

# CCRIF

The Caribbean Catastrophe Risk Insurance Facility



## CARIBBEAN CATASTROPHE RISK INSURANCE FACILITY

# ST. KITTS AND NEVIS



## COUNTRY RISK PROFILE



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**CCRIF, a Not-For-Profit Company, is the First and Only  
Multi-Country Risk Pool in the World**

# Country Risk Profile

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## St. Kitts and Nevis

CCRIF is a risk pooling facility, owned, operated and registered in the Caribbean for Caribbean governments. It is designed to limit the financial impact of catastrophic hurricanes and earthquakes to Caribbean governments by quickly providing short term liquidity when a policy is triggered. It is the world's first and, to date, only regional fund utilising parametric insurance, giving Caribbean governments the unique opportunity to purchase earthquake and hurricane catastrophe coverage with lowest-possible pricing. CCRIF represents a paradigm shift in the way governments treat risk, with Caribbean governments leading the way in pre-disaster planning. CCRIF was developed through funding from the Japanese Government, and was capitalised through contributions to a multi-donor Trust Fund by the Government of Canada, the European Union, the World Bank, the governments of the UK and France, the Caribbean Development Bank and the governments of Ireland and Bermuda, as well as through membership fees paid by participating governments.

Sixteen governments are currently members of CCRIF. These are: Anguilla, Antigua & Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago and Turks & Caicos Islands

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# LIST OF ACRONYMS

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CCRIF	Caribbean Catastrophe Risk Insurance Facility
CIA	US Central Intelligence Agency
EQ	Earthquake
FCHLPM	Florida Commission on Hurricane Loss Projection Methodology
FEMA	see US FEMA
GESI	Global Earthquake Safety Initiative
GIS	Geographical Information Systems
GDP	Gross Domestic Product
GDP (PPP)	Gross Domestic Product (Purchasing Power Parity)
GDPPC (PPP)	Gross Domestic Product per Capita (Purchasing Power Parity)
IMF	International Monetary Fund
KAC	Kinetic Analysis Corporation
MLR	Mean Loss Ratio
MMI	Modified Mercalli Intensity
MODIS	Moderate Resolution Imaging Spectroradiometer
MPH	Miles per hour
MPRES	Multi-Peril Risk Estimation System
NHC	See US NHC
NOAA	National Oceanic and Atmospheric Administration
PGA	Peak Ground Acceleration
RTFS	Real-Time Forecasting System
TAOS	The Arbiter of Storms
TC	Tropical Cyclone
US	United States of America
USD	United States Dollars
US FEMA	United States Federal Emergency Management Agency
USGS	United States Geological Survey
US NASA	United States National Aeronautics and Space Administration
US NHC	United States National Hurricane Center of NOAA
UWI	University of the West Indies

# INTRODUCTION

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This document provides an outline of the earthquake and tropical cyclone risk profile for St. Kitts and Nevis. It is aimed at providing decision makers with a clear picture of the key risks which the country faces in order to guide national catastrophe risk management and inform decision making for both risk reduction and risk transfer (via CCRIF coverage and other mechanisms which may be available).

This country risk profile also serves as a platform for the provision of more detailed information on the CCRIF Multi-Peril Risk Evaluation System (MPRES) catastrophe risk modelling platform which has been used to underpin CCRIF policies since the 2010/11 policy year and which is available as a regional public-good resource for research and practical application. The MPRES was developed and is supported by Kinetic Analysis Corporation (KAC), a bespoke risk modelling company with strong roots in the Caribbean.

Since the previous release of the country risk profiles, updates have been completed on the MPRES platform resulting in differences in output for the current year relative to the prior version released in early-2012. In addition, CCRIF has launched the GeoNode project, which will allow countries to access the geospatial data which underpins this risk profile, and enable geospatial data management and sharing within a collaborative context.

**Section 1** provides some background information on the MPRES, as well as information on the risk modelling methodology, facility loss model and asset vulnerability.

**Section 2** gives a general overview of Caribbean exposure to earthquake and tropical cyclone hazards.

**Section 3** provides country-specific earthquake and tropical cyclone (wind) hazard profiles, as well as full country economic loss information.

**Annex 1** provides a list of useful reference documents.

**Annex 2** provides an explanation of the Saffir-Simpson Hurricane Intensity Scale.

**Annex 3** provides an explanation of the Maximum Modified Mercalli Intensity (MMI) and Richter Magnitude scales for earthquakes.

**Annex 4** provides an overview of changes in the CCRIF MPRES platform/analysis between version 1 (2012 Country Risk Profile) and the current version 2.

**Annex 5** provides an overview of GeoNode.

**Annex 6** provides a glossary of technical terms used in this document.

# SECTION 1:

## BACKGROUND INFORMATION

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### 1.1 Rationale for Development and Use of CCRIF's Second Generation Modelling Platform

CCRIF has been utilising the Multi-Peril Risk Evaluation System (MPRES) platform to underpin policies since the 2010/11 policy year and intends to continue to do so into the future. With this platform, the Facility is better able to meet the catastrophe insurance needs of its members, offer additional products beyond tropical cyclone and earthquake coverage, expand beyond the present number of clients, and provide a catastrophe risk modelling platform for the regional public good.

The MPRES can handle multiple hazards and hazard assessment methodologies, can accommodate a variety of input/output formats and detailed exposure classifications, and produces accurate loss estimates with known statistical uncertainty.

Benefits of the MPRES platform include a reduction in the basis risk inherent in the loss indexing approach used in the first generation CCRIF model. It also provides a globally consistent platform that is scalable, and makes possible the use of multiple methodologies based on public domain research results and data rather than proprietary information. In addition, it uses open standards for inputs and outputs, and enables incorporation of results in a wide range of platforms in a transparent way. The use of the MPRES supports CCRIF's quest to provide a more open environment to assist Caribbean institutions such as the University of the West Indies (UWI) in developing a regional hazard and risk assessment and mapping capability in support of improved natural hazard risk management in the region.

As an added benefit, the MPRES utilises the same hazard modelling base as CCRIF's Real-Time Forecasting System (RTFS). The RTFS, which is made available to all CCRIF members and many regional institutions and other catastrophe risk management stakeholders, is designed to provide a 'preview' of the likely hazards and risks associated with a tropical cyclone based on US National Hurricane Center (NHC) forecasts. Through the provision of forecast hazard footprint maps and site-

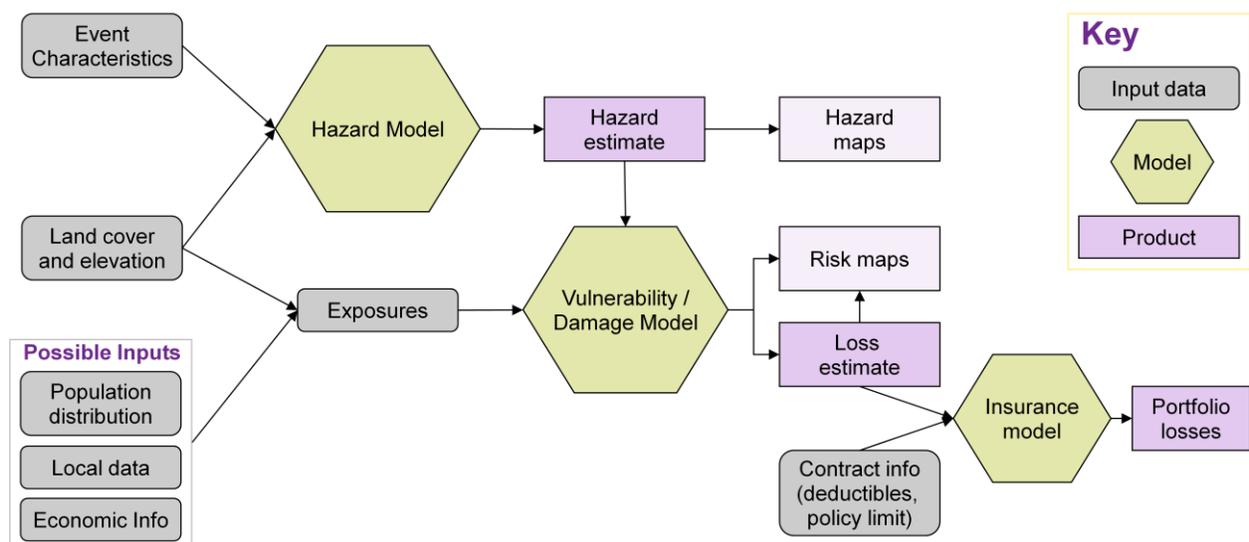
specific hazard and impact data, preparedness and response mechanisms within CCRIF member states are enhanced.

## 1.2 Risk Modelling Methodology

This section presents the KAC hazard and loss estimation methodology, first as a generic modelling framework and then as specifically applied in the CCRIF modelling platform.

### Modelling Specific Events

The hazard and loss modelling process includes the following generic stages (see Figure 1.1).



*Figure 1.1: Hazard and loss modelling generic framework.*

1. **Hazard Assessment** - Using characteristics for a specific event (historical, active or hypothetical), apply numerical modelling to estimate the resulting hazard forces at all locations of interest affected by the event. Hazard maps or GIS data can be produced from the hazard assessment results to show the extent and severity of the hazards generated by the modelled event(s). The specific hazard

models used in the MPRES for tropical storm and seismic event modelling are described below.

2. ***Damage and Vulnerability Modelling*** - Using damage functions appropriate to each class of assets included in the analysis, calculate the extent of damage from the site-specific hazard forces from the event (based on model estimates) to each element in the exposure database.
3. ***Loss Estimation*** - Calculate the event losses by applying the location- and asset class-specific damage assessments to the asset valuations for each individual element in the exposure database. The MPRES calculates losses for each individual asset in the exposure database using damage functions specific to the asset class and the specific hazard levels at the asset site. Aggregate loss estimates can be produced for specific geographic areas (e.g., a country or smaller administrative area) or specific asset classes by summarising expected losses for individual exposures by location or class.
4. ***Portfolio Loss Calculation*** - Using an insurance model and specific contract terms, translate exposure loss estimates into loss estimates for a portfolio of assets across multiple countries. For each policy, payout estimates are determined by the terms of the insurance contract and the expected losses for the assets covered by the insurance contract.

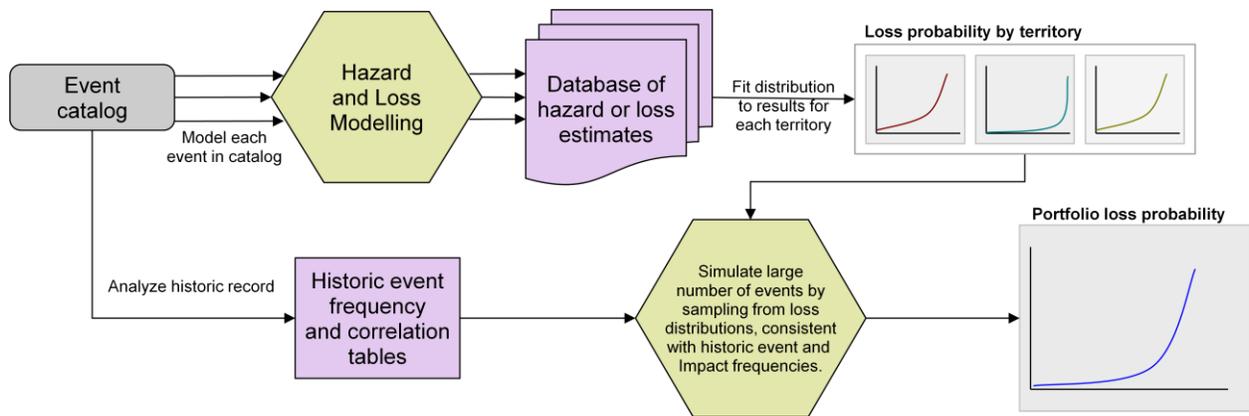
### **Hazard and Loss Probability Analysis**

Using hazard and loss assessment results from a large number of known events, KAC produces hazard severities across an evenly distributed grid and loss estimates for a specified exposure set for a wide range of event probabilities. Hazard and risk profiles and probabilistic hazard maps are derived from this information. KAC also generates 'stochastic' databases of hazard events which provide a longer, though more uncertain, view of hazard frequency and severity than the historical record alone.

The overall approach described below applies to tropical storm-related and seismic hazards (as well as other hazards). For estimating current loss probabilities, databases of current exposures are used, as we are interested in potential current losses from the event, rather than replicating the specific losses experienced at the time of the event.

KAC uses the following steps to produce loss probability estimates (see Figure 1.2):

1. ***Model every event in the historical record or the stochastic database*** - For each event, KAC applies the selected hazard and damage function modules to generate hazard and loss estimates from the event. The event-specific peak hazard and total loss estimate is recorded for each grid cell. It is important that the modelling directly generates the parameters of interest in the overall analysis. For instance, if the objective is to estimate loss probabilities for a portfolio, portfolio losses are recorded for each hazard event in the catalogue; due to the non-linear relationship between hazard values and losses, it is not valid to estimate loss probabilities from a fitted hazard probability curve.
2. ***Fit a probability distribution to the raw modelled loss results*** - Fitting distributions to event losses allows KAC to estimate losses for events that have not occurred in the historical record, including extreme events. The probability distribution captures the stochastic nature of the loss levels of historical events. KAC has found that the 2-parameter Weibull distribution generally provides the best fit over a wide range of scenarios. If a stochastic event database is used then fitting of a probability distribution may not be required.
3. ***Simulate future events by sampling from the territory-specific loss curves (guided by historic frequencies and probabilities) for a large number of simulated event years*** - This analysis integrates the separate probabilities of 1) the occurrence of an event, 2) the probability of a specific territory being affected by the event, and 3) the probability and level of loss for affected territories. Historic event frequency and territory impact probability tables are used to maintain consistency with historic patterns when carrying out this simulation. Simulating a large number of years (for instance, one million years) ensures consistency in the loss estimates produced from this analysis. Again, if a stochastic event database is used, then this simulation process may not be required.
4. ***Create loss probability estimates*** - The final loss probabilities are created directly from the simulation results (or the raw stochastic event results) by sorting the individual loss estimates by their frequency of occurrence.



*Figure 1.2: Loss probability analysis.*

### 1.3 Policy Pricing, Portfolio Analysis and Real-time Loss Calculation

The objective of the loss modelling approach is to equip the CCRIF with the capacity to estimate loss probabilities for individual territories, price contracts for specific territories, and estimate site-specific hazard levels and losses for specific events during the contract period. Given these and other operational needs of CCRIF, KAC implements the modelling framework described above in two phases: 1) historical analysis using KAC’s cluster computing facilities and 2) active event analysis in a stand-alone software package which can utilise CCRIF’s own computer hardware (and is installed at offices of the CCRIF Facility Supervisor and Policy Verification Agent).

For full compatibility, both parts are implemented using the exact same hazard and loss modelling code base. Key strengths of this approach are that it:

- Is built upon a strong, validated hazard modelling base;
- Uses the same techniques and code for both historical hazard assessment and loss modelling as well as real-time event modelling and payout calculation;
- Is implemented using open modelling techniques from the published scientific literature;
- Is highly scalable and has been applied at a wide range of modelling resolutions; and

- Is implemented on a geographic base, enabling generation of results in mapping formats.

## Generating Losses for Pricing and Portfolio Analysis

### *Full Historical Analysis*

1. **Model every event in the input catalogue**, using current exposures and the selected hazard and damage function modules.
2. **Create long-term loss event sets for each peril**. For both earthquake and tropical cyclone events, a synthetic loss event set is generated, and applied as described below.
  - a. **Tropical Cyclone Return-period Analysis:** For assessment of tropical cyclone hazards and losses, KAC generates a 1,000-year synthetic Atlantic tropical cyclone track event set based on the overall characteristics of the historical record. For each event in both the historical Atlantic event set and the synthetic tropical cyclone event catalogue, KAC simulates the event to generate hazard footprints and loss estimates for CCRIF territories. Final, long-term, territory-specific loss curves are generated for the territory-specific losses from both the historical event simulations and the synthetic loss event catalogue. In both cases, the loss curves were generated directly from the sorted empirical losses in the loss catalogues. CCRIF utilises the loss curves from the synthetic event set as a basis for its pricing of policies, and those results are presented here (in Section 3); the full historical event set is used for comparative and benchmarking purposes and to provide as-if hazard and loss outputs for historical events (as presented in Section 3.)
  - b. **Seismic Return-period Analysis:** KAC has developed a model that uses historic earthquake event information from the USGS, and best-practice techniques of probabilistic earthquake hazard and risk mapping, to create a synthetic catalogue with 10,000 years of earthquake events (magnitude, hypocentral location and moment tensor information.) This is necessary as the historical record is insufficiently rich to enable probabilistic hazard and risk assessment. KAC also run a catalogue of historical events provided by CCRIF for comparative and benchmarking purposes. The process of loss curve

generation then follows the same schema as described above for tropical cyclones.

3. ***Generate loss probability curves from the results in the long-term loss event set***— Given a known number of event years in the loss event set, annual aggregate loss probability curves were derived directly from the discrete, empirical loss set.

### ***Pricing and Portfolio Analysis***

The loss event set derived from the synthetic catalogue for each of the two perils is used by CCRIF to generate a national loss profile, against which possible policy conditions are applied to provide the basis for pricing of policies and to provide governments with options for different coverage characteristics. This is undertaken as follows:

1. ***Create government loss and payout probability tables*** from the event set through applying policy conditions to each national loss, including an initial scaling factor to provide an indicative ‘government loss’ from the national loss amount.
2. ***Complete portfolio analysis*** through application of final policy conditions for each territory into CCRIF-level payout probability.

### **Loss Calculation Model Methodology**

In order to price country insurance contracts and estimate site-specific hazard levels and national losses for specific events — either historical or active events, CCRIF maintains its own version of the MPRES which replicates many of the functions of the full modelling platform described above. This enables CCRIF to run earthquake and tropical cyclone events as soon as event input information becomes available from the relevant reporting agency. The CCRIF software then runs the MPRES model for a real-time event using exactly the same methodology as was used in running each historical or stochastic event as described above. This ensures full compatibility between probabilistic loss results used for policy pricing and real-time loss results used for calculation of payouts.

### *Real-time Event Trigger Calculation*

For tropical cyclones, event information from the National Hurricane Center's Automated Tropical Cyclone Forecasting System, is used to run a tropical cyclone event hazard simulation that generates hazard estimates for the storm. Using these results, damage and loss estimates are produced for the CCRIF exposures. The exact same methodology used in calculating historical hazards and losses from synthetic catalogue events is used to calculate hazard, damage and loss from an event in real time.

For earthquake events, event information from the USGS is used to run a seismic hazard simulation to generate ground motion hazard estimates for the seismic event. Using these results, damage and loss estimates are produced for the CCRIF exposures.

Territory-specific event loss estimates from the single-event hazard and loss simulations are converted to CCRIF policy and portfolio loss estimates by applying the government loss and the territory policy limits and adjustments.

## **1.4 Asset Vulnerability**

Asset vulnerability is defined as the degree to which an asset may be damaged when subjected to the hazard forces exerted by the peril. The hazards considered here are wind and storm surge for the tropical cyclone peril, and ground shaking for the earthquake peril.

Using appropriate damage functions, the loss model computes the damage to each exposure class as a function of the hazard level impacting that class, and estimates the resulting loss based on the value of that class. The loss modelling can produce multiple metrics, including: a mean loss ratio (MLR) for a class of assets (representing the ratio of repair/replacement cost to the total value of the asset class), and a total loss in value by asset class.

### **Damage Functions**

Damage functions translate the peak hazard level at the site into the likely damage level to the structure.

### *Wind Hazard*

Eight separate damage function families are used, for assessment of losses for both historical and real-time events. Individual functions within a family are defined by the particular configuration of parameters that best fit the structural characteristics of the exposure class.

The following damage function families were used in the CCRIF analysis:

- Australian—Leicester and Beresford (1978)
- Clemson, claims basis—Rosowsky et al (1999)
- Clemson, engineering basis—Sill et al (1997)
- Foremost Ins Co (1976)
- Friedman (1984)
- FCHLPM ProTeam—Florida Commission on Hurricane Loss Projection Methodology (2002)
- Stubbs (1996)
- X<sup>3</sup>—Howard et al (1972)

The parameters used in these damage function curves are based on published literature. Further information about these damage functions is available in Watson and Johnson (2004).

### *Storm Surge Hazard*

The flood damage from static and moving waters is computed using an adaptation of the simple two-dimensional flood model and flood damage curves developed by the US Federal Emergency Management Agency (FEMA) for the HAZUS-MH model.

### *Seismic Ground Motion*

Seismic damage functions developed by the Global Earthquake Safety Initiative (GESI) for standard building types are used to calculate damage from seismic ground motion (GeoHazards International, 2001). Construction types in areas of lower Gross Domestic Product Per Capita (GDPPC) are mapped to less resilient asset categories.

# SECTION 2:

## REGIONAL HAZARD PROFILE

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### 2.1 Introduction

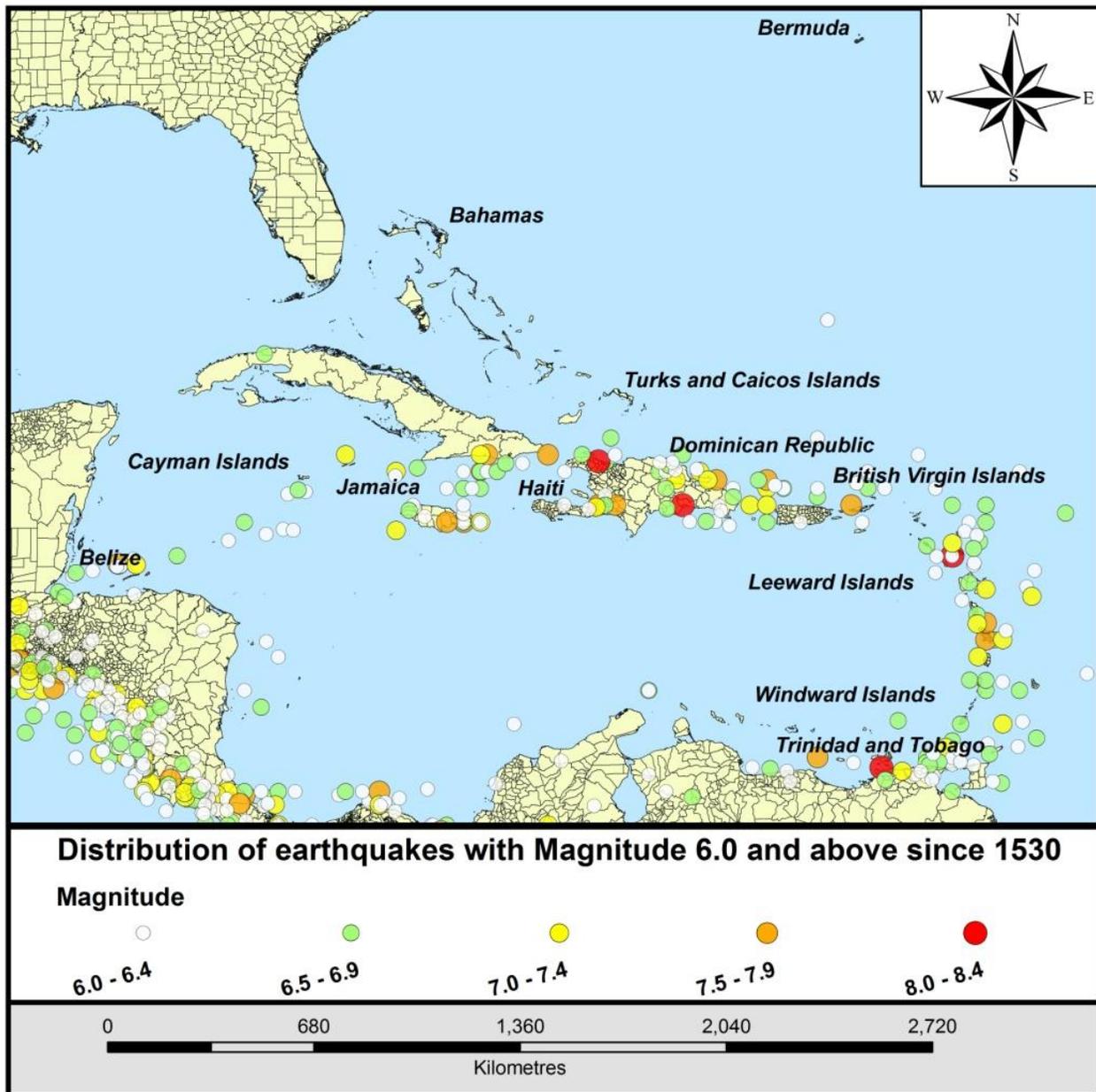
The Caribbean faces a number of primary natural hazard risks, particularly earthquake and hurricane risks, and to a lesser extent volcanic risks in certain areas. The region also faces secondary risks from flooding and landslides, storm surge and wave impacts, and tsunamis.

### 2.2 Earthquake Hazards

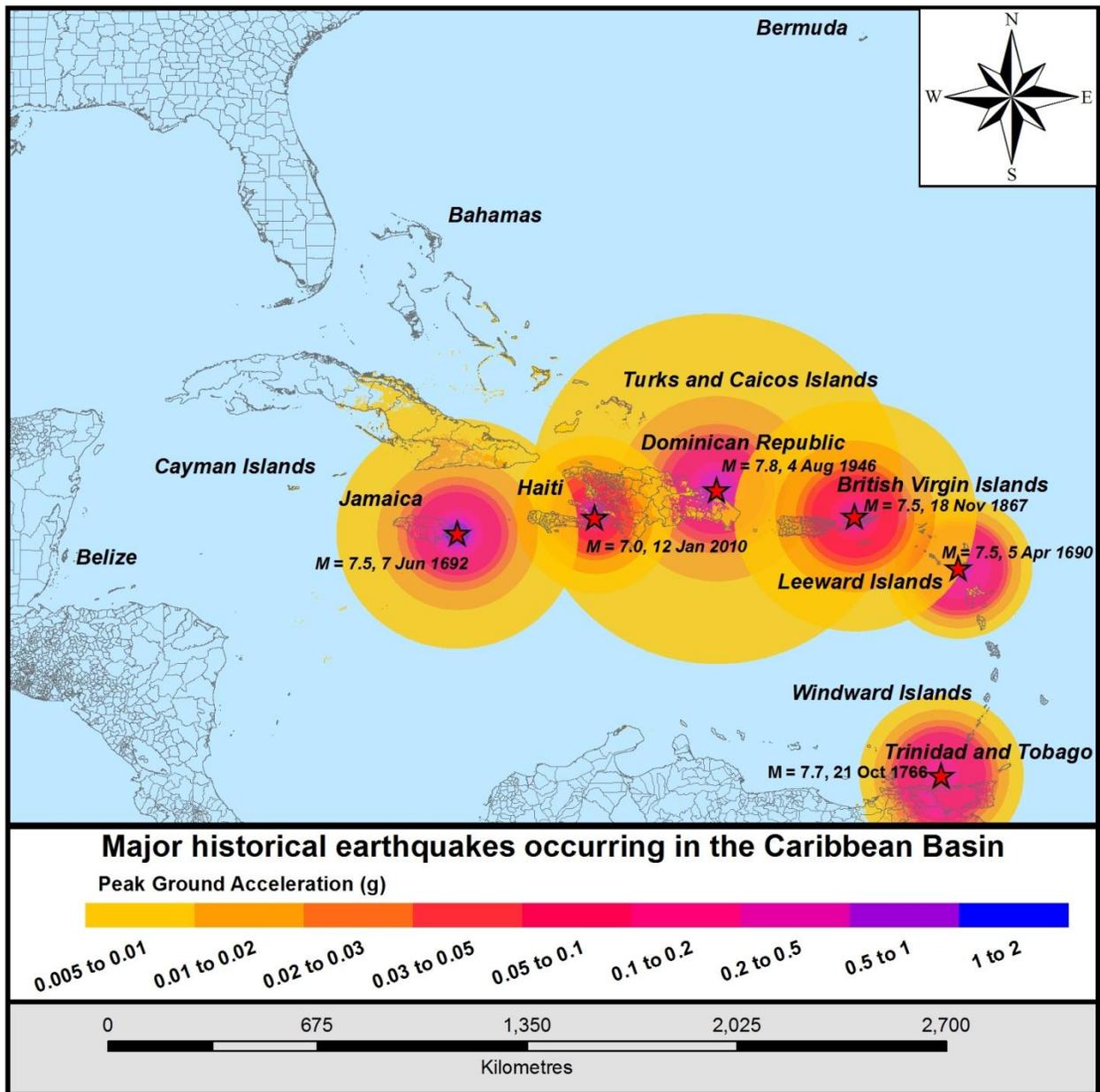
As shown in Figure 2.1, most of the Caribbean countries lie close to the boundary of the Caribbean Plate, making most of the region susceptible to damaging levels of earthquake shaking. Figure 2.2 shows the epicentral location of earthquakes of magnitude 6.0 and above occurring in the region since 1530, while Figure 2.3 shows a small selection of shaking footprints for the major historical earthquakes affecting the region.



*Figure 2.1: Caribbean Plate and regional faults. Source: USGS.*



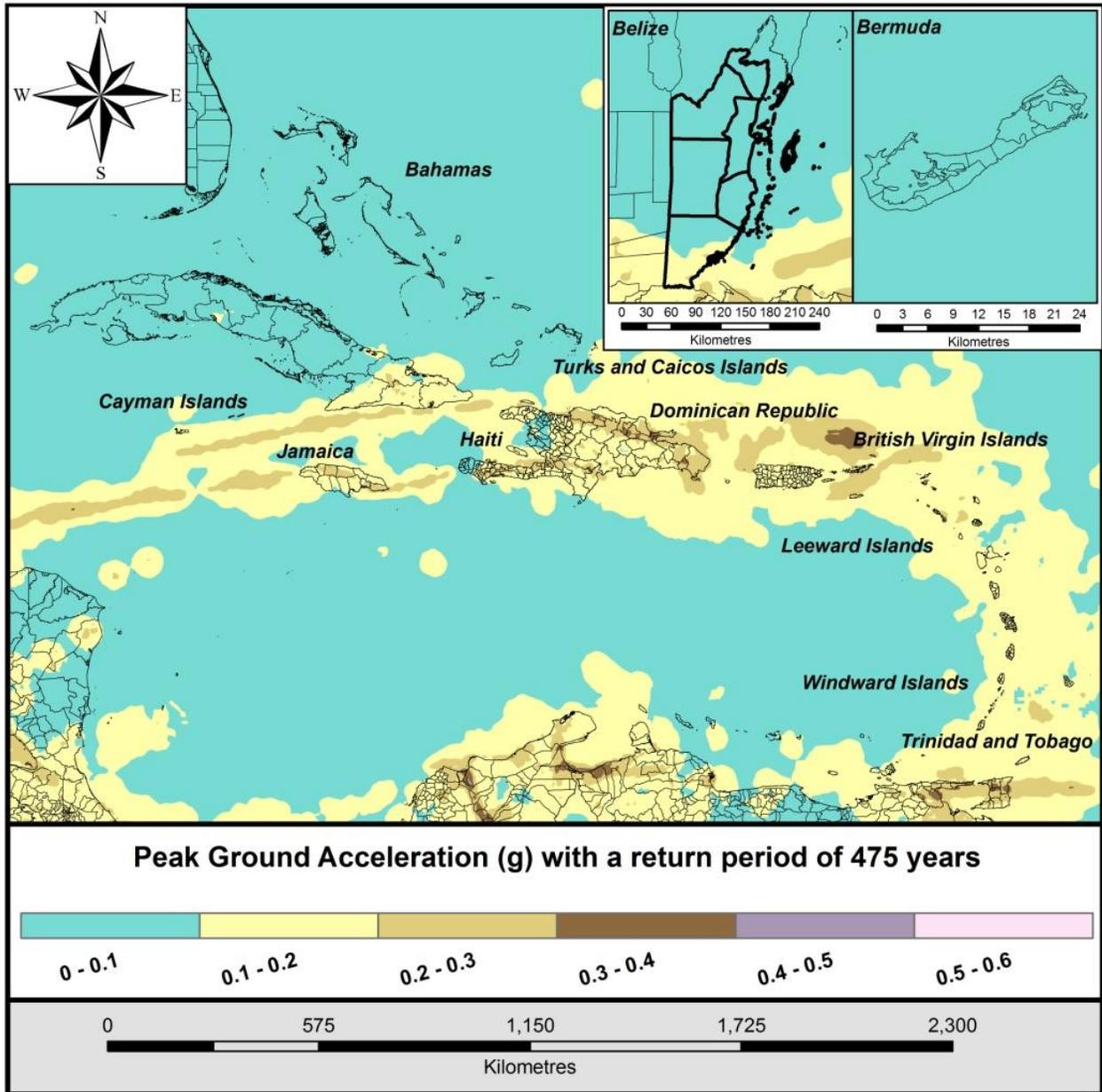
*Figure 2.2: Earthquakes of magnitude 6.0 or greater since 1530. Sources: Pan-American Institute of Geography and History (PAIGH) and USGS*



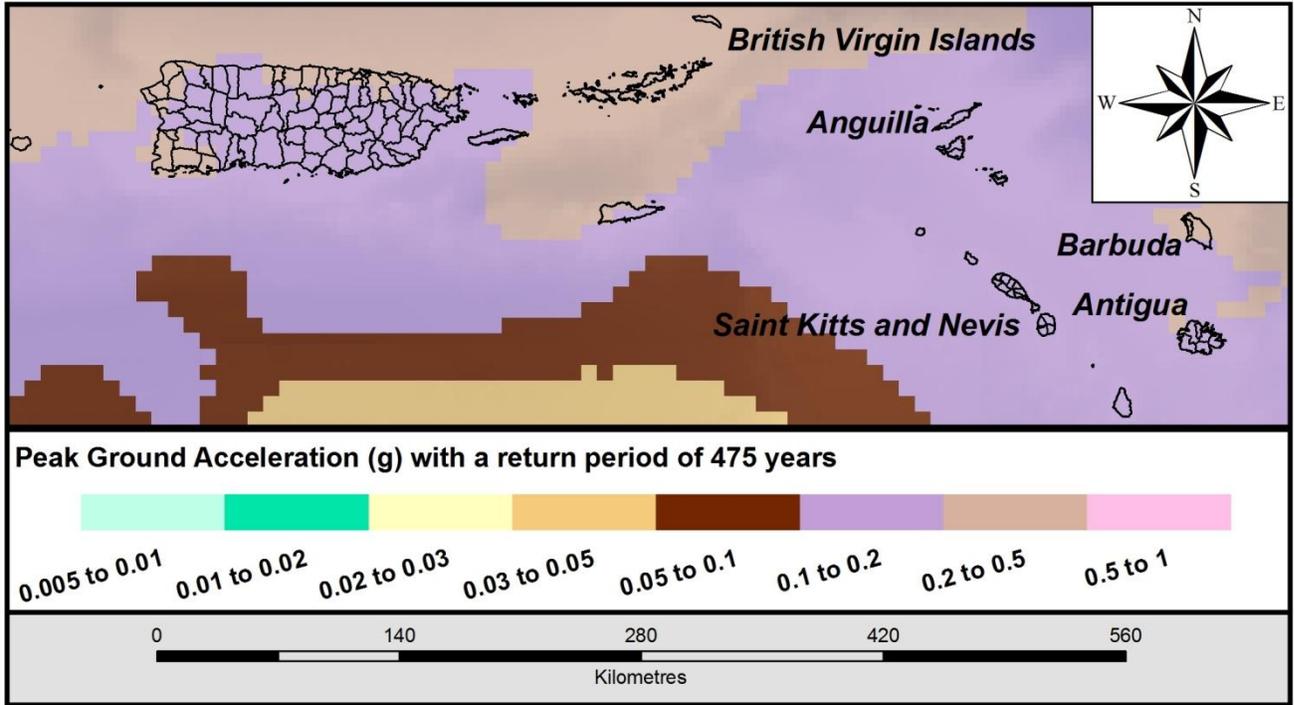
*Figure 2.3: Major historical earthquakes in the region. Source: hypocentre locations from : Pan-American Institute of Geography and History (PAIGH), shaking intensity from MPRES model.*

Figures 2.4 and 2.5 show the peak ground acceleration (PGA) expected to be exceeded once every 475 for the Caribbean region. Figure 2.5 is an expanded version of Figure 2.4 showing in greater detail the peak ground acceleration for this sub-region of the Caribbean. Figure 2.6 shows the peak ground acceleration expected to be exceeded once every 2475 years. To create these probabilistic ground shaking hazard maps, the region is divided into 30 arc-second (~1km) grid cells. KAC fits hazard exceedance probability curves of PGA from the results of thousands of individual stochastic earthquake events for each grid cell. From these curves, the expected PGA at the required return period is logged and mapped across the region.

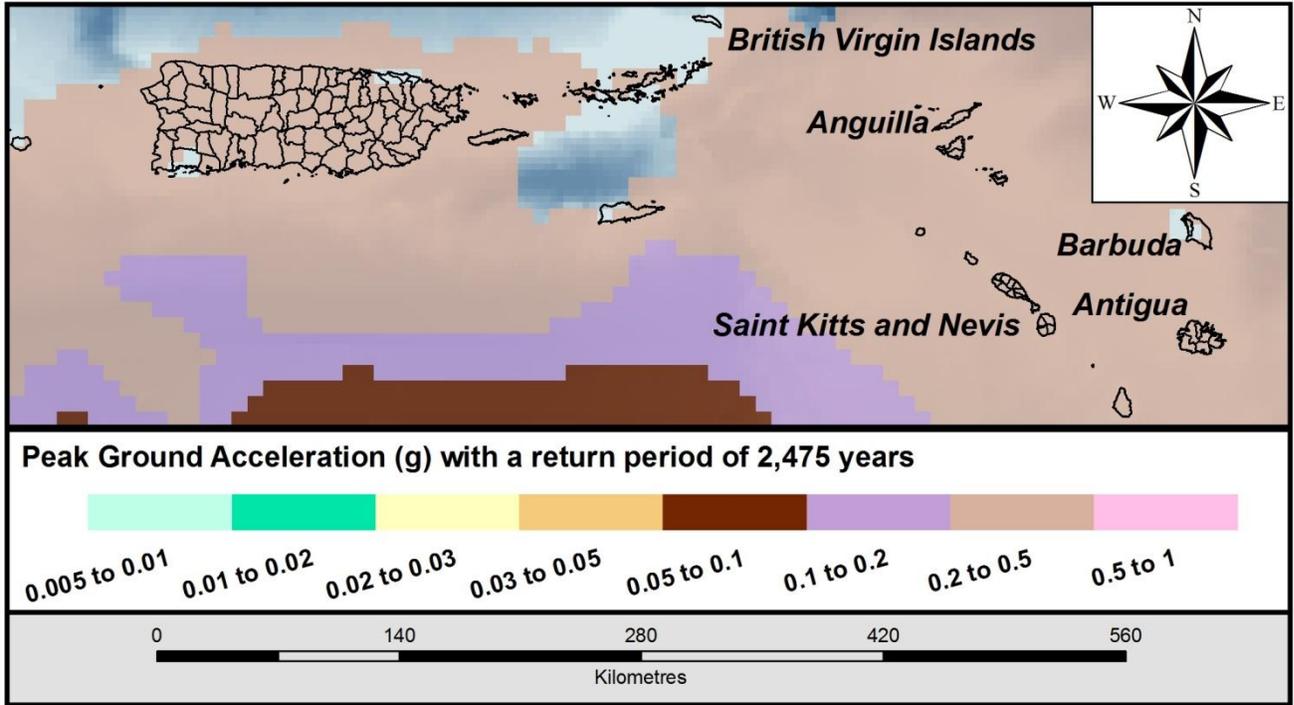
We note that the following maps use PGA buckets for illustrative purposes and therefore appear at lower resolution than the raw dataset.



*Figure 2.4: Peak Ground Acceleration with return period of 475 years (equivalent to 10% probability of exceedance in 50 years).*



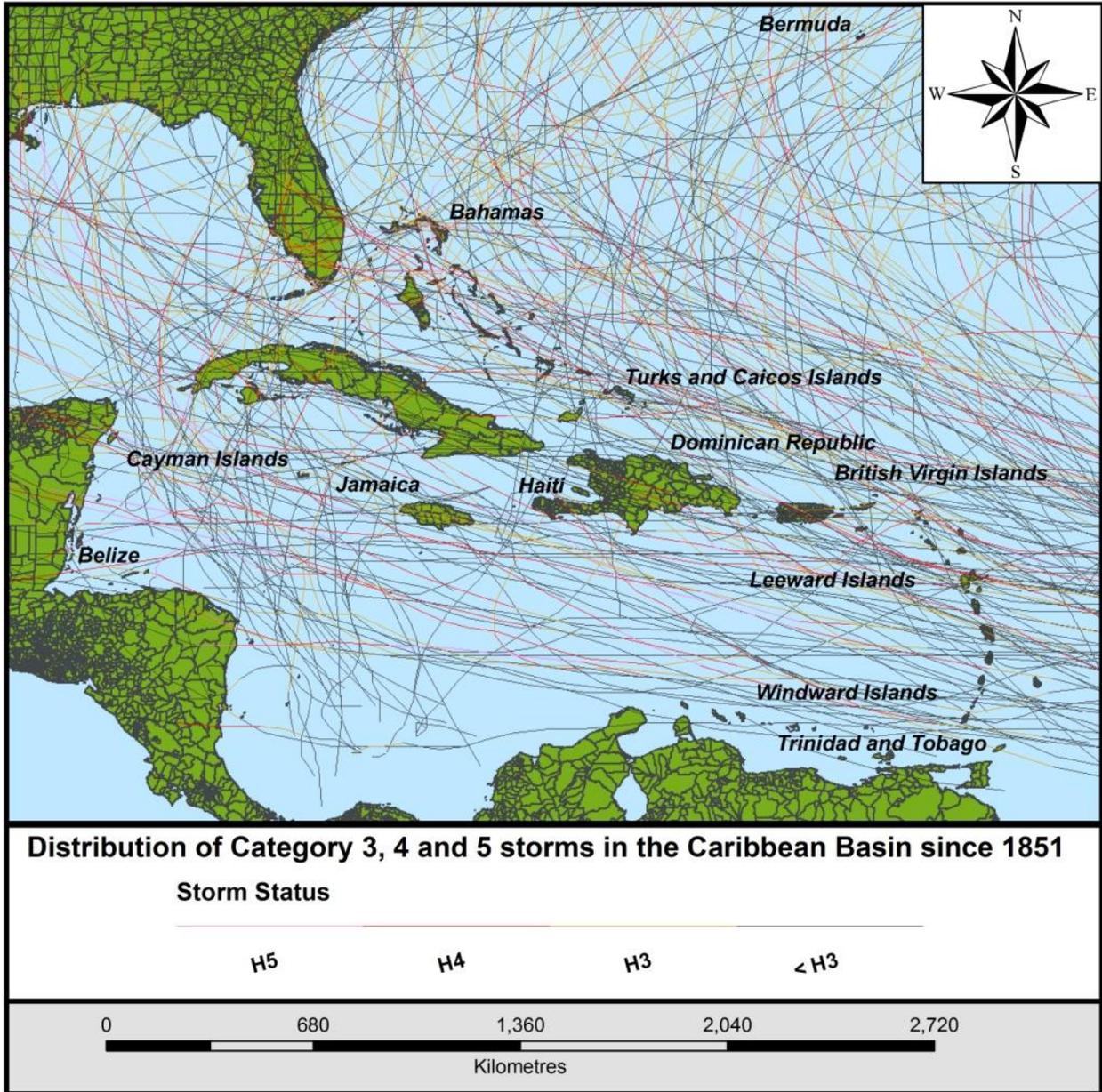
*Figure 2.5: Sub-regional map for peak ground acceleration with return period of 475 years.*



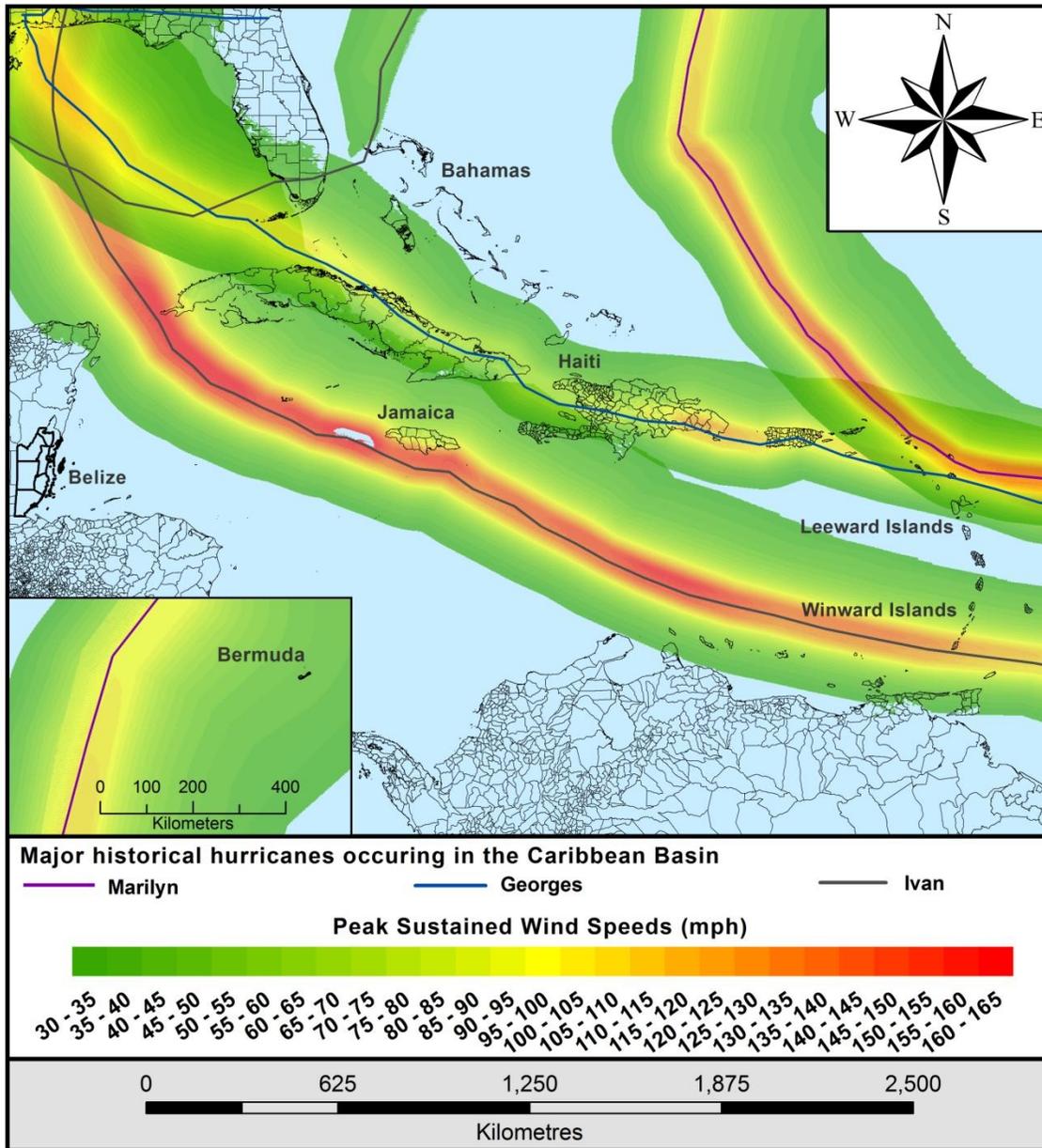
*Figure 2.6: Peak Ground Acceleration with return period of 2,475 years (equivalent to 2% probability of exceedance in 50 years).*

## 2.3 Hurricane Hazards

The most significant natural hazard risk in the Caribbean is hurricane risk, particularly because of the possibly large span of territories which can be impacted by any single event. Figure 2.7 shows tracks of Category 3, 4, and 5 storms that have impacted the region since 1851. The significant impact that single hurricane events can have is illustrated in Figure 2.8, which shows three hurricanes (Ivan, Georges, and Marilyn), and their impacts on multiple islands. These three events alone impacted Antigua and Barbuda, Barbados, British Virgin Islands, The Bahamas, Cuba, Dominican Republic, Guadeloupe, Haiti, Grenada, Jamaica, Saint Lucia, St. Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, and Puerto Rico.



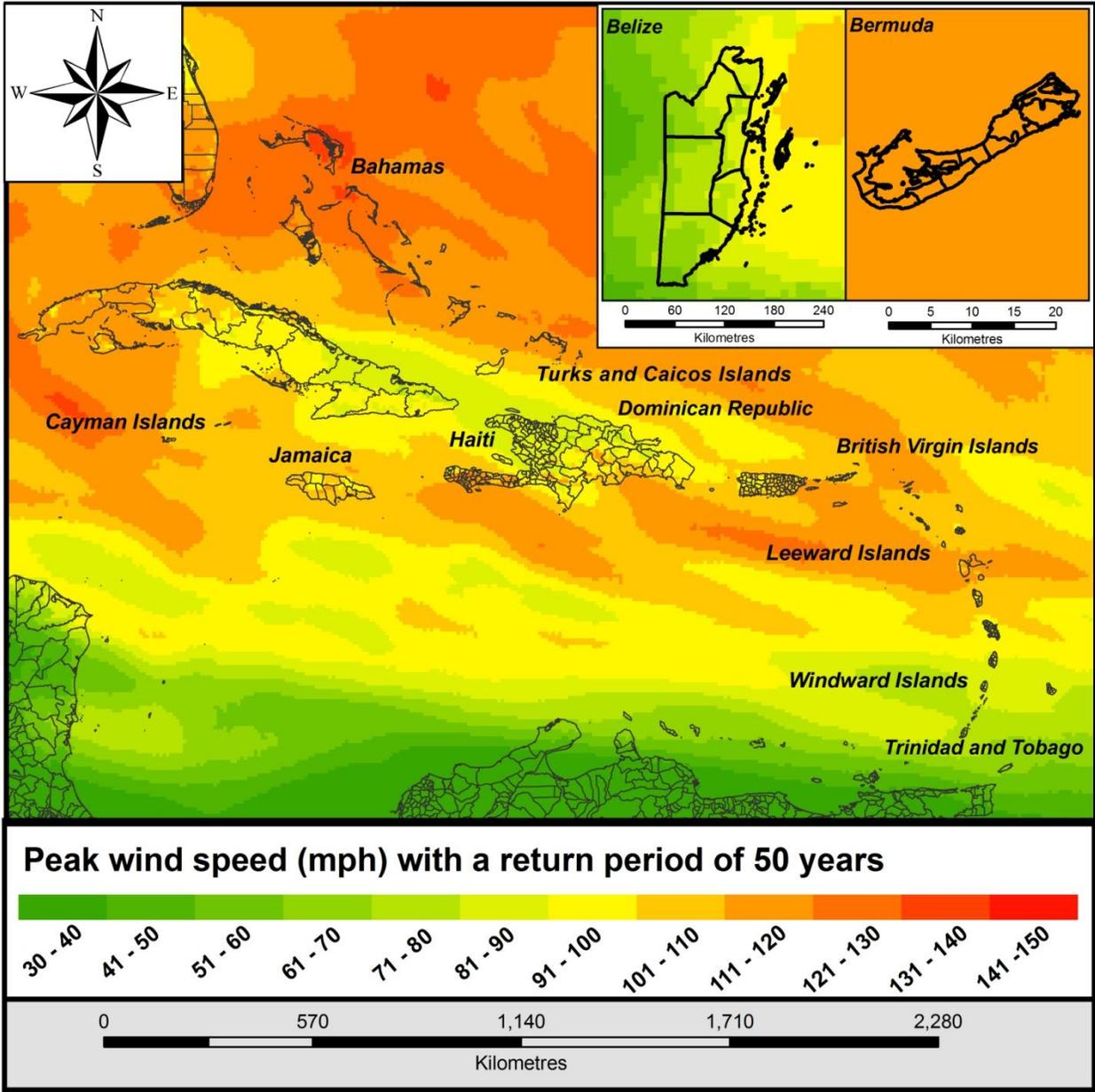
*Figure 2.7: Category 3, 4 and 5 storms affecting the Caribbean Basin since 1851. Source: NOAA-NHC.*



*Figure 2.8: Peak wind footprints of hurricanes Marilyn (1995), Georges (1998) and Ivan (2004) across the Caribbean region.*

Figures 2.9 and 2.10 are probabilistic wind hazard maps for 50- and 100-year return periods, with Figure 2.11 showing a more detailed sub-regional version of the 100-year return period map. To create these maps, the Caribbean is divided into 30 arc-second (~1km) grid cells and hazard exceedance probabilistic curves of peak wind speed from the results of thousands of individual events are fit for each grid cell. From these curves, the expected peak wind speed at the required return period is logged and mapped across the region.

As with the earthquake hazard maps, we note that the following maps use wind speed buckets for illustrative purposes and therefore appear at lower resolution than the raw dataset.



*Figure 2.9: Peak wind speed with return period of 50 years.*

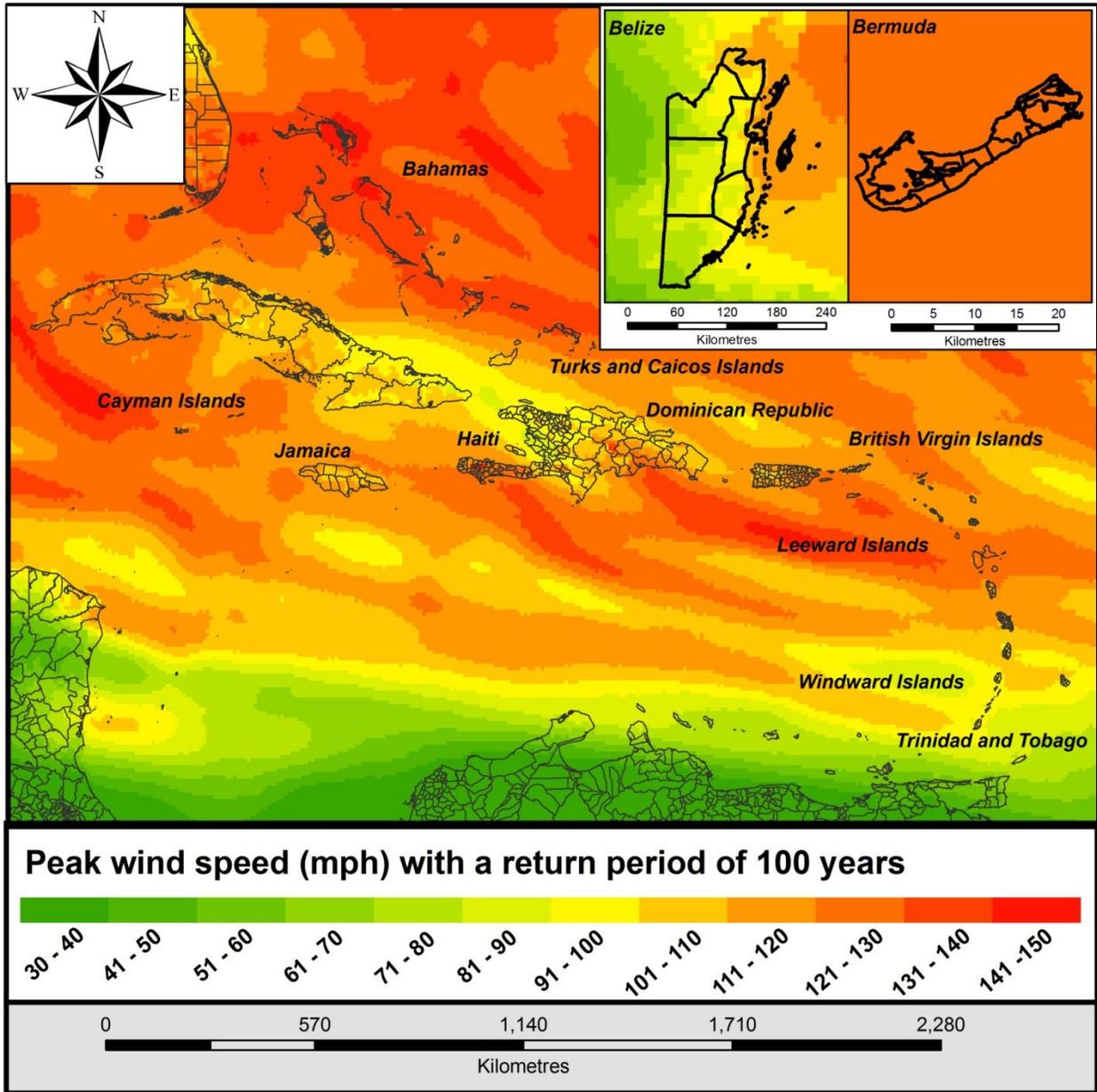
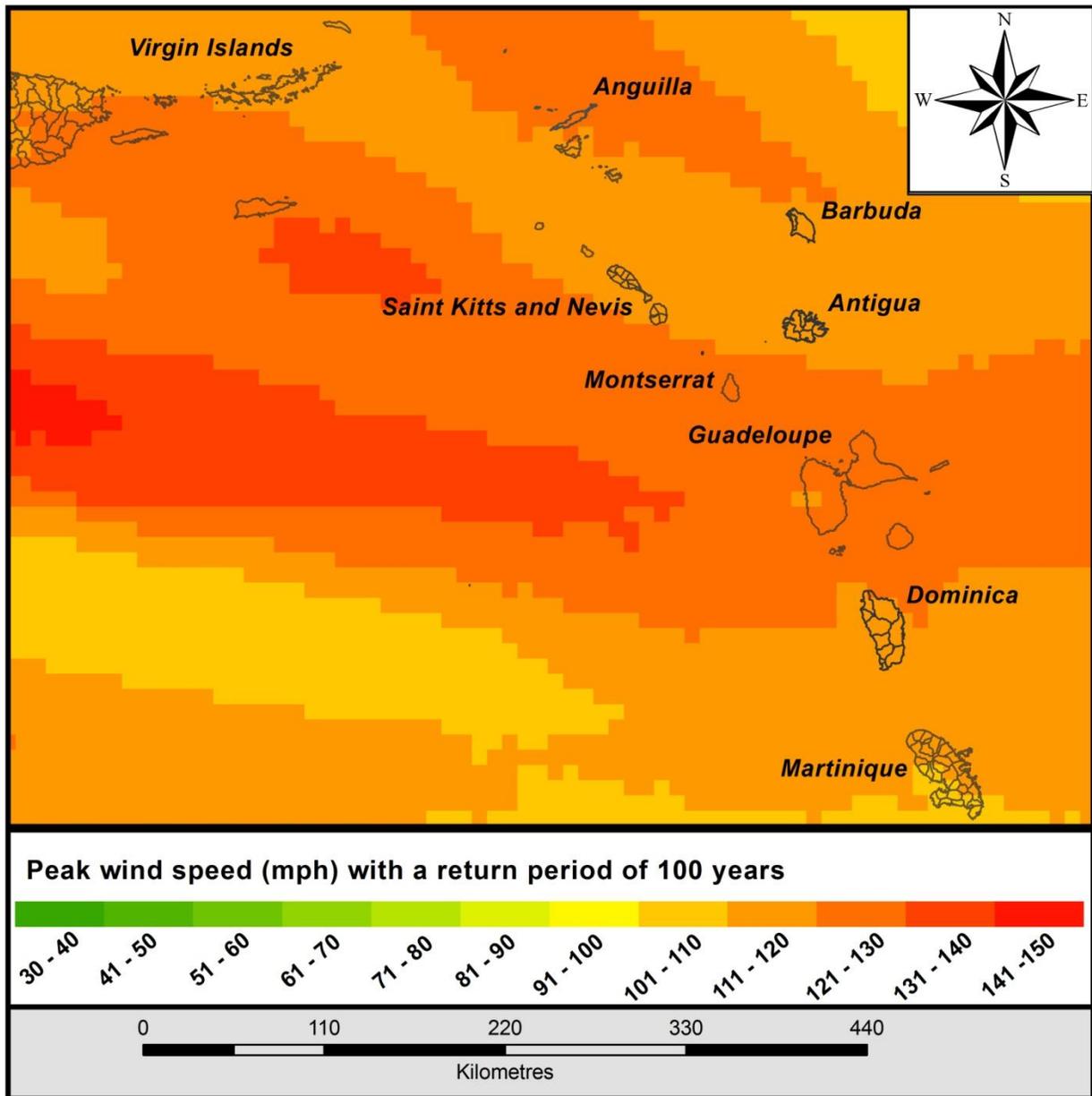


Figure 2.10: Peak wind speed with return period of 100 years.



*Figure 2.11: Sub-regional map of peak wind speed with return period of 100 years.*

# SECTION 3:

## RISK PROFILE OF ST. KITTS AND NEVIS

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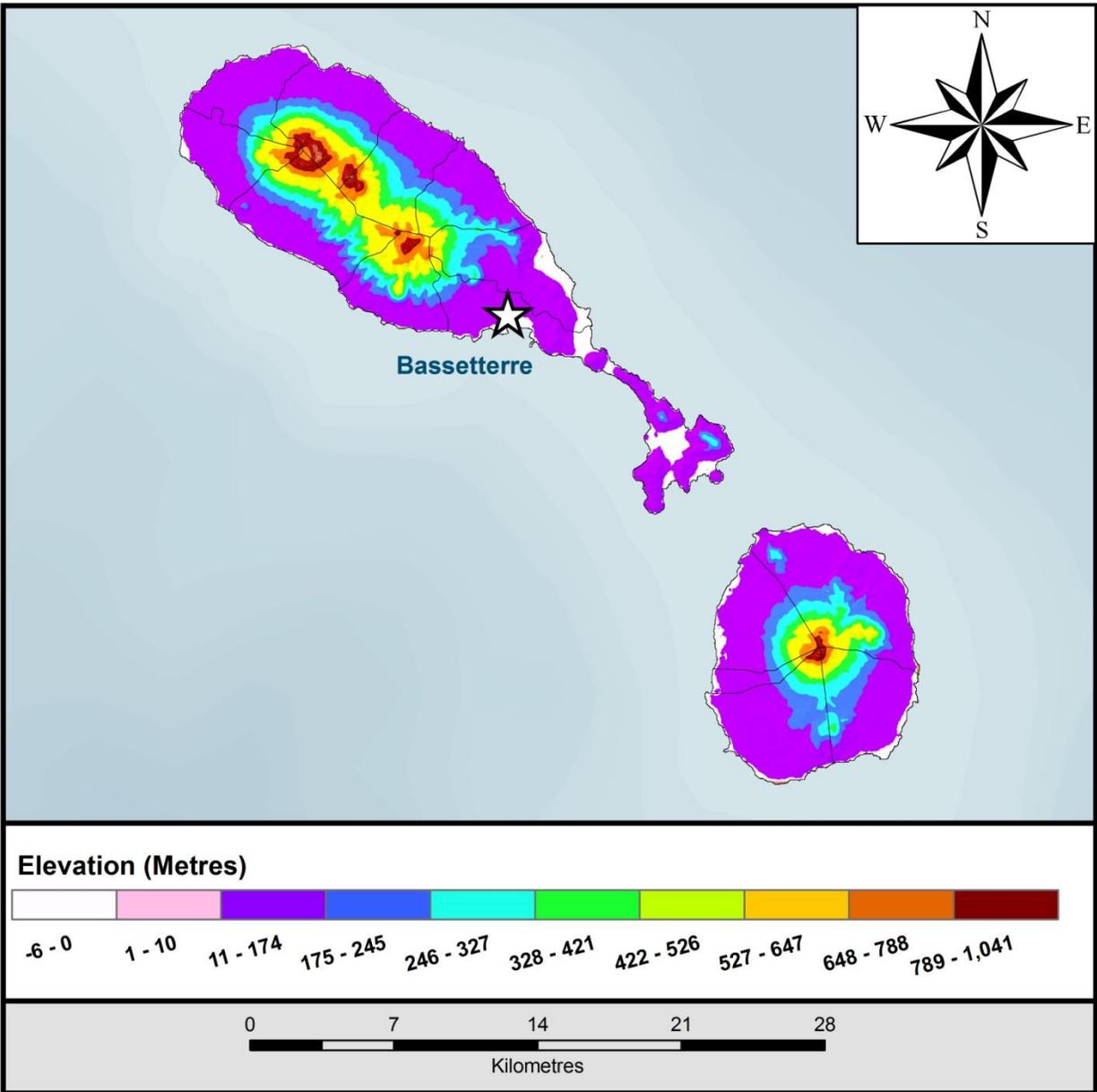
### 3.1 Introduction

St. Kitts and Nevis consists of two main islands, Saint Kitts and Nevis, with St. Kitts being the larger of the two islands. The islands are geographically part of the Leeward Islands. The islands cover an area of 261 sq km. The islands are both volcanic.

In 2011, the population of St. Kitts and Nevis was estimated at about 49,898 with a growth rate of about 0.8% per annum. About 32% of the population reside in urban areas. The economy is fuelled mainly by tourism. The country's GDP per capita is estimated as US\$16,400 (IMF database).



*Figure 3.1: St. Kitts and Nevis - geography and regional location.*



*Figure 3.2: Topography of St. Kitts and Nevis.*

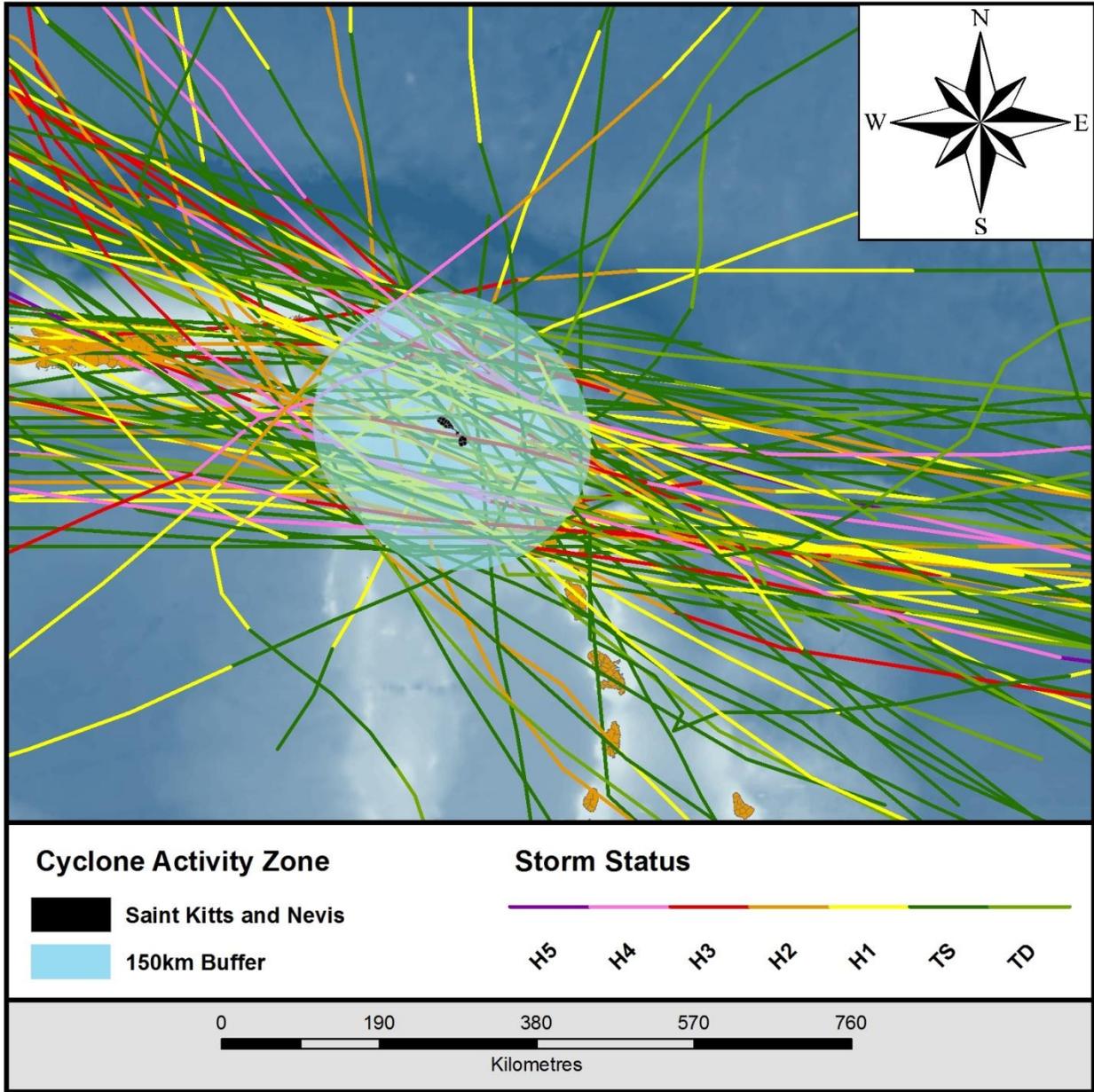
## 3.2 Country Hazard Profile

Saint Kitts and Nevis is located within the main Atlantic hurricane belt and both are susceptible to severe hurricane hazards, as highlighted by a series of storms in the late 1990s. Earthquake hazards are also high, with a seismically active area of the Caribbean plate boundary located to the east of the islands. Landslide hazards are moderate. Inland flooding occurs in low-lying areas during heavy rain. Both islands have potentially active volcanoes; Nevis Peak dominates Nevis and the entire island is within the main hazard zone. Mt Liamuiga, a stratovolcano on St. Kitts, does not directly threaten Basseterre (the country's capital).

### Hurricane Hazard Profile

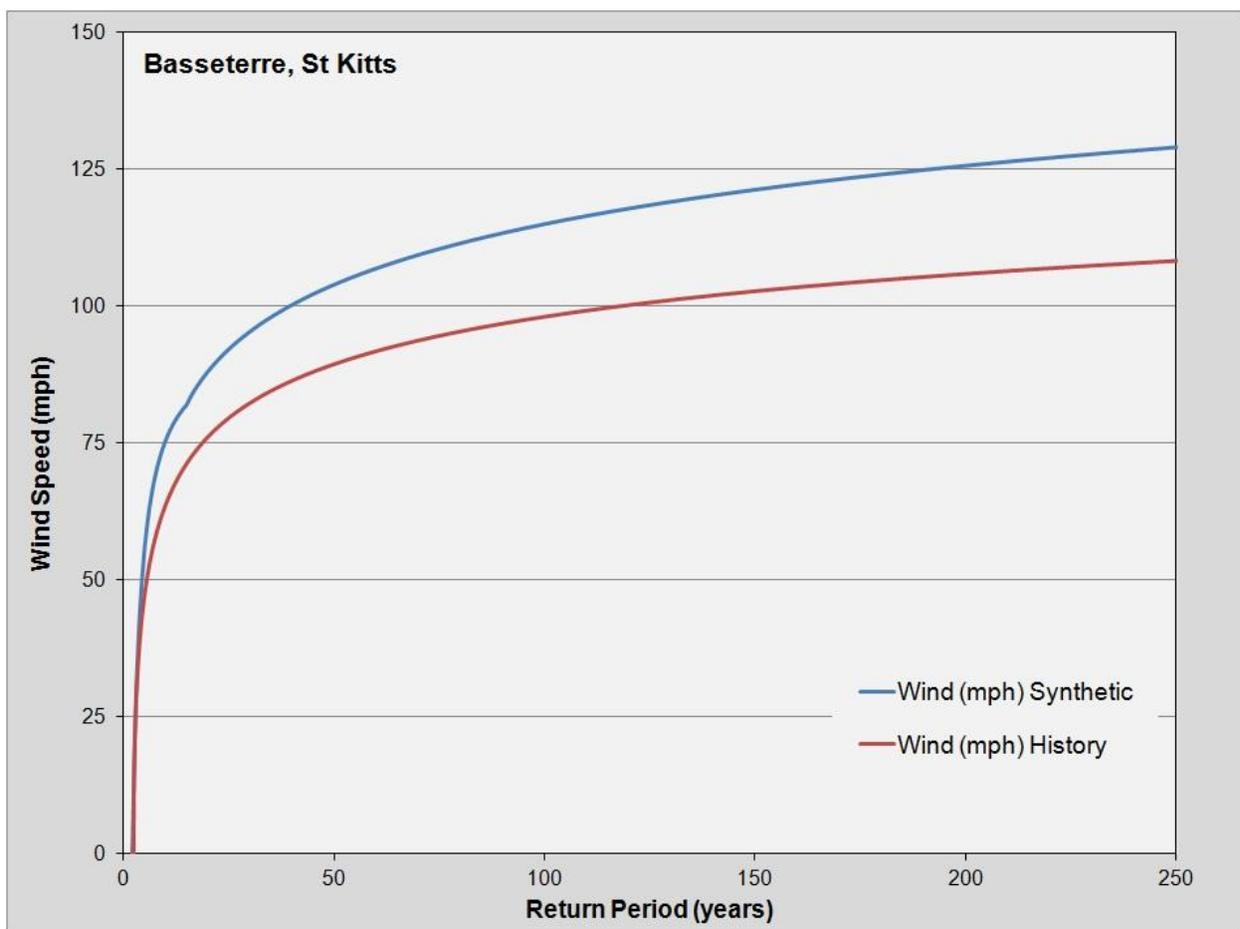
Hurricanes are categorised according to the strength of their winds using the Saffir-Simpson Hurricane Scale (see Annex 2). Each year, an average of 10 tropical storms develop over the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.

The St. Kitts and Nevis economy is dominated by tourism, a sector which is particularly vulnerable to hurricane impacts. There is no enforced building code and, although engineered structures are built to resist earthquake shaking and high winds, the general level of building vulnerability to both earthquakes and hurricane hazards is modest at best which, given the high hazard levels, leads to high risk. Poorly enforced development planning and growing reliance on a single economic engine both tend to increase catastrophe risk. St. Kitts and Nevis has had a number of significant storm impacts since the Atlantic Basin entered its current 'busy' multi-decadal cycle in the mid-1990s. Hurricanes Luis (1995), Georges (1998) and Lenny (1999) all rank in the top 10 storms for wind speed. Hurricanes Donna (1960), Hugo (1989) and three unnamed storms (1871, 1899 and 1928) join Luis and Georges in being severe hurricanes in Saint Kitts and/or Nevis. Storm surge and wave exposures are generally moderate.



*Figure 3.3: Tracks of Tropical Cyclones moving within 150km of St. Kitts and Nevis since 1851.*

Figure 3.4 shows the wind hazard profile for Basseterre, St. Kitts and Nevis. The graph shows a fitted probability distribution to empirical historical data as well as the actual curve generated from the synthetic tropical cyclone track data. To produce the synthetic data, 1,000 years of hurricane activity is simulated, and used to determine a wind hazard profile for the location. This is in contrast to the historical wind profile which is based on ~160 years of historical data and curve fitting to that data. It plots wind speed against return period; for example, the wind speed taken from the curve at the 100-year return period is likely to be exceeded once every 100 years, or has an annual probability of exceedance of one in one hundred.



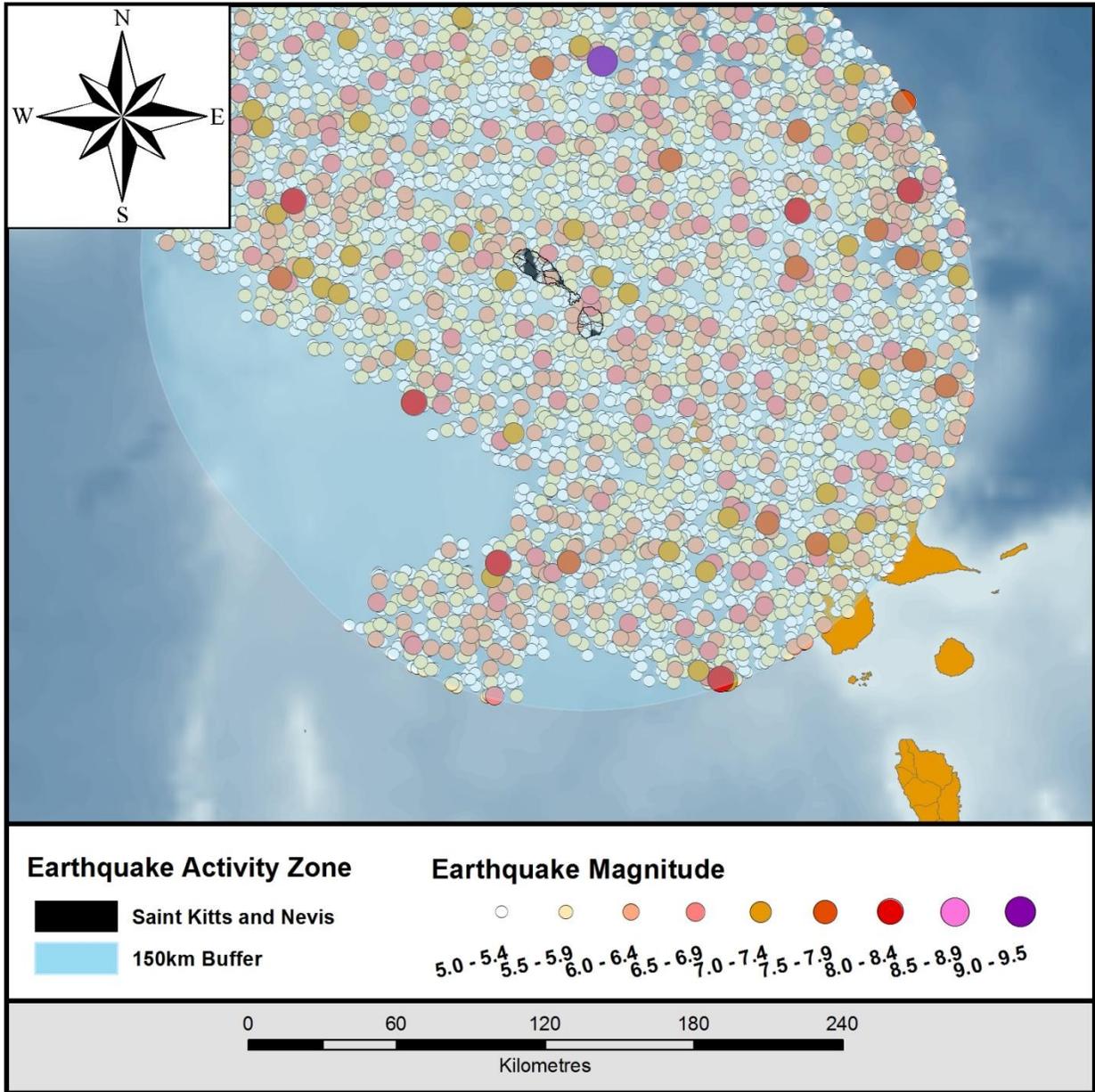
*Figures 3.4: Wind hazard profile for Basseterre, St. Kitts and Nevis.*

## Earthquake Hazard Profile

An earthquake is the sudden release of stored energy in the earth crust; most earthquakes occur along a fracture within the earth, called a fault. The shaking caused by this sudden shift is often very small, but occasionally large earthquakes produce very strong ground shaking. It is this strong shaking and its consequences – ground failure, landslides, liquefaction – that results in damaged buildings and structures and often results in negative impacts on the economy.

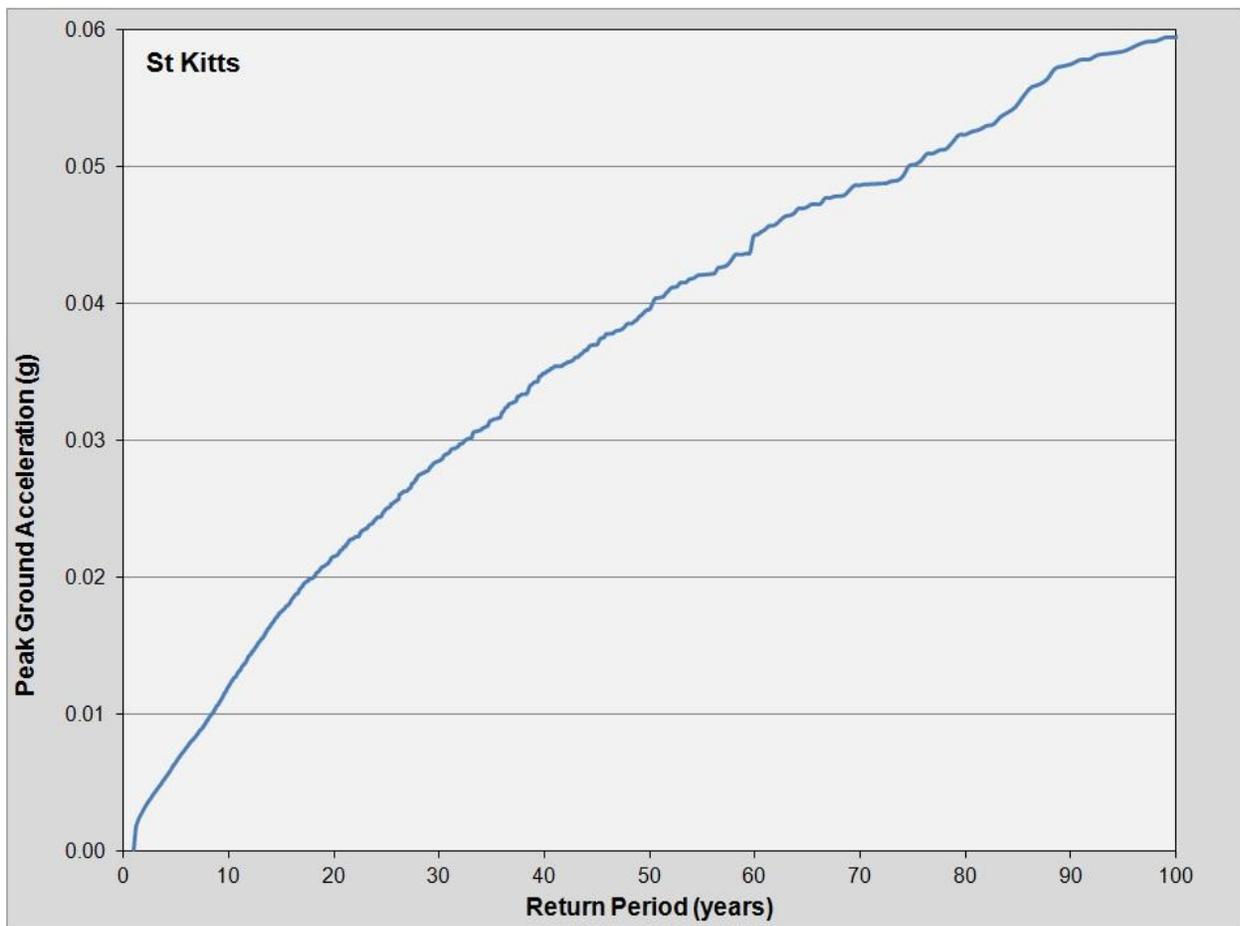
Earthquake magnitude and intensity are measured on two different scales, the Richter Magnitude scale for source magnitude (the amount of energy released by the event) and the Modified Mercalli Intensity (MMI) scale for the amount of shaking felt at a specific place on the ground. Annex 3 provides the classification definitions for the two scales.

Saintt Kitts. and Nevis is close to the most active sector of the eastern margin of the Caribbean Plate. There have been a number of significant shaking events in recorded history, including MMI IX events in 1690 and 1843, an MMI VIII event in 1833 and MMI VII events in 1930 (Nevis) and 1974. The first two of these events were extremely damaging to both Saint Kitts and Nevis, and the third moderately so. Earthquakes close to Saint Kitts or Nevis could produce tsunami waves and/or landslides (the 1690 quake did both.) Shallow volcano-tectonic earthquakes preceding any eruptive activity on either island could be damaging.



*Figure 3.5: CCRIF stochastic earthquake catalogue.*

Figure 3.6 shows the earthquake hazard profile for Basseterre, St. Kitts and Nevis. It plots peak ground acceleration against return period; for example, the peak ground acceleration taken from the curve at the 100-year return period is likely to be exceeded once every 100 years, or has an annual probability of exceedance of one in one hundred.



*Figures 3.6: Earthquake hazard profile for Basseterre, St. Kitts.*

### 3.3 Country Exposure Profile

#### Asset Classification and Valuation

Using remote sensing data and economic and demographic statistics for 2011 and 2012 (the most recent base years for which complete data sets were available), KAC generated a database with the spatially distributed density and value of physical assets at risk in St. Kitts and Nevis for the MPRES. This compilation was performed at the same grid scale as the one used for the hazard assessment (30 arc-seconds or approximately 1km grid cells).

The exposure databases developed are designed specifically to provide acceptable estimates for losses from hydro-meteorological and geophysical hazards suffered by physical assets in the territory. The valuations in these databases represent the 'exposed value' (*i.e.* the amount of value at risk of total loss), which is not necessarily equal to the absolute value of the asset. Consequently, these exposure databases are neither suitable for disaggregating by class of assets, nor for general use as a representation of the economic valuation of national assets.

#### Input Data Sources

- MODIS (used as a source of data for land cover) is a satellite-based instrument, designed and deployed by US NASA to “improve understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.” [<http://modis.gsfc.nasa.gov/>]
- Landscan 2011 (used as a source of data for distribution population information and administrative areas) is a global population database compiled by the (US) Oak Ridge National Laboratory’s Global Population Project. [<http://www.ornl.gov/sci/landscan/>]
- CIA World Factbook (used as a source of data for national and sectoral economic data) is a general reference source for a wide variety of country data. [<https://www.cia.gov/library/publications/the-world-factbook/index.html>]
- IMF database (used as source of data for GDP per capita). [<http://www.imf.org/external/data.htm>]

## Methodology

Using the remotely sensed data and economic statistics listed above, KAC estimated exposure units and valuations by type in each grid cell in the analysis area (Figure 3.7).

Exposure	Geographic Distribution Source	Valuation Derivation
Residential	Population distribution	Number of dwelling units calculated based on population, age distribution, population density and Purchasing Power Parity GDP per capita (GDPPC-PPP). Land cover types and population information used to determine residential construction types. Asset category selection informed by population density and GDPPC. The household size is informed by both the population density and GDPPC.
Non-residential: includes commercial, industrial, government/institutional and agriculture (crops)	Satellite imagery	Asset categories determined both as mixed development within larger residential areas and as concentrated types (for instance, areas with dense development but low population density). Agriculture component estimated from MODIS land cover and agriculture contribution to GDP.
Infrastructure	Satellite imagery	Estimated from density and distribution of population and building types, and per-capita GDP.

*Figure 3.7: Sources of valuation.*

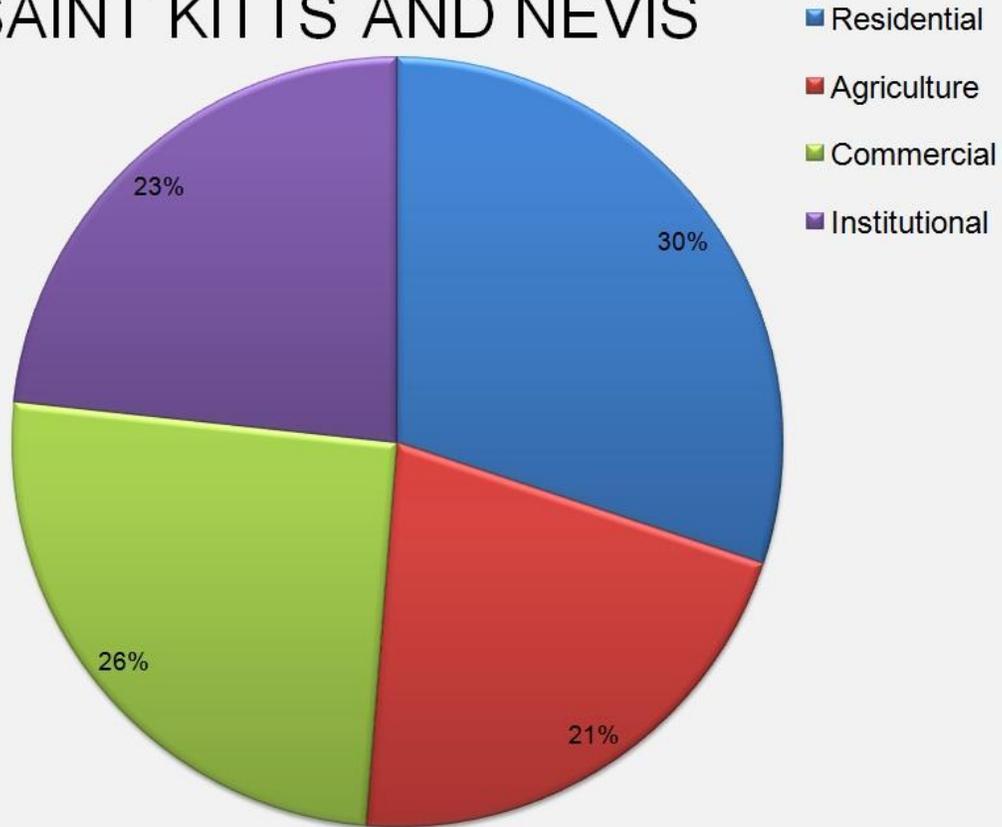
In the resulting exposure databases, infrastructure is not defined as a separate exposure type, rather it is incorporated into the residential, commercial / institutional and agriculture exposure values. The exposure generation assigns a higher quality to residential and commercial construction in areas where infrastructure is identified as present.

The key exposure values used in the loss modelling for St. Kitts and Nevis are summarised in Figure 3.8, and the breakdown of GDP exposure is shown in Figure 3.9. The economic composition data is from the CIA World Factbook, which provides a consistent and independent region-wide database.

Population	GDPPC	Economic Composition (%)		
		Agriculture	Industrial	Services
49,898	US\$16,400	1.5%	16.4%	82.1%
Landscan 2011	IMF Database	CIA World Factbook	CIA World Factbook	CIA World Factbook

*Figure 3.8: Economic and population statistics.*

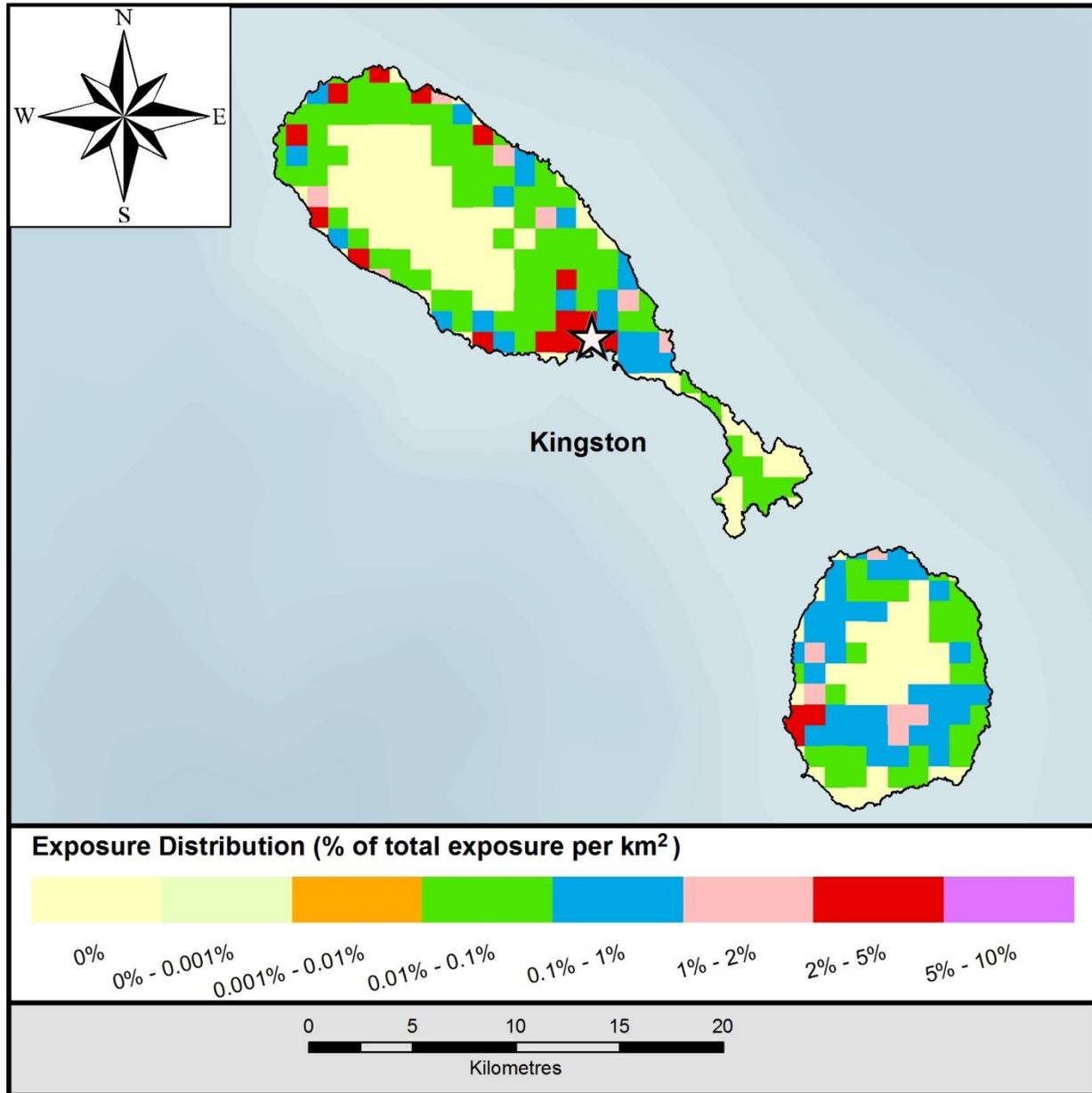
# SAINT KITTS AND NEVIS



*Figure 3.9: Breakdown of GDP by exposure type in St. Kitts and Nevis.*

In generating the exposure database, KAC assumes that GDP is relatively consistent across a territory (adjusted for population density).

Figure 3.10 provides a map showing the distribution of exposure for St. Kitts and Nevis.



*Figure 3.10: Exposure map of St. Kitts and Nevis as used in CCRIF MPRES model.*

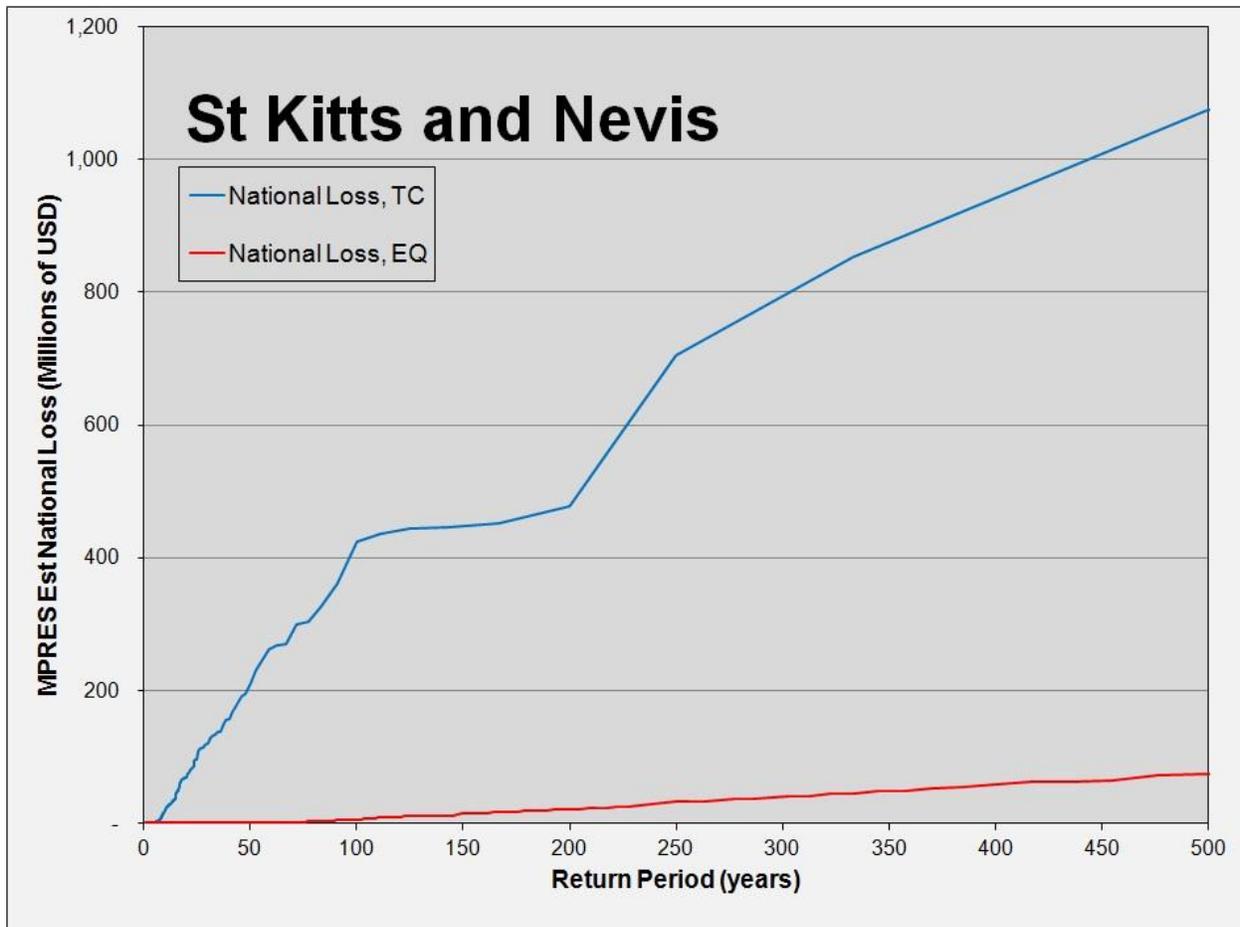
### 3.4 Country Risk Profile

The risk profile for a country presents losses for the country at different probabilities of occurrence (more precisely referred to as probabilities of exceedance). It acts as the basis for pricing of the risk transfer product (i.e. CCRIF's insurance policy) and represents the established way of quantifying risk. As described earlier, a synthetic catalogue of hazard events, generated in the modelling process, and having the same statistical characteristics as the historical record of events, is used to estimate national losses (the total amount of loss sustained in the country before consideration for how much is actually lost by the government, and before any policy terms such as deductibles are applied), and for a range of levels of probabilities of occurrence.

Saint Kitts and Nevis is located within the main Atlantic hurricane belt and both islands are susceptible to severe hurricane hazards, as highlighted by a series of storms in the late 1990s. Earthquake hazards are also high, with a seismically active area of the Caribbean plate boundary located to the east of the islands. Landslide hazards are moderate. Inland flooding occurs in low-lying areas during heavy rain. Both islands have potentially active volcanoes; Nevis Peak dominates Nevis and the entire island is within the main hazard zone. Mt Liamuiga, on Saint Kitts, does not directly threaten Basseterre (the country's capital).

Figure 3.11 provides Tropical Cyclone (excluding rain) and Earthquake national risk profiles (in the form of loss exceedance curves) for Saint Kitts and Nevis. Government losses (defined in the glossary) are determined as a percentage of the national losses, where the percentage applied varies by country.

Figure 3.12 tabulates the key statistics drawn from the loss exceedance curve. The average annualised loss (AAL) represents the loss that is expected each year when averaged over the full synthetic catalogue period. Actual losses in any one year will vary widely from the AAL – many years will have no losses, a few years will have very large losses; the standard deviation of the AAL is the standard metric used to describe this volatility in annual losses. The AAL and the standard deviation are the two metrics used as the basis of pricing of policies (once policy conditions are applied). The losses at given return periods are a numerical description of the shape of the risk profile and represent the amount of loss expected at each return period.



*Figure 3.11: Tropical Cyclone and Earthquake loss curves for St. Kitts and Nevis.*

Return Period (yrs)	TC National Loss (USD)	EQ National Loss (USD)
20	68,466,085	-
50	210,071,000	161,403
100	424,022,000	5,145,760
250	704,950,000	32,341,200
500	1,075,440,000	72,927,700
750	1,081,610,000	115,609,000
1,000	1,081,610,000	145,328,000
AAL	15,154,053	707,317
SD of AAL	76,561,870	16,783,743

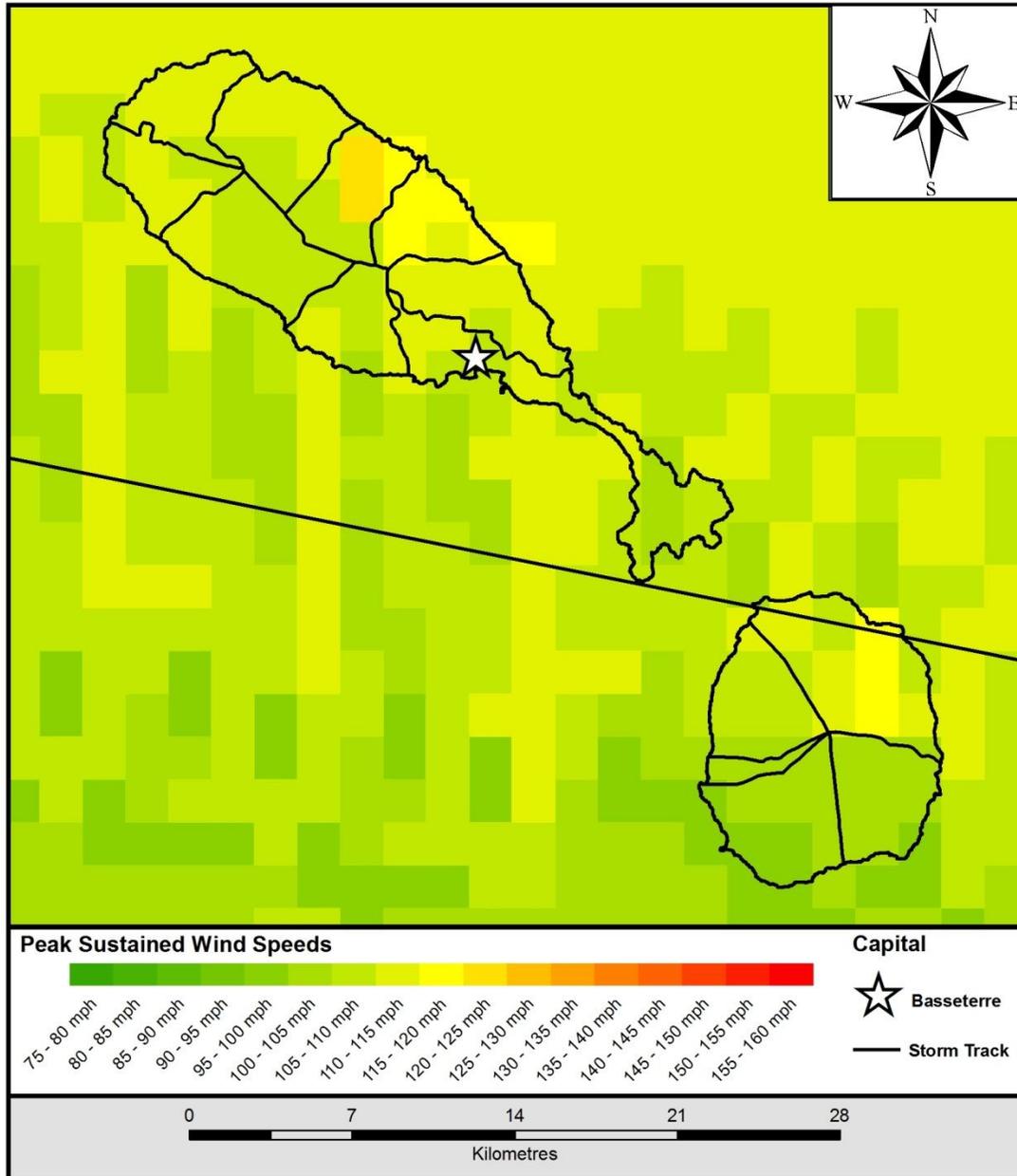
*Figure 3.12: Summary of Tropical Cyclone and Earthquake losses for St. Kitts and Nevis.*

## Significant Historical Events

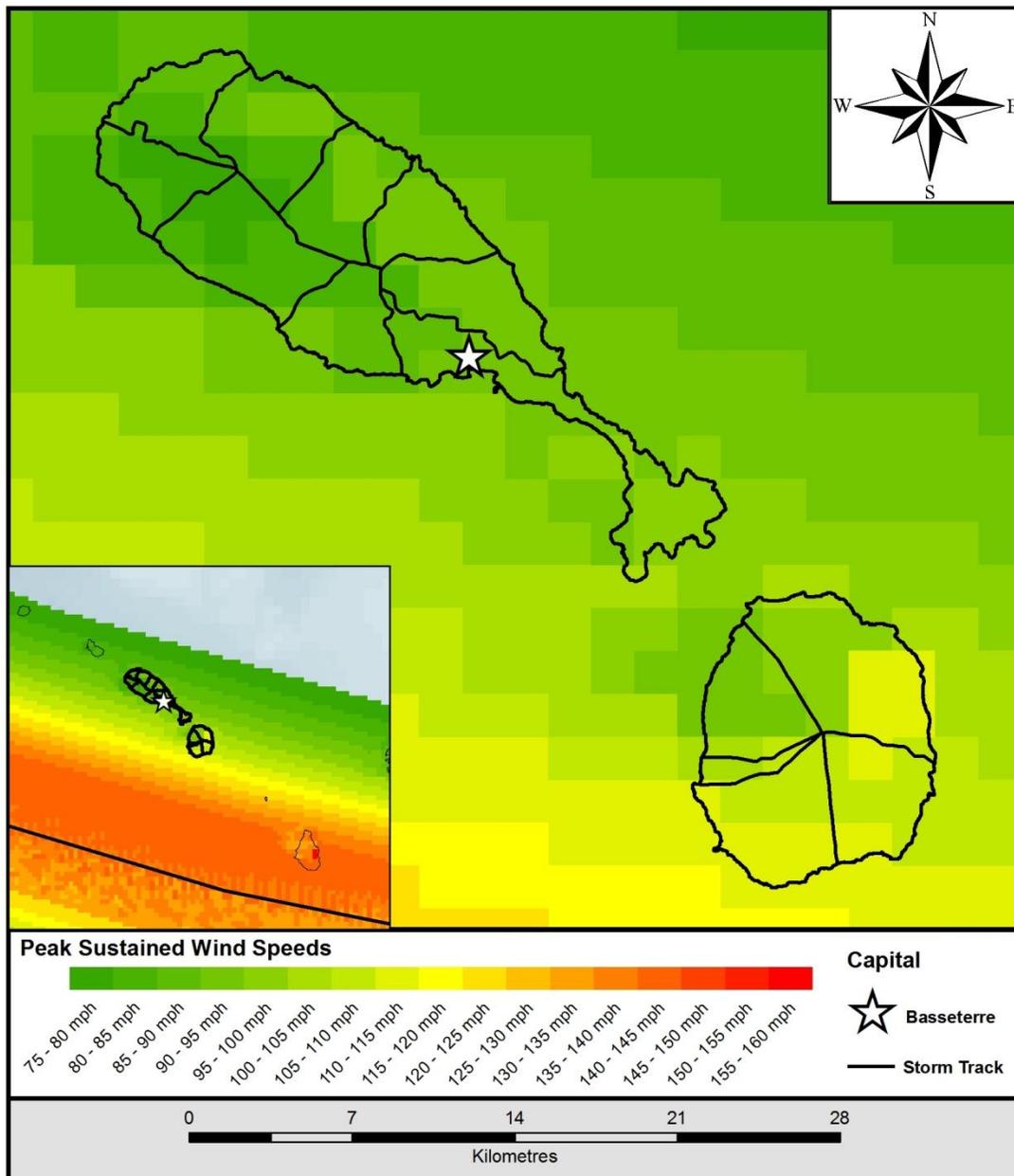
Figure 3.13 shows the three most significant recorded tropical cyclones and earthquake events to affect Saint Kitts and Nevis. The most significant cyclone event was Hurricane Georges in 1998. Footprint maps for hurricanes Georges and Hugo are shown in Figures 3.14 and 3.15 respectively. The most significant earthquake events occurred in 1843 and 1974, and their footprint maps are shown in Figures 3.16 to 3.17. The MPRES model updates may have resulted in some differences in estimated losses (for instance, wind fields for tropical cyclones have changed, and so have exposure compositions) for events, and therefore a slight re-ordering of the most significant events from previous risk profiles.

	Hurricane Event	Loss (USD)	Earthquake Event	Loss (USD)
Most severe	1998(Georges)	216,345,456	1843	122,415,664
Second-most severe	1989(Hugo)	84,776,248	1974	48,194,093
Third-most severe	1899	82,410,848	1690	39,204,268

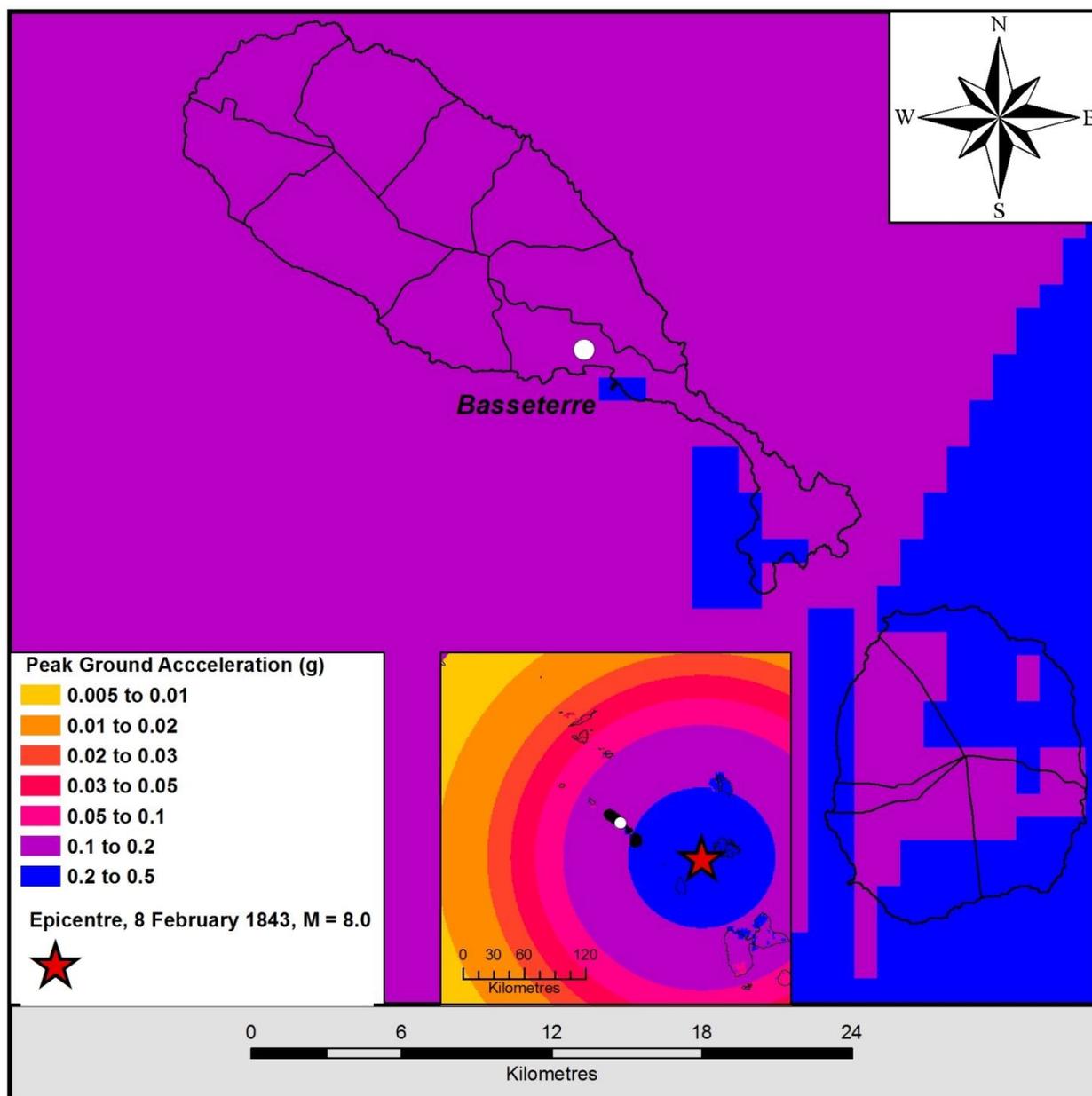
*Figure 3.13: Most significant historical hazard events affecting Saint Kitts and Nevis.*



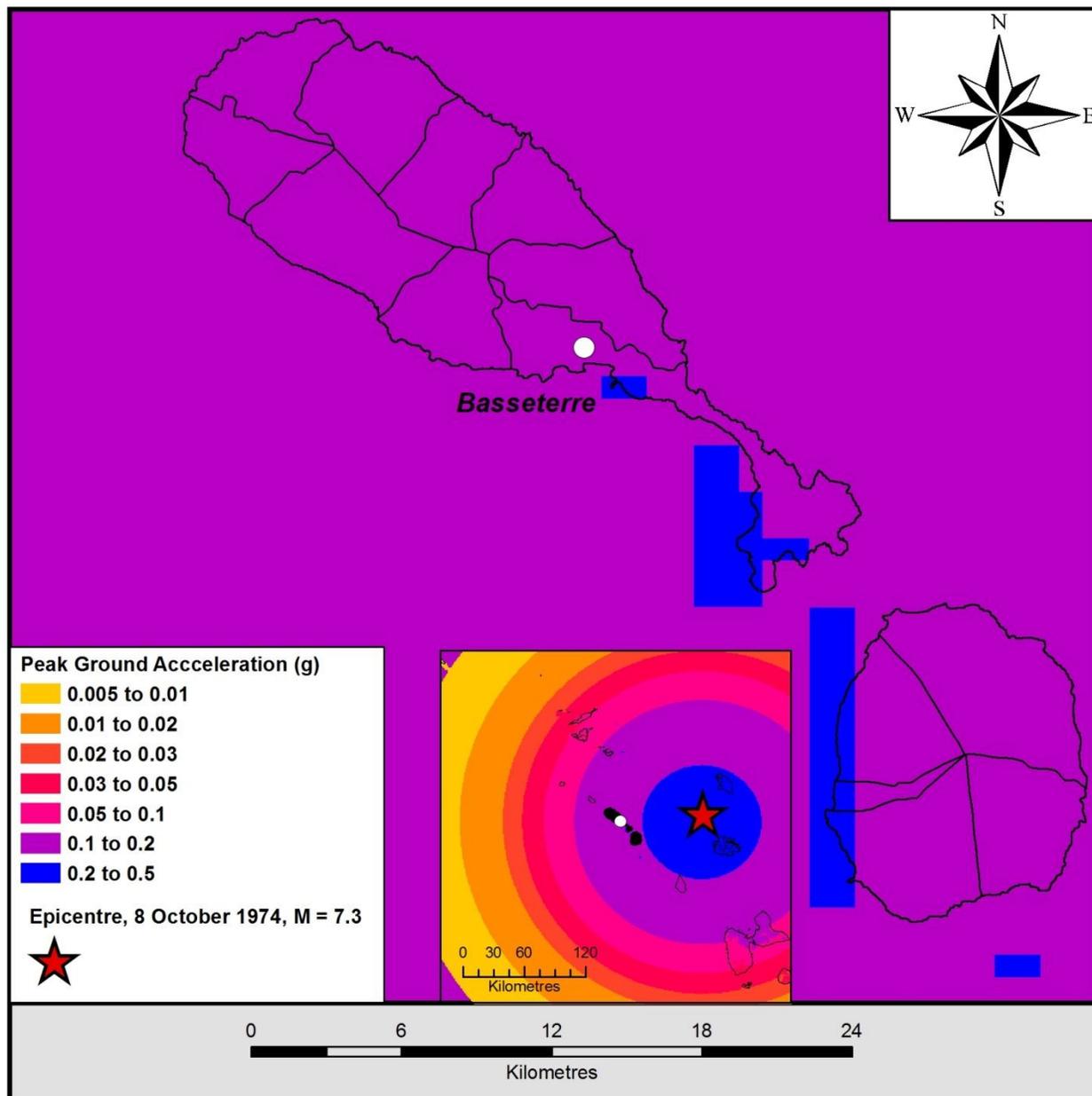
*Figure 3.14: Peak sustained winds associated with Hurricane Georges in 1998.*



*Figure 3.15: Peak sustained winds associated with Hurricane Hugo in 1989.*



*Figure 3.16: Peak Ground Acceleration associated with the 1843 earthquake.*



*Figure 3.17: Peak Ground Acceleration associated with the 1974 earthquake.*

# ANNEXES

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# ANNEX 2: SAFFIR-SIMPSON SCALE

Category/Wind Speeds (mph)	Damage Level	Description
5 (>155 mph)	<b>Catastrophic</b>	Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Massive evacuation of residential areas on low ground within 5 to 10 miles of shore possibly required.
4 (131-155mph)	<b>Extreme</b>	Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows and doors. Complete failures of roofs on many small residences. Complete destruction of mobile homes. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches. Massive evacuation of all residences within 500 yards of shore possibly required, and of single-story residences within 2 miles of shore.
3 (111-130mph)	<b>Extensive</b>	Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some wind and door damage. Some structural damage to small buildings. Mobile homes destroyed. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline possibly required.
2 (96-110mph)	<b>Moderate</b>	Considerable damage to shrubbery and tree foliage; some trees blown down. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings. Coast roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying areas required.
1 (74-95mph)	<b>Minimal</b>	Damage primarily to shrubbery, trees, foliage, and unanchored homes. No real damage to other structures. Some damage to poorly constructed signs. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.

# ANNEX 3:

## EARTHQUAKE MAGNITUDE AND INTENSITY CLASSIFICATION

The following table provides the approximate conversion from Richter Magnitude to Modified Mercalli Intensity (MMI) and the MMI scale itself.

Richter Magnitude Scale	Typical peak Modified Mercalli Intensity
1.0 to 3.0	I
3.0 to 3.9	II to III
4.0 to 4.9	IV to V
5.0 to 5.9	VI to VII
6.0 to 6.9	VII to IX
7.0 and Higher	VIII or Higher

### Modified Mercalli Intensity Scale

I	Not felt except by a very few under especially favourable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognise it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors, disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

# ANNEX 4: CHANGES TO MPRES PLATFORM IN 2013

The following changes were made in 2013:

## VULNERABILITY MODULE UPDATES

### *Updates To Exposures:*

- New countries/territories included in analysis: former Dutch territories, French Departments, Puerto Rico, and Dominican Republic.
- Economic and population data updated with currently available data from Landscan, IMF, and other sources.
- Exposure generation and damage estimation algorithms updated to:
  - 1) separate estimation of physical damages from broader economic impacts,
  - 2) refine handling of agricultural exposures, and
  - 3) refine valuations of rural versus urban exposures.
- Services class of exposure is now merged into broader commercial class.

## HAZARD MODULE UPDATES

### *Tropical Cyclones*

- History: storm track set extended to 2012
- Modeling: more robust storm geometry calculations, particularly for missing wind parameter estimation

Synthetic event set: generated 1,000-year synthetic track set, for use as a basis for synthetic hazard and loss modeling (compared with generation of synthetic loss set, not full track set, for 2011 update). The following steps are applied to derive the wind profile curves for a given catalog:

- For each wind profile location / point
  - For each year in the catalog (history or synthetic), review the maximum wind hazard level recorded (in the modeling) for that location in each event during that year, to identify the maximum wind value experienced there during the year. Repeat for all years in the catalog.
  - Wind profile curves are generated from the resulting list of annual wind hazard maxima (sorted by wind value):
    - the *probability* of any given value in the list is  $(\text{rank}/(\text{num\_years}+1.0))$ , where 'rank' is its order in the list (counting from the lowest value) and 'num\_years' is the number of years in the catalog. For example, for a 150-year catalog, if the 3rd highest value (148th from

the bottom) in the list is 62 m/s, the probability of experiencing a maximum wind speed of 62 m/s in a given year is  $(148/(150+1)) \sim 0.98$ .

- the *return period* can be calculated from the probability:  $rpd = 1 / (1 - prob)$  -- in this case  $1 / (1 - 0.98) = 50$  yr return period.

### *Earthquakes*

- Modeling code: Added 'next generation' attenuation functions to modeling platform for use by CCRIF
- Synthetic catalog: generated a 10,000-year synthetic catalog. 2011: 5,000-year catalog.
- Analysis: Selected attenuation functions for modeling event based on event location and depth [selection scheme and attenuation function selections determined by CCRIF]. All events simulated using two attenuation functions, and loss estimates are generated from the merged (averaged) hazard results from the two simulations. 2011: all events simulated using a single, composite attenuation function.

## **VULNERABILITY MODULE UPDATES**

While much of the attention has focused on the value of the exposures between these updates, it is critical to remember that the exposures and the damage modeling are deeply interconnected. Whereas the original system was geared to provide a single estimate of overall impacts, changes were made to both the exposure generation system and outputs (as outlined above) so as to enable separate assessments of physical impacts from purely economic impacts. These changes include:

- Damage probability -- damage replacement values [more precise term in this place than 'loss'] (both in 2011 and 2013) are calculated based on 1) the value of the asset or exposure and 2) from the damage modeling: a) the percent damage to the exposure and b) the probability of damage. The damage probability is based on results from an ensemble of damage functions (run for each asset), and is much more sophisticated today than it was in 2011, resulting in finer-detailed differentiations in damage probabilities across the landscape. Since the probability of damage rises with higher wind speeds, damage probabilities vary much more in lower wind-speed areas on the edges of the event.
- Physical damage focus -- With the updated damage modeling, we are separately calculating the physical damages and secondary impacts (e.g. evacuation expenses) from the event. In the 2011 analysis, the damage analysis included a component of secondary impacts. In 2013, the damage estimates produced for CCRIF focus on the replacement cost of the physical damages from the event -- the separately calculated secondary / economic impacts are not included in these numbers. The differences between these two approaches are again particularly evident in areas at the edges of the event, where there are fewer physical damages, but where some secondary impacts would have been included in the 2011 results.

# ANNEX 5: GEO NODE

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The aftermath of the devastating earthquake event which struck Haiti on 12 January, 2010 was characterised by the presence of numerous disaster agencies at the various affected sites all seeking to assess, collect and map data related to the damage of infrastructure, loss of lives and the event's overall impact on Haiti's economic sectors. In a retrospective analysis of the damage assessment efforts from the various disaster entities, the World Bank concluded that greater value could have been derived through a more coordinated and collaborative approach by the combined agencies. It was determined that to best achieve this ideal, a platform specifically designed to enable geospatial data management and sharing within a collaborative context would be required. This led to the development of what is now known as GeoNode.

GeoNode is essentially an amalgamation of several open source platforms such as GeoServer ([www.geoserver.org](http://www.geoserver.org)), Pycsw ([www.pyctsw.org](http://www.pyctsw.org)), Django ([www.djangoproject.com](http://www.djangoproject.com)) and GeoExt ([www.geoext.org](http://www.geoext.org)). These platforms are all united through a single web interface that enables users to upload and style geospatial data; create, publish and print maps and grant registered users the ability to access/download geographic content in several formats. GeoNode is considered a very effective risk management platform because of the ease with which users not trained in traditional GIS technologies may quickly compile data/maps to better understand and manage their risk. More importantly, GeoNode's community oriented approach whereby users are encouraged to access datasets, improve upon them and resubmit them to the GeoNode community is most critical. This culture of data sharing, fostered in part by GeoNode, creates opportunities for CCRIF to acquire data that maybe then be used to enhance the value of work done on behalf of member territories such as hazard analyses, loss and event reporting and risk modeling.

CCRIF intends to use GeoNode as an alternative medium for publishing the static geospatial risk profile maps, contained within this publication, as well as any other relevant data or maps pertaining to the hazard profile. The CCRIF GeoNode is in its final development stages and is scheduled to launch in 2013, with access provided via <http://GeoNode.ccrif.org>. Visit [www.GeoNode.org](http://www.GeoNode.org) for more details on GeoNode.

# ANNEX 6:

## GLOSSARY

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Administrative area:	District or parish of a country.
Average Annualized Loss(AAL):	Average or expected loss of an insurance policy.
Catastrophe model:	Computer-based model that estimates losses from natural or man-made disasters.
Damage function:	Equation describing expected loss in terms of intensity of the disaster event.
Exceedance probability:	Probability that a certain risk level will be surpassed during a future time period.
Exposure:	Assets at risk from a hazard.
GDP :	Market value of all final goods and services produced in a country in a given time period.
GDP (PPP):	A measure of GDP where all value of goods and services are valued at prices prevailing in the United States.
GDPPC (PPP)	Gross Domestic Product (Purchasing Power Parity) per capita.
Government losses:	The short term (one to three months) shortfall in a government's current account directly caused by the impact of a disaster, and represents such items as loss in revenue from tourism and other exports, clean-up and relief expenditures, and emergency repairs to public infrastructure and housing. It is determined as a percentage of national ground-up losses.
Mean Loss Ratio (MLR):	Average of incurred losses to premiums expressed as a percentage.
Modified Mercalli Intensity:	Seismic scale used to measure intensity of an earthquake.
MODIS:	Moderate Resolution Imaging Spectroradiometer is an instrument launched into earth orbit by NASA, which captures changes in cloud cover, radiation budget, processes occurring in the oceans, on land, and in the lower atmosphere.
Peak Ground Acceleration:	The maximum absolute magnitude of ground acceleration during an earthquake.
Return Period:	Expected time between loss events of a certain magnitude.
Synthetic Events:	Set of simulated years (in this case 1,000 years) of natural disaster activities that is run through the model and used to create exceedance probability curves.
Vulnerability:	Defines the susceptibility of an asset to a particular natural or man-made disaster.
Weibull distribution:	One of several continuous probability distributions.

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