

Research for Action on Climate Change and Health in the Caribbean: **A Public, Private, People's and Planetary Agenda**

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1. HEALTH IMPACTS OF EXTREME WEATHER EVENTS

1.1. WHAT IS HAPPENING?

Extreme events are occurrences of unusually severe weather or climate conditions that can have devastating impacts on communities and agricultural and natural ecosystems, and multiply the threats to human health (Dubrow, 2021). Extreme events relevant to Caribbean Small Island Developing States (SIDS) include hurricanes, heavy downpours, floods, heatwaves (see Chapter 6, “Heat-related illness”), drought and wildfire outbreaks (U.S. Department of Agriculture Climate Hubs, 2022). Climate change increases the frequency, intensity and duration of these events and interferes with traditional seasonal patterns.

Extreme events often coincide or follow each other, with a cascade of devastating consequences (Taylor, 2021). For instance, heavy downpours following drought lead to landslides and flooding. Prolonged hot periods can lead to drought and wildfires. New patterns of precipitation are predicted in Caribbean countries as the average temperature in the region approaches 1.5 °C above the 1860–1900 pre-industrial average. This is likely to be followed by overall drier conditions interspersed with heavier downpours and more severe hurricanes as the temperature increase reaches 2 °C, which is projected to happen by about the 2050s (Taylor et al., 2013, 2018). We are already seeing storm events of unprecedented severity in the region (Bell et al., 2018). Each year from 2016 to 2021, the Atlantic hurricane season saw more frequent storms than normal, with 2020 being the most active Atlantic hurricane season on record, with 30 named storms (Beven, 2021; Klotzbach et al., 2022; Wikipedia, 2022). In 2017, the region was hit by Hurricane Irma, the strongest Atlantic storm on record, and Hurricane Maria, which devastated Dominica and Puerto Rico (Government of the Commonwealth of Dominica, 2017; NASA Earth Observatory, 2017). In 2019, Hurricane Dorian devastated several islands of the Bahamas as it moved across them very slowly over three days with Category 3 to 5 strength (Greig et al., 2020). Hurricanes are becoming even more destructive as a result of heightened storm surges linked to climate change-induced sea level rise and loss of natural barriers, including coral reefs (which are being damaged by ocean warming and acidification) and mangrove forests (which are being destroyed by coastal development and pollution) (Dubrow, 2021).

The geography and topography of Caribbean countries place people at risk (Weaver, 2021). In Dominica, torrential downpours brought by Hurricane Maria cascaded down mountainsides, destroying bridges, roads, houses, water pipes, power lines, health centres and crops (Government of the Commonwealth of Dominica, 2017). Other Caribbean countries, such as Trinidad and Tobago, have large, inhabited plains that are prone to flooding (R4ACCHC, 2022a). Some settlements, such as Georgetown, Guyana, are built below sea level, while some entire islands, such as most of the Bahamas, are at low elevation, making them very vulnerable to storm surges (CARPHA, 2018; Greig et al., 2020).

Because these extreme manifestations of climate change are diverse, so are their impacts on health – particularly the systems that sustain health. Most directly, health facilities, equipment, medication and supplies can be damaged. Hurricanes affecting sources of medical supplies, such as those that affect the United States of America, can affect health in the Caribbean (Dubrow, 2021). Caribbean economies, infrastructure, agriculture and healthcare systems have been constructed under certain assumptions about the climate, weather and seasonality. For instance, buildings are constructed to withstand and provide shelter from certain levels of rain and wind (Weaver, 2021). In the words of Professor Michael Taylor, “We depend on familiarity” (Taylor, 2021). This also applies to animals and plants, with climate change reducing biodiversity and threatening ecosystems such as coral reefs. Major economic sectors on which Caribbean people depend for their livelihoods and therefore to maintain their health, such as tourism and fisheries, are severely threatened because of these impacts on the natural environment (Dubrow, 2021; R4ACCHC, 2022b). For instance, the Caribbean Hotel and

Tourism Association has estimated that 25% of the Caribbean tourism industry was affected by Hurricanes Irma and Maria in 2017, with closures, loss of business and government revenue, and loss of jobs (R4ACCHC, 2022c).

Floods and storms are climate-related hazards that pose a high mortality risk in Caribbean countries. An ecological study was conducted investigating risk factors for flood and storm lethality in Caribbean Community (CARICOM) nations for the 1980–2012 period. Significant predictors of lethality – deaths versus no deaths per disaster event – included the percentage of total land dedicated to agriculture and the percentage of the population living in urban areas. Deaths were more likely in the 2000–2012 period than in the 1980–1989 period. The authors indicated that changes in land use that had damaged natural ecosystems may help to explain the findings. Urbanisation marked by the absence of effective land use planning, which led to low-income households residing in hazardous areas, may be another explanation (Andrewin et al., 2015).

Official death tolls from hurricanes tend to mostly include only deaths occurring during or immediately after the event and directly caused by forces related to the event (e.g. drowning, trauma), and that have been confirmed as such by a medical examiner or forensic scientist (CARPHA, 2018). Deaths after the event – particularly from infectious diseases (e.g. waterborne infections due to damaged water supply and sanitary systems) and noncommunicable diseases (NCDs) left untreated because of a lack of access to medical care (due to damaged infrastructure, e.g. electric power, transport, communication, and healthcare facilities themselves) (Dubrow, 2021) – do not tend to be included in official death tolls. These types of indirect deaths may occur weeks to months after the event. Recent studies have calculated excess deaths in the period after a hurricane compared with a previous period (e.g. the same season the year before) to help estimate hurricanes' impacts on health. For example, Kishore et al. (2018) estimated that excess deaths in Puerto Rico following Hurricane Maria were 70 times higher than official estimates (Kishore et al., 2018). Studies of excess morbidity are rare.

Being displaced by extreme events can cause mental stress and can lead to lack of access to medication, violence against women and girls, and increased risk of infectious diseases (CARPHA, 2018; Dargin et al., 2021; Government of the Commonwealth of Dominica, 2017; R4ACCHC, 2022b, d; Wang et al., 2021) (Box 1). The psychological impacts of destruction, displacement and illness following hurricanes can be severe and long-lasting (Benjamin, 2015; Herran and Biehler, 2021; Penn and Greaves, 2021; Ravalieri and Murphy, 2017; Shultz et al., 2020). People living with NCDs are particularly vulnerable because their access to medication, health care and healthy food supplies may be severely curtailed (Elias et al., 2021; Hassan et al., 2020; Joshipura, 2021; Martinez-Lozano et al., 2021). In addition, people with disabilities may not be able to use or access conventional forms of emergency assistance and disaster prevention arrangements (Carby, 2021).

People are particularly susceptible to waterborne, foodborne and vector-borne infectious diseases following hurricanes and floods (Allen et al., 2019a). This may be due to damage to utilities such as water and sanitation facilities and electricity for refrigeration and cooking. Furthermore, hurricanes and floods create additional pools of water where mosquitoes can breed (CARPHA, 2017, 2018; Medlock, 2021). The bacteria that cause leptospirosis are spread through the urine of infected animals, which can get into water or soil and survive there for weeks to months. Flood conditions are particularly conducive to the spread of leptospirosis (Boston and Kurup, 2016; CARPHA, 2017; Chery et al., 2020).

Box 1: Health and other challenges of hurricanes in the Bahamas

“Being an archipelago provides challenges to displacement as any of the thirty inhabited islands can be affected. There can be great displacement and injuries, infections (including from injuries), lack of access to medication, anxiety and depression after hurricanes or other disasters. There is little warning for hurricanes – there are only hours before hurricanes may hit any of the islands. People get trapped due to the closure of land and air transportation. It’s important that all islands are adequately stocked with medications.”

Source: R4ACCHC (2022b).

Infectious and chronic respiratory diseases, including COVID-19, are likely to be aggravated by severe weather events. Both humidity and dusty conditions are associated with increased healthcare admissions for asthma (Cadelis et al., 2014; Hambleton, 2008; Prospero et al., 2008). Floods can lead to the growth of mould, which can become airborne in hot, dry weather. Hurricanes can create fine particles of airborne debris. Wildfires and fires deliberately set to dispose of debris adversely affect respiratory health (Allen et al., 2019b; CARPHA, 2018).

Extreme weather events of all sorts harm the agriculture sector, which relies on predictable weather conditions (Gamble et al., 2010). Hurricanes can destroy all agricultural crops in an individual SIDS, as happened in Dominica following Hurricane Maria (CARPHA, 2018). Food security is a challenge in the Bahamas, and this was aggravated by Hurricane Dorian in 2019 (R4ACCHC, 2022b). Because land, equipment and supplies are also severely damaged by extreme weather events and some crops take years to grow, indigenous agriculture can take years to recover. Droughts, which are becoming more frequent and severe, can harm or kill crops and livestock. The increasing likelihood of alternating severely dry and severely wet conditions can prevent proper absorption of rainfall and aggravate drainage difficulties. Access to fresh foods critical to health and the prevention of NCDs is reduced. The food provided in emergency supplies is generally highly processed and may contribute to NCD risk, and the affected SIDS may continue to rely more than ever on imported, processed food as the agriculture sector struggles to recover (CARPHA, 2018; R4ACCHC, 2022e; Watson-Duff and Cooper, 1994).

Research on the health impacts of extreme climate events in the Caribbean is a relatively new field and has focused on the following areas:

- The use of post-hurricane morbidity or mortality statistics to estimate impact (Allen et al., 2019b; Cruz-Cano and Mead, 2019; Kishore et al., 2018);
- The impact on infectious and vector-borne diseases (Allen et al., 2019a; Boston and Kurup, 2016; Medlock, 2021);
- Health aspects of hurricane preparedness and response (Carby, 2021; Dargin et al., 2021; Greig et al., 2020; Harewood, 2021; Hassan, 2021; Joshipura, 2021);
- The impact on environmental determinants of health and on key economic sectors (Allen et al., 2019b; Dasent et al., 2021; Gamble et al., 2010; Medlock, 2021);
- Pathways affecting vulnerabilities associated with mental health, NCDs and/or disabilities (Benjamin, 2015; Carby, 2021; Elias et al., 2021; Hassan et al., 2020; Herran and Biehler, 2021; Joshipura, 2021; Kim and Hassan, 2021; Martinez-Lozano et al., 2021; Penn and Greaves, 2021; Ravaliere and Murphy, 2017; Watson-Duff and Cooper, 1994).

1.2. WHAT SHOULD BE DONE?

Individual and community actions and how to support them

Involve civil society in extreme event preparedness and response activities

Civil society organisations at the regional, national and local community levels should play an integral role in preparedness activities by receiving and delivering education about health risks associated with extreme events and how to avoid and respond to them. They should advise the government about local needs and appropriate responses. At the regional level, the Healthy Caribbean Coalition has been involved in awareness-raising and advocacy on these issues (R4ACCHC, 2022f). At the University of the West Indies, the Students Today Alumni Tomorrow organisation has a disaster mitigation and climate change arm, showing that young people are taking these issues seriously (R4ACCHC, 2022g).

Training should be provided to communities using a multihazard framework, given that different hazards can occur simultaneously or one after the other, including hurricanes, heavy downpours, inland and coastal floods, heatwaves, droughts and wildfire outbreaks. Community members can be specifically trained to prepare and respond to extreme events. Because they know first-hand the needs and wants of the community, such as medication and supplies, they can assist greatly in preparedness and response. Desktop exercises and simulations are important to help personnel to get familiar with each hazard and to forge new solutions. Pre- and post-training assessments are critical tools for consolidating information. Emergency medical and mental health teams can collaborate with community members to share skills (R4ACCHC, 2023).

Tailor disaster preparedness messages and increase access to them among people with noncommunicable diseases, disabilities and/or mental health challenges

People with NCDs (see Chapter 4, “Noncommunicable diseases and risk factors”), disabilities and/or mental health challenges (see Chapter 7, “Mental health”) are particularly vulnerable to extreme weather events, as these events can aggravate their health conditions and cause crises, in part because of restricted access to health care (Carby, 2021; Elias et al., 2021; Harewood, 2021; Hassan et al., 2020; Joshipura, 2021; Kishore et al., 2018). There is evidence in the Caribbean that people with known risk factors such as obesity have a higher risk of developing NCDs such as diabetes following extreme weather events (Martinez-Lozano et al., 2021; R4ACCHC, 2023). People with these health conditions and risk factors should be provided with clear information about how to protect their health during and after severe weather events, tailored to each health condition or risk factor (Joshipura, 2021; R4ACCHC, 2023). A variety of traditional and social media, hard-copy booklets and in-person messaging from healthcare workers may be used. Information should include details of how to access supplies of medication and nutritious food. Information in braille and sign language should be provided (Carby, 2021).

Provide tailored disaster preparedness messages and training for healthcare workers

Healthcare workers experience the same devastating effects of severe weather events as the general population but face additional stress in providing services under traumatic conditions. To supplement the health and safety measures already in place, providing tailored information to healthcare workers is important, including information on specialised transport, emergency shelter arrangements and psychosocial support. Training on providing post-disaster health care can help to build resilience (Penn and Greaves, 2021). Emergency response providers should receive training on providing food, water and shelter in the aftermath of severe weather events (Dubrow, 2021).

Structural/governmental and private sector actions

Strengthen linkages between agencies responsible for health and disaster preparedness

Health needs to be more deeply integrated into disaster responses both nationally and regionally. Therefore, there is a need to strengthen collaborative mechanisms and for emergency management authorities and teams to integrate health into their planning and procedures (Kim and Hassan, 2021; R4ACCHC, 2023).

Include mental health in disaster preparedness and response

Training in psychological first aid can be provided to the general population as well as to healthcare workers and can strengthen psychological resilience in the face of disaster (Benjamin, 2015; Dominica Community Mental Health Team, 2017). Psychological resilience can be further boosted by providing clear post-disaster procedures to help life “get back to normal” (Ravaliere and Murphy, 2017; Sharma et al., 2018; R4ACCHC, 2023). Because of the additional stress placed on healthcare workers, especially the emergency services, mental health first aid should also be made available to these workers.

Collaboration between mental health teams in different countries and territories can boost the human resources available to deal with mental health challenges post disaster. For example, first responders, including psychologists, from the United States Virgin Islands assisted with recovery in Puerto Rico after Hurricanes Irma and Maria in 2017. It is important to sustain these links between countries and territories to assist with subsequent disasters (R4ACCHC, 2022g).

Strengthening disaster preparedness will reduce uncertainty and bolster mental resilience. Reducing uncertainty and increasing the adequacy of safety and security measures can increase the emotional well-being of populations affected by severe weather events and reduce the likelihood of mental ill health and negative consequences such as looting and violence. Having a comprehensive and well-established evacuation plan, safe and secure shelters with an adequate supply of water, food and electricity, and taking measures to secure workplaces and schools can bolster mental resilience in the population (Benjamin, 2015; Sharma et al., 2018).

Maintain local registers of people with noncommunicable diseases, disabilities and/or mental health issues and develop tailored disaster preparedness and response activities

People with NCDs, disabilities and/or mental health issues (including some older people; see Chapters 4, “Noncommunicable diseases and risk factors”, and 7, “Mental health”, for more detailed recommendations relating to NCDs and mental health, respectively) are highly vulnerable to the negative health impacts of severe weather events and find it particularly difficult to access health care (R4ACCHC, 2023). It is important to maintain a register of these people at the local level, such as the village or town level, and develop tailored disaster evacuation, shelter and healthcare plans for each person (CARPHA, 2018). Hurricane shelters should be adapted for people with mobility challenges or other disabilities (Carby, 2021). Stocks of medication to maintain care regimes should be stored in resilient healthcare facilities locally. The development of NCD kits to hand out in emergencies may be helpful (Harewood, 2021; Hassan et al., 2020). Systems to prioritise access to nutritious food supplies for vulnerable people should also be established.

Establish measures to prevent violence against women and girls and infectious disease transmission in emergency shelters

Emergency shelters and procedures should be designed to ensure protection from further health risks, including violence against women and girls and infectious disease transmission. Separate, secure sleeping and other arrangements can be put in place to protect women, children and other vulnerable people, such as older people and people with NCDs and disabilities. Protection from infectious diseases is inherently difficult during situations of displacement and when people from different households are gathered in shelters. Risks can be reduced by

ensuring adequate water supply and sanitation facilities, providing toiletries (including sanitisers) and face masks, and maintaining separation between different family or friendship groups (Dargin et al., 2021). The sexual and reproductive health needs of displaced populations should also be addressed, including access to contraception, options for the prevention of HIV and other sexually transmitted infections, and antenatal and postnatal care (R4ACCHC, 2023).

Develop climate-resilient health facilities

Severe weather events can cause major damage to health centres and hospitals. For instance, 56% of Dominica's health centres were completely or partially nonfunctional after Hurricane Maria. One was completely destroyed by a river that broke its banks (Ministry of Health and the Environment, 2017). Severe events also damage critical support infrastructure, such as access roads, and utilities, such as electricity and water supplies. For these reasons, it is critical that health facilities are built and equipped to be highly resilient. Several Caribbean governments are collaborating with the Pan American Health Organization/World Health Organization (PAHO/WHO) to build and retrofit health facilities to climate-resilient standards through the Smart Health Facilities initiative (Hassan, 2021; PAHO, n.d., 2013). Further details are provided in Chapters 15, "Climate-friendly health-promoting infrastructure", and 16, "Smart health facilities".

Support building back better across sectors

Destroyed and damaged buildings, infrastructure delivering public utilities, and agricultural production and delivery facilities should be reconstructed according to building codes that will mean that they are better protected against damage from future extreme events. Mechanisms and actions to enforce building codes should be actively supported and publicised by governments. If fossil fuel power plants are destroyed, they should be replaced by renewable electricity power plants. See Chapter 15, "Climate-friendly health-promoting infrastructure".

Research gaps and how to address them

Increase research on the indirect impacts of extreme weather events on mortality and morbidity

Research that documents both the direct and indirect health impacts (both mortality and morbidity) of specific hurricane events is crucial to understanding the full impact of hurricanes; informing risk reduction, preparedness and adaptation measures aimed at lessening the adverse impacts of future hurricanes; and effectively communicating their full impacts, and strategies for lessening those impacts, to the policymakers and government and nongovernmental organisation officials responsible for hurricane preparedness and response, and to the general public. Only a few Caribbean studies have measured excess deaths and the impact of hurricanes and other extreme events on health systems; more of these studies must be carried out. There is a pressing need for research on the impacts of hurricanes and other extreme events on morbidity in particular (Dubrow, 2021). To achieve this, surveillance systems need to be strengthened as outlined below. New methodological approaches to measuring health outcomes of disasters, such as those of the United States National Academies of Sciences, Engineering and Medicine, should be applied to studies in the Caribbean (National Academies of Sciences, Engineering and Medicine, 2020; Stoto et al., 2021). Longitudinal studies are needed to capture pre-hurricane risk factors and health status, and assess the impacts of extreme events (Dubrow, 2021).

Research and monitor key aspects of hurricane preparedness and response

The role of hurricane preparedness and response in protecting health should be researched, and key aspects of the response should be monitored to assess effectiveness. Topics should include:

- Public awareness of the significance of climate change in leading to extreme events, with severe health consequences in the Caribbean (R4ACCHC, 2022b);
- Hurricane preparedness and the response of regional agencies and national and local governments during pandemics;
- How civil society organisations, communities and individuals respond to and assist and cope with extreme events, and how they contribute to mental health and access to health care (R4ACCHC, 2022f);
- The extent of adherence to evacuation and development of behavioural interventions to increase adherence and population safety (Harewood, 2021);
- Messaging regarding hurricane preparedness;
- Hurricane preparedness and response to meet the needs of vulnerable populations, including the elderly, children, people living with disabilities, indigenous people and people living with NCDs;
- Sustainable hurricane preparedness and response (e.g. provision of water filters and rainfall storage systems instead of single-use plastic water bottles) (Dubrow, 2021).

Conduct research to identify key elements for making health facilities and the agriculture sector resilient to extreme weather events in the Caribbean

Health facilities and the agriculture sector are essential to health, and programmes of research should be dedicated to both, to identify key elements that should be built into their design and processes so that they can withstand the types of extreme weather events that are typical and predicted to increase in the Caribbean. See Chapters 12, “Agriculture and food safety and security”, and 16, “Smart health facilities”, for further recommendations. Building on the work of PAHO/WHO and others to develop climate-smart health facilities, it is important to develop health facility and technology design standards that are forward-looking, based on climate projections for the region (Dubrow, 2021). It is also very important to explore the effectiveness of nature-based solutions, given that changes in land use and urbanisation have been found to contribute to the lethality of hurricanes and floods (Andrewin et al., 2015; Asian Development Bank, 2022; Environment Agency, 2023).

Surveillance gaps and how to address them

Calculate excess deaths and excess incidence of health conditions to measure the health impacts of severe weather events

It is important to move beyond the current methodology used to produce official death tolls from severe weather events, which tend to be restricted to deaths that occur during the event itself. As was done in Puerto Rico following Hurricane Maria, the number of deaths in the three months following a hurricane could be compared with a similar period the previous year, for example (Kishore et al., 2018). Along similar lines, the number of deaths following an extreme weather event could be compared with the average number of deaths over the same time period in previous years without extreme events, as this would enable a comparison between mortality following an extreme weather event with mortality under average conditions in the recent past.

An important contribution of Kishore et al.’s (2018) study was conducting a parallel survey in which people were asked to report on deaths in their household and disruption to medical care and to utilities such as water and electricity. This methodology can assist in explaining excess deaths that may have resulted from disruption to health systems, utilities and infrastructure (Dubrow, 2021).

Syndromic surveillance data should be closely monitored in the period immediately following severe weather events to detect outbreaks of infectious diseases. To assess whether outbreaks can be attributed to the severe weather event, incidence in the weeks following the event can be compared with the average incidence in the same weeks in previous years, or with incidence rates in countries that have not experienced the same severe

weather events. These methods were used to analyse data reported to CARPHA following Hurricanes Irma and Maria, and increased rates of gastrointestinal symptoms were found (Allen et al., 2019a).

A limitation in assessing the health impact of extreme events is the lack of reporting of some disease conditions to governments, including gaps in reporting of some notifiable diseases. Disease surveillance systems require considerable strengthening so that the range of impacts of climate change on health can be properly measured and assessed. To assess impacts on vulnerable populations, morbidity data need to be disaggregated by age, gender and local area.

Strengthen monitoring of population displacement and migration resulting from severe weather events

Following hurricanes, the number of people in shelters is taken as a measure of population displacement. See Chapter 8, “Population displacement and migration”, for further recommendations. This is of limited value, since many people may take shelter in other households or buildings, and some may find no shelter following damage to their accommodation. It is important that local, regional and national government bodies investigate patterns of displacement and shelter-seeking, and provide support to households and other private and public bodies providing shelter to others. In the months following severe hurricanes, it is important to monitor travel patterns to assess the extent of temporary and permanent internal and external migration.

Strengthen integrated risk management and early warning systems

Disaster preparedness reduces vulnerability in the face of climate and weather hazards. See Chapter 11, “Research and surveillance on climate change and health”, for more details. Integrated risk management (IRM) and early warning systems (EWSs) are essential for providing information to guide the design of effective preparedness measures (R4ACCHC, 2023). IRM takes a society-wide approach to risk identification, analysis and evaluation, and includes a wide variety of stakeholders. Risk identification and analysis are followed by measures to address the risks, communication to ensure that these measures are implemented, and monitoring and evaluation of these measures. EWSs are intended to give advance notice of impending hazards; enable the timely activation of preparedness, prevention and mitigation activities; and ultimately reduce harm (Harewood, 2021). Most EWSs focus on weather hazards, but there is a growing body of research on EWSs for climate-sensitive diseases, such as vector-borne diseases (Lowe et al., 2020; Stewart-Ibarra, 2021). It has been suggested that EWSs be expanded to include measurement of air quality and heat-related illness risk. The views of community members and policymakers on the utility of EWSs should be sought (Harewood, 2021). Adjusting seasonal forecasting to include evidence of climate change is an important aspect of EWSs (R4ACCHC, 2023).

Research and surveillance capacity-strengthening needs

To implement the recommended extreme weather event research agenda above, some key skills areas in Caribbean countries will need to be strengthened, such as those related to:

- Evaluating communication and behavioural interventions;
- Designing climate-resilient health facilities, technologies and public utilities, to account for projected Caribbean weather conditions;
- Designing communication strategies for people with physical and mental disabilities;
- Conducting emergency response management, including management of health facilities and shelters;
- Maintaining disease surveillance and statistical capacities post disaster;
- Designing climate-smart agriculture and food distribution systems;
- Building disease surveillance capacities and infrastructure;
- Performing statistical analysis, including data analysis, presentation and modelling;
- Understanding the demography of migration;

- Communicating complex scientific information to key audiences, including policymakers and the general public.

Climate-resilient information technology and electronic communication infrastructure should also be developed and expanded.

1.3. REFERENCES

- Allen, C. F., Adams, R., West, R. M., Johnson, D., Hospedales, C. J. (2019a). Using public health surveillance data to assess health impacts of severe weather events in Caribbean countries (O-53). *West Indian Med J.* 68 (Supplement 1):37.
- Allen, C. F., West, R. M., Johnson, D., St Ville, S., Cox, I., Hospedales, C. J. (2019b). Impact of Hurricane Maria on environmental determinants of health in Dominica (O-52). *West Indian Med J.* 68 (Supplement 1):37.
- Andrewin, A. N., Rodriguez-Llanes, J. M., Guha-Sapir, D. (2015). Determinants of the lethality of climate-related disasters in the Caribbean Community (CARICOM): a cross-country analysis. *Sci Rep.* 5(1):11972. Available from: <https://doi.org/10.1038/srep11972>.
- Asian Development Bank. (2022). Nature-based solutions for flood risk management: revitalizing Philippine rivers to boost climate resilience and enhance environmental sustainability. Mandaluyong: Asian Development Bank. Available from: <https://www.adb.org/sites/default/files/publication/774721/revitalizing-philippine-rivers-climate-resilience.pdf>.
- Bell, G. D., Blake, E. S., Landsea, C. W., Goldenberg, S. B., Pasch, R. J. (2018). The tropics: tropical cyclones: Atlantic basin [in "State of Climate in 2017"]. *Bull Amer Meteor Soc.* 99(8):S114–S118. Available from: https://www.ametsoc.net/sotc2017/Ch04_Tropics.pdf.
- Benjamin, G. (2015). Post Tropical Storm Erika: mental health situation analysis and action plan. Roseau: Community Mental Health Team, Ministry of Health and the Environment.
- Beven, J. L. (2021). The 2020 Atlantic hurricane season: the most active season on record. *Weatherwise.* 74(5):33–43. Available from: <https://doi.org/10.1080/00431672.2021.1953905>.
- Boston, C., Kurup, R. (2016). Estimated effects of climate variables on transmission of malaria, dengue and leptospirosis within Georgetown, Guyana. *West Indian Med J.* 65(Supplement 3):43.
- Cadelis, G., Tourres, R., Molinie, J. (2014). Short-term effects of the particulate pollutants contained in Saharan dust on the visits of children to the emergency department due to asthmatic conditions in Guadeloupe (French Archipelago of the Caribbean). *PLOS One.* 9(3):e91136. Available from: <https://doi.org/10.1371/journal.pone.0091136>.
- Carby, B. (2021). Hurricane planning for people with disabilities: removing the barriers. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- CARPHA (Caribbean Public Health Agency). (2017). State of public health in the Caribbean region 2014-2016: building resilience to immediate and increasing threats: vector-borne diseases and childhood obesity. Port of Spain: CARPHA. Available from: <https://carpha.org/Portals/0/Publications/State-of-Public-Health-in-the-Caribbean-2014-2016.pdf>.
- CARPHA (Caribbean Public Health Agency) (2018). State of public health in the Caribbean report 2017-2018 – climate and health: averting and responding to an unfolding health crisis. Port of Spain: CARPHA. Available from: <https://carpha.org/What-We-Do/Health-Information/State-of-Public-Health>.
- Chery, G., Francis, L., Hunte, S.-A., Leon, P. (2020). Epidemiology of human leptospirosis in Saint Lucia, 2010–2017. *Rev Panam Salud Publica.* 44:e160. Available from: <https://doi.org/10.26633/RPSP.2020.160>.
- Cruz-Cano, R., Mead, E. L. (2019). Causes of excess deaths in Puerto Rico after Hurricane Maria: a time-series estimation. *Am J Public Health.* 109(7):1050–1052. Available from: <https://doi.org/10.2105/ajph.2019.305015>.
- Dargin, J. S., Li, Q., Jawer, G., Xiao, X., Mostafavi, A. (2021). Compound hazards: an examination of how hurricane protective actions could increase transmission risk of COVID-19. *Int J Disaster Risk Reduct.* 65:102560. Available from: <https://doi.org/10.1016/j.ijdrr.2021.102560>.
- Dasent, C., Lewis, A., Floyd, S. (2021). A review of the implications of drought on the health sector in the Caribbean region. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Dominica Community Mental Health Team (2017). Hurricane Maria emergency response in Dominica: rapid MHPSS assessment – October 2017. Los Angeles: International Medical Corps.

- Dubrow, R. (2021). Research on impact of climate on health: research and implementation agenda preparatory document. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Environment Agency (2023). Use nature-based solutions to reduce flooding in your area. London: United Kingdom Government. Available from: <https://www.gov.uk/guidance/use-nature-based-solutions-to-reduce-flooding-in-your-area>.
- Elias, C., Mendez, P., Martinez, E., Ortiz, A. (2021). Stressors that affected gynecological cancer patients in Puerto Rico during and after Hurricane María. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Gamble, D. W., Campbell, D., Allen, T. L., Barker, D., Curtis, S., McGregor, D., Popke, J. (2010). Climate change, drought, and Jamaican agriculture: local knowledge and the climate record. *Ann Assoc Amer Geographers*. 100(4):880–893.
- Gordon-Strachan, G. (2021). Health co-benefits of mitigation and adaptation: research and implementation agenda preparatory document. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Government of the Commonwealth of Dominica. (2017). Post-disaster needs assessment, Hurricane Maria, September 18, 2017. Roseau: Government of the Commonwealth of Dominica. Available from: <https://reliefweb.int/sites/reliefweb.int/files/resources/dominica-pdna-maria.pdf>.
- Greig, E., Green, B. A., Ford, H. R., Farmer, D. B., Nottage, K. M., Espinel, Z., et al. (2020). Extreme population exposure: Hurricane Dorian medical response in Great Abaco, Bahamas. *eClinicalMedicine*. 20:100274. Available from: <https://doi.org/10.1016/j.eclinm.2020.100274>.
- Hambleton, I. (2008). Constituents of African dust and paediatric asthma in Barbados (1996 – 2005). Cave Hill, Barbados: Chronic Disease Research Centre, University of the West Indies.
- Harewood, H. (2021). Emergency preparedness and management: research and implementation agenda preparatory document. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Hassan, S. (2021). Climate resilient health systems: research and implementation agenda preparatory document. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Hassan, S., Nguyen, M., Buchanan, M., Grimshaw, A., Adams, O. P., Hassell, T., et al. (2020). Management of chronic noncommunicable diseases after natural disasters in the Caribbean: a scoping review. *Health Aff (Millwood)*. 39(12):2136–2143.
- Herran, K., Biehler, D. (2021). A comparison study: analysis of mental well-being of environmental migrants versus other forced displacement migrants. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Joshiyura, K. (2021). Hurricanes Irma and Maria, preparedness, resilience and health. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Kim, E., Hassan, S. (2021). Understanding challenges to managing non-communicable diseases after natural disasters in the Caribbean: a qualitative study. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Kishore, N., Marqués, D., Mahmud, A., Kiang, M. V., Rodriguez, I., Fuller, A., et al. (2018). Mortality in Puerto Rico after Hurricane Maria. *New Eng J Med*. 379:162–170. Available from: <https://doi.org/10.1056/NEJMsa1803972>.
- Klotzbach, P. J., Wood, K. M., Bell, M. M., Blake, E. S., Bowen, S. G., Caron, L.-P., et al. (2022). A hyperactive end to the Atlantic hurricane season October–November 2020. *Bull Amer Meteor Soc*. 103(1):E110–E128. Available from: <https://doi.org/10.1175/bams-d-20-0312.1>.
- Lowe, R., Ryan, S. J., Mahon, R., Van Meerbeeck, C. J., Trotman, A. R., Boodram, L.-L. G., et al. (2020). Building resilience to mosquito-borne diseases in the Caribbean. *PLOS Biology*. 18(11): e3000791. Available from: <https://doi.org/10.1371/journal.pbio.3000791>.

- Martinez-Lozano, M., Noboa-Ramos, C., Alvarado-Gonzales, G., Joshipura, K. (2021). Impact of Hurricanes Irma and Maria on diabetes incidence and management. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Medlock, J. (2021). Challenges posed by hurricanes to vector control. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Ministry of Health and the Environment. (2017). Final Dominica health post disaster needs assessment – post Maria – 27 October 2017. Roseau: Government of the Commonwealth of Dominica.
- NASA Earth Observatory. (2017). Hot water ahead for Hurricane Irma. Greenbelt, MA: NASA Earth Observatory. Available from: <https://earthobservatory.nasa.gov/images/90912>.
- National Academies of Sciences, Engineering and Medicine (2020). A framework for assessing mortality and morbidity after large-scale disasters. Washington, DC: National Academies Press.
- PAHO (Pan-American Health Organization) (n.d.). Smart Hospitals Toolkit: a practical guide for hospital administrators, health disaster coordinators, health facility designers, engineers and maintenance staff to achieve Smart Health Facilities by conserving resources, cutting costs, increasing efficiency in operations and reducing carbon emissions. Washington, D.C.: PAHO.
- PAHO (Pan-American Health Organization) (2013). A model policy for SMART health facilities. Washington, D.C.: PAHO.
- Penn, A., Greaves, N. (2021). Factors affecting resilience and stress in health care professionals – first responders post cyclonic natural disasters: results of a systematized review. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Prospero, J. M., Blades, E., Naidu, R., Mathison, G., Thani, H., Lavoie, M. C. (2008). Relationship between African dust carried in the Atlantic trade winds and surges in pediatric asthma attendances in the Caribbean. *Int J Biometeorol.* 52(8):823–832. Available from: <https://doi.org/10.1007/s00484-008-0176-1>.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022a). R4ACCHC dialogue with the Caribbean Association of Local Government Authorities.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022b). R4ACCHC dialogue with the University of the West Indies, School of Clinical Medicine and Research, the Bahamas.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022c). R4ACCHC dialogue with the Caribbean Hotel and Tourism Association.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022d). R4ACCHC dialogue with the Caribbean College of Family Physicians.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022e). R4ACCHC dialogue with key stakeholders from Saint Lucia.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022f). R4ACCHC dialogue with the Healthy Caribbean Coalition.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2022g). R4ACCHC dialogue with the Caribbean Alliance of National Psychological Associations.
- R4ACCHC (Research for Action on Climate Change and Health in the Caribbean) (2023). Feedback from breakout room session on health impacts of extreme weather events. Stakeholder Dialogue: Caribbean Research for Action Agenda on Climate and Health. 9–10 May.
- Ravaliere, T., Murphy, M. (2017). Displacement post-natural disaster: an exploration of the needs of survivors displaced due to storm Erika in Dominica. *West Indian Med J.* 66(Supplement 1): Abstract P-6:41.
- Sharma, D., McIntyre, R., Cuffy, M., Masicot, A. (2018). Post-traumatic stress disorder prevention for medical students evacuated from Dominica following Hurricane Maria. *West Indian Med J.* 67 (Supplement 2): 64.
- Shultz, J. M., Sands, D. E., Holder-Hamilton, N., Hamilton, W., Goud, S., Nottage, K. M., et al. (2020). Scrambling for safety in the eye of Dorian: mental health consequences of exposure to a climate-driven hurricane. *Health Aff (Millwood).* 39(12): 2120–2127.

- Stewart-Ibarra, A. M. (2021). The co-creation of a dengue early warning system for the health sector in the Caribbean. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Stoto, M. A., Rothwell, C., Lichtveld, M., Wynia, M. K. (2021). A national framework to improve mortality, morbidity, and disparities data for CoViD-19 and other large-scale disasters. *Amer J Pub Health*. 111(S2):S93–S100.
- Taylor, M. A. (2021). Downsizing climate science to the Caribbean: implications for health and research. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Taylor, M. A., Centella, A., Charlery, J., Bezanilla, A., Campbell, J., Borrajero, I., et al. (2013). The Precip Caribbean Story: lessons and legacies. *Bull Amer Meteor Soc*. 94(7):1065–1073. Available from: <https://doi.org/10.1175/bams-d-11-00235.1>.
- Taylor, M. A., Clarke, L. A., Centella, A., Bezanilla, A., Stephenson, T. S., Jones, J. J., et al. (2018). Future Caribbean climates in a world of rising temperatures: the 1.5 vs 2.0 dilemma. *J Climate*. 31(7):2907–2926. Available from: <https://doi.org/10.1175/jcli-d-17-0074.1>.
- U.S. Department of Agriculture Climate Hubs (2022). Extreme weather. Washington, D.C.: U.S. Department of Agriculture. Available from: <https://www.climatehubs.usda.gov/content/extreme-weather>.
- Wang, K., Oladele, C., Uriyoan, C., Brandt, C., Srinivasan, A. (2021). Analysis of the impact of Hurricane Isaias on health care access in Puerto Rico using mobility data. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Watson-Duff, E. M., Cooper, E. S. (1994). Neural tube defects in Jamaica following Hurricane Gilbert. *Amer J Pub Health*. 84(3):473–476.
- Weaver, S. (2021). The impact of multiple intersecting hazards during Hurricane Maria. Conference on Climate Change and Health in Small Island Developing States: Focus on the Caribbean (A Virtual Conference); 5–8 October.
- Wikipedia (2022). 2021 Atlantic hurricane season. San Francisco: Wikimedia Foundation. Available from: https://en.wikipedia.org/wiki/2021_Atlantic_hurricane_season.