of about 2.7 million in 2018 (STATIN 2018), there are still large numbers of people in vulnerable contexts. As such, these trends would need to continue to address deeper rooted issues – crime and violence levels are as yet high, signalling the role and further encouragement of education, social cohesion and youth employment programmes, while sustained poverty reduction requires stronger and more resilience economic growth. The country is pursuing efforts towards economic stabilisation, debt reduction and growth through an ambitious reform programme encouraging development policy and investment financing in support of private sector-led growth, public sector transformation and building social and climate resilience. However, in this context, Jamaica's susceptibility to natural hazards and other external shocks within such a high debt/low growth context encourages a heightened attention to understanding and appropriately utilising climate information towards reducing risk and building resilience.

2.4.2 Climate information for Jamaica

The *State of the Jamaican Climate 2015* (Climate Studies Group 2017) highlights the necessary role of climate information specific to Jamaica for the purposes of planning, local action and decision-making. Such a role has been encouraged within projects such as the *Improving Climate Data and Information Management Project* (ICDIMP) of Jamaica's Pilot Programme for Climate Resilience (PPCR) (financed by the Climate Investments Fund [CIF] and administered by the World Bank), as it specifically 'targets improving the quality and use of climate-related data and information for effective planning and action at local and national levels'. At the same time, understanding the scope of climate information in Jamaica is consistent with Outcome 14 (Climate Change Adaptation and Hazard Risk Reduction) of the Vision 2030 Jamaica National Development Plan (Climate Studies Group 2017).

The *State of the Jamaican Climate 2015* report has stated that it is 'intended as a first reference point with respect to climate information for Jamaica', and includes local primary data relating to the island's climatology and observed variability, trends and extremes (including for variables such as temperature, rainfall, hurricanes, droughts and floods, and sea levels), in addition to climate scenarios and projections using a variety of global and regional climate models. The report offers information on some region-specific impacts and sectoral profiles, in addition to tables of climate tools, products and services which offer wider and agricultural-specific information to 'allow decision makers and policy makers to make informed decisions on climate-sensitive projects'. Such research is invaluable to document and understand the mean patterns and baseline conditions of climate within the country, towards an improved awareness of how likely impacts may affect the present and future climate vulnerabilities of the island and the relevant decision-making necessary to take precaution. The report also notes existing gaps, Including: '(i) inadequate climate observation station coverage over the island in general and glaring gaps in (among other places) St Ann and Portland; (ii) the need for more ensembles of regional models run using the Representative Concentration Pathways (RCP) scenarios to provide sub-island data; (iii) the need for more targeted research on climate impacts on some understudied sectors including education, the private sector and biodiversity; and (iv) processes for translating the science into real plans and then into actions'.

In light of these advised gaps in climate observation coverage and the role of targeted insights to relate climate information within the science/policy dialogue process, and the potential for using state-of-the-art climate information to strengthen DRR, generally and also particularly in small island states, this chapter highlights a few additional examples of Jamaica-relevant satellite data/climate information and disaster/knowledge portals of potential interest and use. Complementing the climate information products sourced within the *State of the Jamaican Climate 2015* report, Table 2.2 covers a wide range of mostly satellite-derived products: rainfall, surface soil moisture, root-zone soil moisture, evaporative stress, agricultural stress, ENSO forecasts, sub-seasonal and seasonal rainfall and temperature forecasts, flood forecasting, drought information, food insecurity, deforestation, extreme rainfall forecast, groundwater, land cover, emergency/damage response data, as well as a host of databases offering products catering to wider climate monitoring, climate services and global earth visualisations (such as Google Earth Engine and the related Earth Engine Data Catalog). As these products evolve and develop, new technologies such as machine learning can assist in providing new ways of looking into the complex relationships between hazard and impact, and provide more accurate, efficient and useful answers (e.g. GFDRR 2019).

Ahead of that, it is important to catalogue climate information resources to create an awareness of the availability of datasets, which are mostly and usually free for public use, to encourage their integration into public and private decision-making workflows. While there are some challenges in using these, as outlined in the next section, this awareness of the potential for supplementing evident gaps in local observation coverage is a pivotal step to empower local teams with knowledge. Such knowledge development can encourage appropriate activism and action based on pertinent needs and engender innovation within small states to transform communities from being vulnerable and/or passive victims, to veritable agents and actors for change. Furthermore, combined with additional information, such as socioeconomic and related data, evaluated climate information could be used to better understand local areas and pockets of the population that are at an increased risk of vulnerability to natural hazards and extreme weather events. For instance, Figure 2.5, Figure 2.6, Figure 2.7 and Figure 2.8 offer additional context of risk in Jamaica that could be considered alongside available climate information to hone in on actions needed to support local priorities.

While these resources are based on agricultural priorities, they could also be used to highlight the potential challenges for disaster risk reduction. A more targeted focus on the use of climate information and related socioeconomic data in various contexts could prove beneficial for understanding and monitoring natural hazards and extreme weather events and, ideally, informing relevant decisions. However, limitations arise not only on a data level, but in different sectors like technical capacities, awareness of freely available datasets, data processing and storage, or trained personnel. In the case of Jamaica, which is highly dependent on weather- and

Table 2.2 List of satellite products relevant for Jamaica/Caribbean context

Type of dataset	Name	Source/comment	URL
Rainfall	Climate Hazards group InfraRed Precipitation (CHIRP)	Satellite-derived; 1981–present; 0.05°; pentad, decadal, monthly	http://chg.geog.ucsb.edu/data/chirps/
Rainfall	CHRS/UC Irvine Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)	Satellite-derived; Mar 2000–present; 0.25°; 30-minute	https://climatedataguide.ucar.edu/climate-data/persiann-cdr-precipitation- estimation-remotely-sensed-information-using-artificial
Rainfall	CPC Morphing Technique (CMORPH)	Satellite-derived; Dec 2002–present; 0.25°; 3-hourly	http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html
Rainfall	Global Satellite Mapping of Precipitation / JAXA Global Rainfall Watch	Satellite-derived; 2000–present; 0.10°; hourly	https://sharaku.eorc.jaxa.jp/GSMaP/index.htm
Rainfall	SM2Rain	Rainfall estimated via satellite-derived soil moisture	http://hydrology.irpi.cnr.it/research/sm2rain/
Surface soil moisture	ASCAT (Advanced Scatterometer) soil moisture	Satellite-derived; available in near real-time (within 135 min)	https://navigator.eumetsat.int/product/EO:EUM:DAT:METOP:SOMO25
Surface soil moisture	ESA Climate Change Initiative (CCI) soil moisture	Derived from multiple satellite-based sensors (RADAR/radiometer)	https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-soil- moisture?tab=overview

Table 2.2 List of satellite products relevant for Jamaica/Caribbean context (*Continued*)

Type of dataset	Name	Source/comment	URL
Surface soil moisture	Sentinel-1 a/b	Satellite-derived (Synthetic Aperture Radar – SAR), high resolution	https://sentinel.esa.int/web/sentinel
Root-zone soil moisture	Soil Water Index (SWI)	Infiltration model applied to satellite-derived surface soil moisture	https://land.copernicus.eu/global/products/swi
Evaporative stress	Evaporative Stress Index (ESI)	Satellite-derived land-surface temperature	http://catalogue.servirglobal.net/Product?product_id=198
Agricultural stress	UN FAO Agricultural stress index system (ASIS)	Satellite-derived vegetation and land-surface temperature estimates	http://www.fao.org/giews/earthobservation/asis/index_1.jsp?lang=en
ENSO forecast	IRI (International Research Institute for Climate and Society, Columbia University) ENSO forecast	Based on the NINO3.4 index	https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/
Sub-seasonal rainfall / temperature forecast	IRI sub-seasonal forecast	Multi-model ensemble forecasts (lead time up 40 days)	http://iridl.ldeo.columbia.edu/maproom/Global/ForecastsS2S/precip_subx.html?S=0 000%204%20Jan%202019
Seasonal rainfall / temperature forecast	IRI seasonal forecast	Multi-model ensemble forecasts (lead time up 6 months)	http://iridl.ldeo.columbia.edu/maproom/Global/Forecasts/index.html
Flood forecasting	Global flood awareness system	Coupled weather forecasts and hydrological model	http://www.globalfloods.eu/
Global drought information	Global Drought Observatory	Satellite-derived precipitation (also SPI) and soil moisture anomaly	http://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001

(*Continued*)

Table 2.2 List of satellite products relevant for Jamaica/Caribbean context (*Continued*)

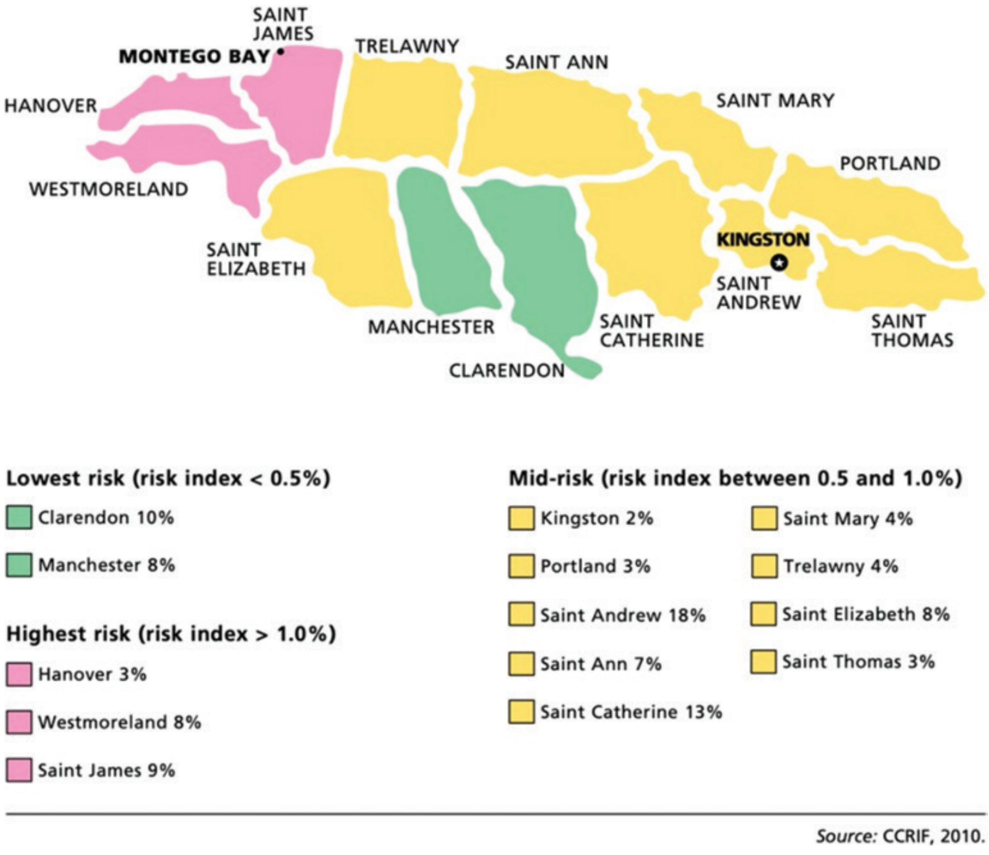
Type of dataset	Name	Source/comment	URL
Global drought information	Standardised Precipitation Evapotranspiration (SPEI) drought index	Gridded station data	http://spei.csic.es/map/maps.html#months=1
Global drought forecast	6-month Forecasted Standardised Precipitation Index (SPI), IRI	3 months of observed precipitation linked to 3 months of seasonal rainfall forecasts	http://iridl.ldeo.columbia.edu/maproom/Global/World_Bank/Drought_Monitor/index 3.html
Food insecurity	Famine Early Warning Systems Network (FEWS NET)	Various input sources (satellite-derived, socioeconomic, economic)	http://www.fews.net/
Deforestation	Global forest watch	Satellite-derived	http://data.globalforestwatch.org/
Extreme rainfall forecast	International Federation of Red Cross and Red Crescent Societies: Forecasts in Context	Daily ensemble-mean forecast precipitation totals; contextualised for humanitarian decision-making	http://iridl.ldeo.columbia.edu/maproom/IFRC/index.html
Groundwater	Gravity Recovery and Climate Experiment-Follow- On (GRACE-FO)	Satellite-derived (soon available)	https://podaac.jpl.nasa.gov/GRACE-FO
Land cover	ESA CCI land cover	Satellite-derived	https://maps.elie.ucl.ac.be/CCI/viewer/
Emergency data portal	Copernicus Emergency Management System	Satellite-based emergency/damage and risk mapping	https://emergency.copernicus.eu/

Table 2.2 List of satellite products relevant for Jamaica/Caribbean context (*Continued*)

Type of dataset	Name	Source/comment	URL
Knowledge portal	United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN SPIDER)	Description and database of satellite-derived products (focus on emergency applications)	http://www.un-spider.org/ http://www.un-spider.org/links-and-resources/data-sources
Crowdsourcing / data collection platform	Kobo Toolbox	Open-access, fully customisable software/app platform	https://www.kobotoolbox.org/
Various	Copernicus global land	Collection of satellite-derived datasets	https://land.copernicus.eu/global/index.html
Various	Sentinel data hub	Collection of satellite-derived datasets	https://scihub.copernicus.eu/
Various	US Geological Survey (USGS)–Global Visualization Viewer (GLOVIS)	Collection of satellite-derived datasets	https://glovis.usgs.gov/app?fullscreen=1
Various	USGS Earth Explorer	Collection of satellite-derived datasets	https://earthexplorer.usgs.gov/
Various	NASA Earth Observations (NEO)	Collection of satellite-derived datasets	https://neo.sci.gsfc.nasa.gov/
Various	NASA Earth Data	Collection of satellite-derived datasets	https://earthdata.nasa.gov/
Various	UNITAR (United Nations Institute for Training and Research)/UNOSAT	Collection of satellite-derived datasets/emergency maps	https://unitar.org/unosat/maps
Various	Disaster Charter	Satellite-derived; datasets/maps/reports only available after Charter activation	https://disasterscharter.org/web/guest/home
Various	Earth Engine Data Catalog	Collection of variety of standard Earth science raster datasets (public data catalogue)	https://developers.google.com/earth-engine/datasets/catalog/

Source: Authors' compilation.

Figure 2.5 Geographical distribution of climate-related risk in Jamaica

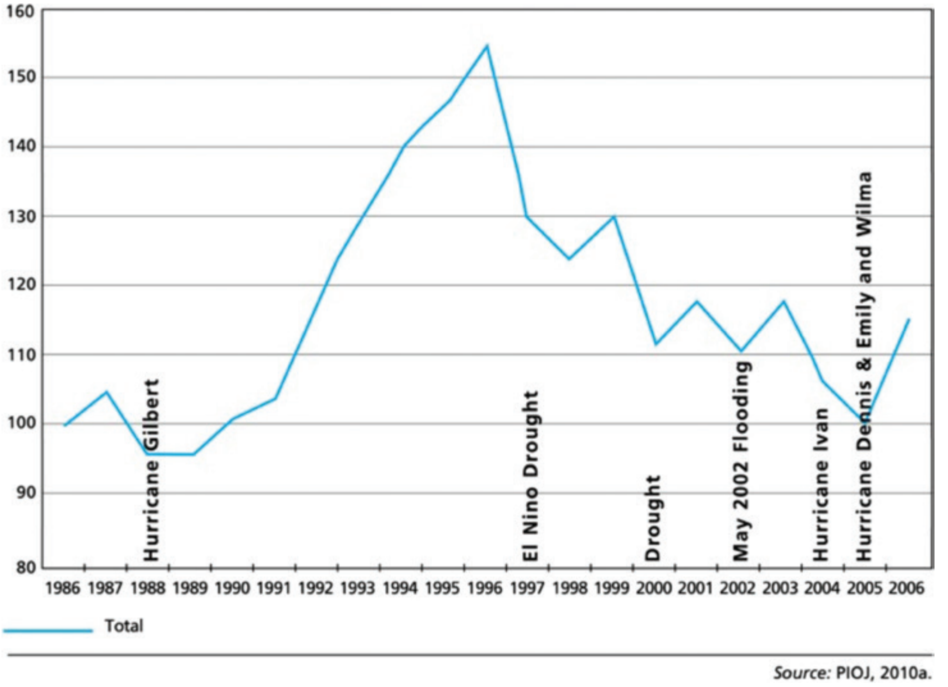


Source: FAO 2013, as sourced from Caribbean Catastrophe Risk Insurance Facility (CCRIF).

climate-related activities such as tourism and agriculture, and where weather-related hazards dominate past disaster events, understanding the availability and relevance of such climate information is essential in minimising disaster risks. Additionally, further to the awareness of available information and related services, it is also important to evaluate the usefulness of such climate information, rather than assume its feasibility for a particular region or context, to ascertain the appropriateness and relevance of use and context.

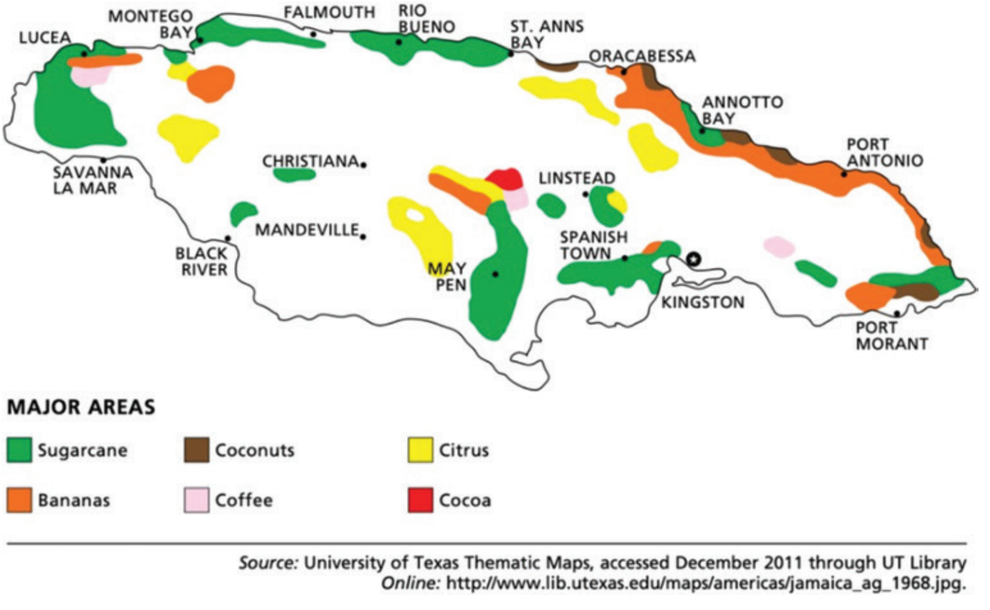
In addition to investing in public sector transformation and encouraging private sector-led growth, and focusing on infrastructural needs in times of disaster response, 'fixing' policy and governance directives to ensure resilience should also be a priority. In a review of climate services governance structures in Jamaica, Kruczkiewicz et al. (2018) highlight challenges to using agro- meteorological climate products and services in the country, including unclear funding to support development of the products, unclear co-ordination, consistency and leadership, in addition to the unavailability of a formalised mechanism to acquire, categorise and effectively utilise feedback on promoted data products (although informal sources may exist).

Figure 2.6 Agricultural Production Index (API) and major events in Jamaica, 1986–2006



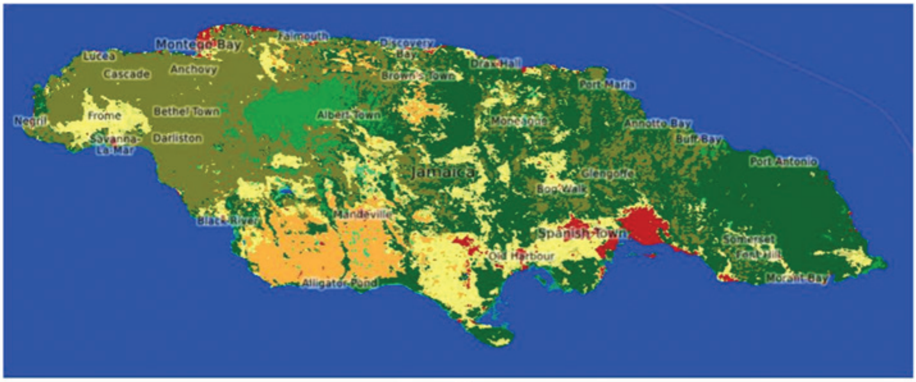
Source: FAO 2013, as sourced from Planning Institute of Jamaica (PIOJ).

Figure 2.7 Spatial distribution of crops in Jamaica



Source: FAO 2013, as sourced from University of Texas.

Figure 2.8 Land-cover distribution in Jamaica, using ESA Climate Change Initiative datasets



Label	Color
No Data	
Cropland, rainfed	
Herbaceous cover	
Tree or shrub cover	
Cropland, irrigated or post-flooding	
Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	
Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	
Tree cover, broadleaved, evergreen, closed to open (>15%)	
Tree cover, broadleaved, deciduous, closed to open (>15%)	
Tree cover, broadleaved, deciduous, closed (>40%)	
Tree cover, broadleaved, deciduous, open (15-40%)	
Tree cover, needleleaved, evergreen, closed to open (>15%)	
Tree cover, needleleaved, evergreen, closed (>40%)	
Tree cover, needleleaved, evergreen, open (15-40%)	
Tree cover, needleleaved, deciduous, closed to open (>15%)	
Tree cover, needleleaved, deciduous, closed (>40%)	
Tree cover, needleleaved, deciduous, open (15-40%)	
Tree cover, mixed leaf type (broadleaved and needleleaved)	
Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	

Label	Color
Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	
Shrubland	
Evergreen shrubland	
Deciduous shrubland	
Grassland	
Lichens and mosses	
Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	
Sparse tree (<15%)	
Sparse shrub (<15%)	
Sparse herbaceous cover (<15%)	
Tree cover, flooded, fresh or brakish water	
Tree cover, flooded, saline water	
Shrub or herbaceous cover, flooded, fresh/saline/brakish water	
Urban areas	
Bare areas	
Consolidated bare areas	
Unconsolidated bare areas	
Water bodies	
Permanent snow and ice	

Source: European Space Agency Climate Change Initiative land-cover datasets are satellite-derived and freely available at: http://maps.elie.ucl.ac.be/CCI/viewer/. It should be noted that current data on land cover, as created by Jamaica's Forestry Department, may not be as freely accessible.

As such, 'the efficacy and reliability of the [agro-meteorological climate] bulletins thus remains unknown and contributes to the persistence of a gap between user perception and producer perception of value. This holds true for both value of the information and functionality of dissemination modalities'. This challenge of limited governance structures must be addressed if the country is to encourage the effective utility of climate information use/services for a wide range of benefits.

2.4.3 Using climate information for DRR in Jamaica

Like in many other SIDS, the largest part of Jamaica's GDP (roughly 90%) is generated close to its 1,200km-long shoreline, in which also agriculture, fishery and tourism are concentrated. According to USAID (2018), it is also particularly these areas that have been struggling with the impacts of hydro-meteorological extreme events. Droughts, floods and tropical storms have affected not only agriculture, fishery and tourism, but general water supply, and energy and transport infrastructure. Long-term below-average rainfall has led to the country's dependence on groundwater, whereas issues like the seawater intrusion of aquifers have further diminished the freshwater supply for drinking water and irrigation purposes. In addition, health issues that are related to extreme climate events and rapid urbanisation (e.g. Leptospirosis) are on the rise (Peters et al. 2017).

Climate projections related to sea-level rise (0.4 to 0.7 meters until 2090), increasing average temperatures (1 to 1.4°C until 2050), an up to 7.2 per cent decrease in average annual precipitation and an increase in consecutive dry days by up to 15 per cent until 2050 (USAID, 2018), led to the development of a long-term National Development Plan (Planning Institute of Jamaica 2009) and a Climate Change Policy Framework (Government of Jamaica 2015). This study aims to discuss the role of available weather, climate and emergency data and how they can be translated into actionable knowledge via research-based approaches to strengthen overall resilience, early warning and early action. We focus particularly on the use of publicly available weather/climate monitoring/forecasting data/services, which can be used individually or combined to cover key elements of the hydrological cycle.

While research on climate data and services has made good progress in recent decades, their operational use is limited in Jamaica for a variety of reasons. First, the island's topography and geography tend to increase errors in datasets, which, if not handled properly, can propagate into data-driven services and decision-support systems. Second, data, services and decision-making workflows seem decoupled, partly due to unclear responsibilities, lack of training, staff and funding for the adaptation of existing products, and the non-existence of formal feedback mechanisms between data/service providers and users/responsible agencies. Third, there are large gaps with regard to records of historical impacts related to extreme weather and climate events, which impede the calibration of monitoring and forecasting systems as well as the services that depend on these data. Despite the existence of low-cost, low-effort mobile data collection tools, socioeconomic data and records of risk perception, if available at all, are generally decoupled from climate information. Fourth, financial instruments, such as the existing tools of the CCRIF SPC (formerly the Caribbean Catastrophe Risk Insurance Facility; see: https://www.ccrif.org/), are neither optimised for SIDS like Jamaica, nor capable of supporting the required level of coverage after major droughts or hurricanes. This is particularly critical, because Jamaica will likely face more frequent droughts and more intense hurricane events (Government of Jamaica 2015). Fifth, while drought maps and other drought-related information exist (see, for example: https://www.jamaicaclimate.net/drought-forecast-map/), there are uncertainties regarding the operational uptake of such information, potentially limiting its added-value for communities at risk. In addition, Jamaica's drought monitoring system is largely based on the Standardised Precipitation Index (SPI). This might leave critical gaps with regard to impacts caused by extreme temperatures (and related increases in evapotranspiration), which can equally lead to crop failure, or socioeconomic information to contextualise the climate hazard based on up-to-date profiles of vulnerabilities and coping capacities.

As mentioned, Table 2.2 represents a non-exhaustive list of datasets, data portals, services, tools and knowledge platforms that can be used in the context of climate-related disaster risk management. In the context of drought risk management, we suggest the consideration of multiple standardised datasets that can be combined to enhance the spatiotemporal understanding of atmospheric/land-surface anomalies (Enenkel et al. 2018; Enenkel et al. 2019), along with information about socioeconomic conditions, updated at high temporal frequencies (ideally sub-monthly). Satellite-derived estimates of rainfall, (root-zone) soil moisture, land-surface temperature, and evaporative and agricultural stress are available free of charge, with an acceptable timeliness, spatial and temporal resolution (for drought monitoring). Usually, different drought types do not appear in parallel. As a consequence, rainfall can be used to keep track of atmospheric deficits (watch level), soil moisture and/or evapotranspiration to monitor anomalies related humidity on the land surface (warning level) and vegetation health estimates to detect agricultural impacts (Sepulcre-Canto et al. 2012; Enenkel et al. 2016). The same approach could be used to strengthen financial instruments like Weather Index Insurance (WII) or Risk Contingency Credit (RCC), which depend equally on the accuracy of drought hazard information, agricultural parameters (start of season, type of crop planted, etc.) and knowledge of risk perception that guide management decisions. Free software packages/mobile apps for georeferenced, low-cost, low-effort, socioeconomic data collection are available (see, for example: https://www.kobotoolbox.org/).

In addition to building capacities to exploit the added-value of existing and new weather, climate and emergency data via dedicated projects, one of the most promising short-term approaches might be to enhance existing drought monitoring strategies, which rely mainly on rainfall estimates (SPI), with state-of-the-art satellite-derived estimations of soil moisture and vegetation greenness as a proxy for vegetation health. Standardised environmental variables could be weighted via the integration of socioeconomic information to avoid the underestimation of subsequent moderate drought events or to highlight areas in which other factors than climate might influence agricultural production (e.g. pests). Integrating information about changes in livelihood conditions via incentivised mobile data collection strategies can result in two major advantages. First, smart incentives help to limit 'strategic reporting'. Second, mobile devices serve as a two-way communication channel. They can be used to communicate added-value information, such as drought hazard data contextualised with information about livelihood conditions, back to data suppliers in affected communities. In parallel, the SPI, which is operationally produced by the Caribbean Agro-Meteorological Initiative (CAMI) programme, can be forced with observed and sub-seasonal forecasts of the same variable (rainfall) (e.g. see IRI 2019a). An initial test at the International Research Institute for Climate and Society (IRI) with seasonal rainfall forecasts has already been successful (see IRI 2019b). Realistic scenarios can help users to integrate such new drought monitoring and forecasting into existing decision-making frameworks.

2.5 The way forward

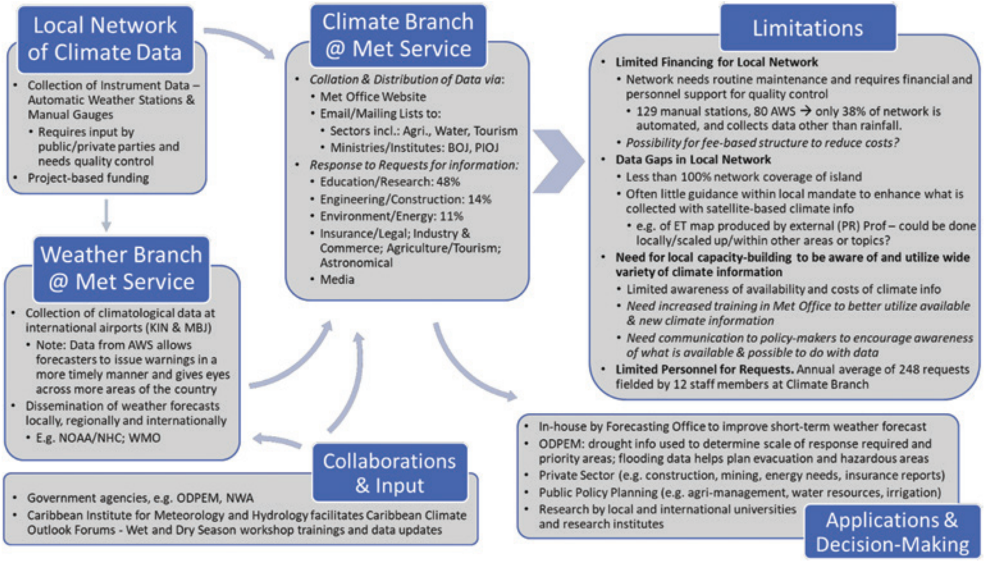
The essence of this chapter is to highlight the nature and potential role of using climate information for strengthening disaster risk reduction and resilience efforts in small states. Enhanced awareness and use of a wide range of weather- and climate-related information, most of which is freely available, can empower small states with data to make appropriate and impactful decisions towards advanced disaster preparedness, disaster risk reduction and future resilience.

In the previous section, we have highlighted how some of the sources offered in Table 2.2 could be practically used in the context of Jamaica, but this is certainly applicable to other island nations within and outside of the Caribbean. For example, in the case of drought risk management, we suggest the consideration of multiple standardised datasets that can be combined to enhance the spatiotemporal understanding of atmospheric/land-surface anomalies and, if this information could be further combined with socioeconomic details of changes in livelihood conditions, it would create a richer dataset for targeted disaster preparedness and response. A potential follow- up study, in collaboration with the Climate Branch of the Jamaica Met Service, could specifically focus on the nature of this data, the applicability to a variety of small states, as well as the practical steps that countries could take in utilising this resource.

The list of climate information sources within Table 2.2 is not an exhaustive one and we will work to update this list and share with relevant parties within the Caribbean, including the Climate Branch of the Jamaica Met Service and also the Caribbean Institute for Meteorology an Hydrology (CIMH), which is based in Barbados and convenes biannual Caribbean Climate Outlook Forums. While we are mindful that new and updated climate information is already shared within these forums, collaboration with CIMH could help to ensure that countries are routinely aware of which data product or existing climate service may be most appropriate and relevant for specific disaster risk management activities. This may require additional regional and/or local validation efforts to evaluate the spatiotemporal characteristics, local utility and feasibility of climate information, as well as capacity building with a focus on the integration of climate data into existing decision-support workflows.

However, as previously mentioned, limitations arise not only at the data level, but also in terms of technical capacities, awareness of free datasets, data processing and storage, and/or trained personnel. To better understand this, Figure 2.9 illustrates the climate information flow to and from the Climate Branch of the Jamaica Met Service. As shown, while the branch does its best to collect and share weather- and climate-related information, there are various challenges which persist and prevent further effective utility of climate information. A salient front-burner challenge faced by the Climate Branch of the Jamaica Met Service is that of the fundamental awareness of the climate information sources, by the office itself but also within various disaster and governmental agencies. There is often little guidance within the local mandate to enhance what kind of knowledge is derived from satellite-based climate information. We highlight the need to connect science and policy-making through the encouragement of workshops involving a wide variety of stakeholders, including decision-makers and those affected by a wide range of disasters, to become better aware of information flows and needs. Climate scientists should continue to work with local partners to better utilise freely available sources as needed. This could stimulate the drive for demanding improved sources of information and, in so doing, enhanced hydromet service delivery.

Figure 2.9 Schematic of flow of climate information to/from Climate Branch of Jamaica Met Service



Source: Authors' compilation and design.
Note: AWS: Automatic Weather Station; BOJ: Bank of Jamaica; PIOJ: Planning Institute of Jamaica; NHC: US National Hurricane Center; NOAA: US National Oceanic and Atmospheric Administration; NWA: National Works Agency (Jamaica); ODPEM: Office of Disaster Preparedness and Emergency Management (Jamaica); PR: Puerto Rico; WMO: World Meteorological Organisation.

In addition, we have noted that Jamaica has been making strides towards action on climate change: the Climate Change Policy Framework for Jamaica was adopted in September 2015 (GOJ 2015), and work is currently underway to develop and implement the action plan.[4] As well, the Ministry of Economic Growth and Job Creation (created in March 2016 due to a change in political administration) has a vision to drive economic growth and sustainable development for the country, and climate change is listed as a critical portfolio activity and headlines a core division of this ministry, alongside divisions of Environment and Risk Management, and Development Planning Policy and Monitoring.[5] It would be vital to share this work with these divisions to holistically encapsulate the wider potential for using climate information for disaster and climate risk management and resilience-building.

To assist this, we highlight the work of World Bank-related projects such as the Climate Risk and Early Warning Systems (CREWS) initiative and the Small Island States Resilience Initiative (SISRI), which are aligned to the Global Facility for Disaster Reduction and Recovery (GFDRR) and which may be pivotal in assisting such development, if it is particularly requested. Another suggestion in this regard could be a possible collaboration with NASA's Applied Remote Sensing Training (ARSET) programme, which provides in-person and online trainings focusing on the access and applications of remote sensing observations for disaster management (see: https://arset.gsfc.nasa.gov/disasters). Their webinars, such as 'Remote Sensing for Disasters Scenarios' which focuses on the applications of remote sensing for tropical storms, floods, earthquakes and landslides, could be quite useful for regional colleagues, and we would advocate for a course specifically tailored for the Caribbean region.

However, we note that data gaps in the network, limited financing to maintain the network, and limited personnel and technical capacity to better respond to queries of information, can hinder the potential of sourcing and connecting localised information to satellite products to enhance the base of information. Claiming that data should be 'better' utilised is not enough if neither the infrastructure, nor the staff or the technical capacities, exist. On the one hand, Jamaica would benefit from dedicated resources to translate existing data/services into decision-support tools or to combine them into new ones. On the other hand, it is also up to data/service providers to update users about the strengths and limitations of their products. Both bottom-up and top-down approaches will be required to strengthen Jamaica's capacities to mitigate the impacts of climate change, communicate early warning information to communities at risk as timely and comprehensibly as possible, teach these communities how to use climate information in the face of uncertainties, and to link quantitative climate information to qualitative socioeconomic assessments about risk perception, agricultural practices or (traditional) coping capacities.

In the context of disaster risk reduction and strengthening resilience, a focus on climate information complements initiatives linking finance and investment, developing technology, improving infrastructure, and promoting environmental governance. Empowering the region with such knowledge could be an essential step towards ensuring local awareness of disaster risks and what could realistically be done with current capacity, signalling leadership and capacity to where assistance is needed, and encouraging dialogue and co-operation to effectively strengthen DRR, minimise disaster and climate risk, and foster resilience.

Notes

1 It should be noted that the EM-DAT database includes all disasters from 1900 until present which fit at least one of the following criteria: 10 or more people dead; 100 or more people affected; declaration of a state of emergency; call for international assistance.

2 The direct contribution of travel and tourism to GDP reflects the 'internal' spending on travel and tourism (total spending within a particular country on travel and tourism by residents and non-residents for business and leisure purposes), as well as spending by government 'individual' spending – i.e. government spending on travel and tourism services directly linked to visitors, such as cultural (e.g. museums) or recreational (e.g. national parks) services (WTTC 2018).

3 The total contribution of travel and tourism includes its 'wider impacts' (i.e. the indirect and induced impacts) on the economy. The 'indirect' contribution includes the GDP and jobs supported by: travel and tourism investment spending; government 'collective' spending; and domestic purchases of goods and services by the sectors dealing directly with tourists. The 'induced' contribution measures the GDP and jobs supported by the spending of those who are directly or indirectly employed by the travel and tourism industry (WTTC 2018).

4 See: https://jis.gov.jm/govt-driving-climate-change-policy/ (accessed 28 April 2019).

5 See: https://megjc.gov.jm/divisions-and-branches/ (retrieved 28 April 2019).

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