CCRIF SPC
The Caribbean Catastrophe Risk Insurance Facility

The CCRIF Earthquake Model

SPHERA: System for Probabilistic Hazard Evaluation and Risk Assessment

Caribbean and Central American countries face a number of primary natural hazard risks, particularly earthquake and hurricane risks.

CCRIF SPC offers parametric insurance products that provide coverage for tropical cyclones, earthquakes and excess rainfall. These products were designed to limit the financial impact of catastrophic tropical cyclones, earthquakes and extreme rainfall events on Caribbean and Central American governments by quickly providing short-term liquidity when a policy is triggered.

Since the introduction of these products, CCRIF has made 38 payouts totaling US$138.8 million, of which US$9.2 million were for earthquake events, to 13 member countries.

During the 2016/17 policy year, CCRIF began the development of new tropical cyclone (TC) and earthquake (EQ) loss assessment models that are collectively called SPHERA (System for Probabilistic Hazard Evaluation and Risk Assessment). SPHERA will replace the current model used by CCRIF – the Multi-hazard Parallel Risk Evaluation System (MPRES). MPRES currently underpins the TC and EQ insurance products purchased by Caribbean and Central American countries.

The new SPHERA loss assessment models employ the most up-to-date datasets and techniques. The new SPHERA EQ model is able to:

- Produce a probabilistic assessment of earthquake risk, measured in terms of likelihood of EQ-induced losses, to be used for parametric insurance policy pricing.
- Estimate in near real time the modelled losses to buildings and infrastructure due to earthquake ground motion a caused by events in the region.
- Compute the payout to the insured countries due to the occurrence of an earthquake according to the event parameters defined by the United States Geological Survey (USGS).

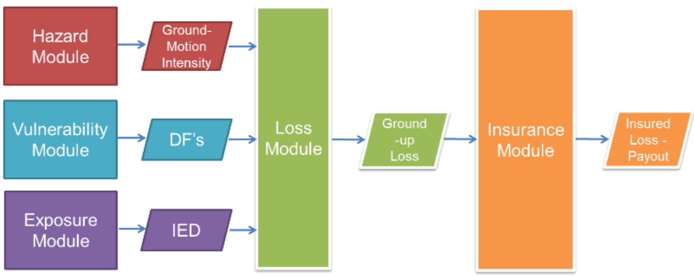
The EQ hazard module has been designed to statistically estimate the impact caused by future earthquakes through a probabilistic seismic hazard analysis (PSHA) approach that combines the frequency of occurrence of future earthquakes with different magnitudes, in time and space and the evaluation of the ground motion random fields generated by each event.

Components of the EQ SPHERA model

The EQ Model is made up of the following modules:

- Exposure module, which describes the built environment in each country together with the replacement cost of each exposed asset.
- Hazard module, which computes in near real time the ground motion intensities induced by the occurrence of an earthquake and estimates the long-term earthquake hazard through a probabilistic seismic hazard analysis.
- Vulnerability module, which defines the probability distribution of economic loss for different levels of ground motion intensity induced by an earthquake.
- Loss module, which – based on the ground motion intensity, exposure data, and vulnerability functions – computes an estimate of the ground-up losses.
- Insurance module, which – based on the policy conditions, specifically the attachment point, exhaustion point and ceding percentage – determines if a country's policy is triggered and if so, computes the payout to the country.

The conceptual flow of the EQ SPHERA Model is shown in the figure below.



The HAZARD module: How frequent are earthquake events?

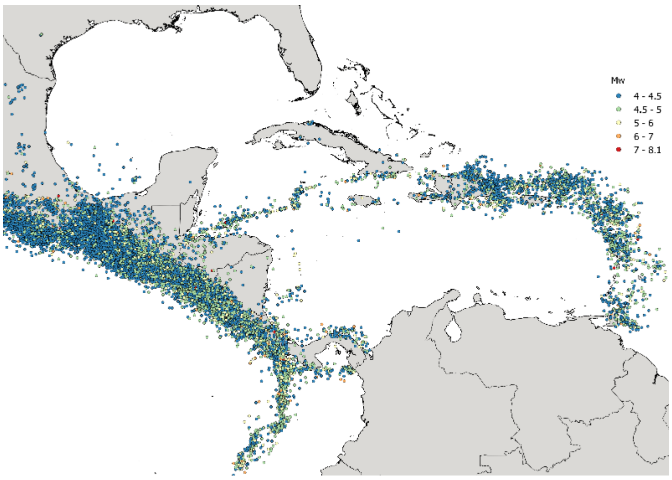
The hazard module works in both a forecasting mode and in a hindcasting mode. It is able to:

- Statistically estimate the impact of future earthquakes through probabilistic seismic hazard analysis (PSHA), evaluating the exceedance rates of ground motion intensities (typically designated by peak ground acceleration or by spectral acceleration) on a defined grid of points.
- Compute in near real time the ground motion intensities induced by the occurrence of an earthquake according to the parameters (such as magnitude, depth and moment tensor solution) provided by reputable scientific agencies such as the USGS.

To accomplish the above requirements an updated earthquake catalogue was compiled to properly characterize the seismic sources in the Central American and Caribbean regions and the most up-to-date and adequate ground motion attenuation models were chosen and combined to compute the ground motion intensities.

Historical catalogue

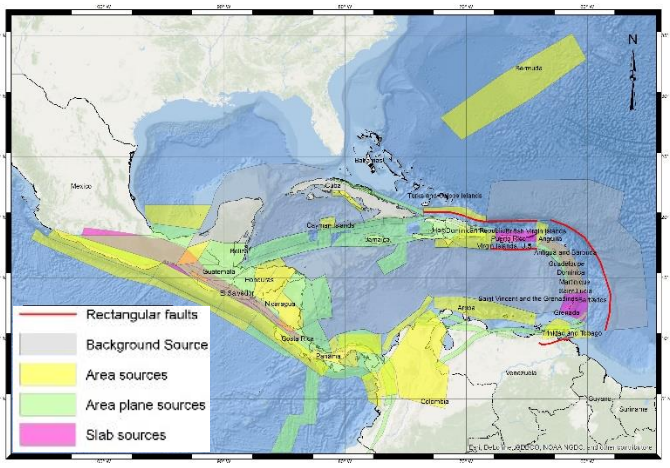
An updated historical earthquake catalogue was compiled to statistically estimate the frequency of occurrence of future seismic events of different magnitudes and their characteristics (e.g. faulting mechanism). The catalogue was built by collecting historical and instrumental information for the events that originated in the Central American and Caribbean region since 1520.



Geographic distribution of earthquakes that occurred in Central America and the Caribbean since 1520

Characterization of seismic sources

Once the historical earthquake catalogue was compiled the next step was to identify and characterize the earthquake sources capable of producing significant ground motion intensities in the Central American and Caribbean regions. The characterization of the sources included definition of the source geometry and seismicity model to evaluate the magnitudes and associated recurrence frequencies of the earthquakes that can be generated by each seismic source. According to the characteristics of each source, different geometric models were used to account for particularities. Occurrence frequencies were obtained after analyzing the historical catalogue and determining the maximum magnitude expected at each source.



Seismic sources and assigned geometrical model

Ground motion estimation

Once the geometry and seismicity parameters of the sources were defined, the next step was to select the most appropriate ground motion attenuation models (GMPEs) to compute the intensities at ground level. These models predict the probability distribution of ground motion intensity as a function of many variables such as magnitude, distance (source-site), faulting mechanism, near-surface conditions, etc. The selection of the GMPEs was based on previous studies specific for the Central American and Caribbean regions or for regions with similar seismo-tectonic environments.

The attenuation model was selected to be able to estimate not only peak ground acceleration (PGA) but also ground motion intensities for other spectral ordinates, mainly for those vibration periods representative for the typologies for buildings and infrastructure included in the exposure database, which are recognized to be good predictors of structural and non-structural damage.

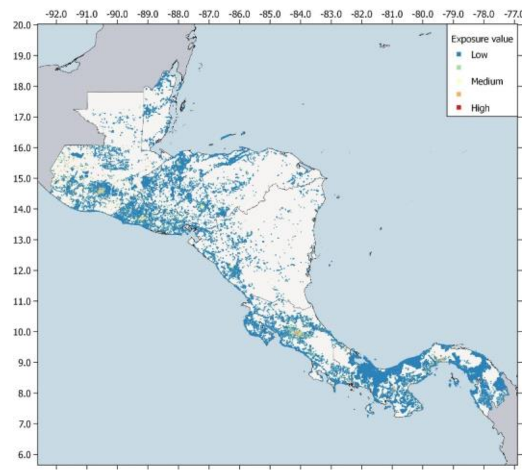
In addition to the GMPEs, an amplification factor based on the Vs30 parameter was used to obtain the intensities at surface level.

Generation of the stochastic event set

To perform the country-specific earthquake loss assessment, a stochastic catalogue of simulated events, compatible with the distributions of location, depth, and magnitude identified in the characterization of the seismic sources was generated. The stochastic catalogue comprises a set of possible future seismic events generated through a sampling in which the uncertainty in location and ground motion intensities for each event have been taken into account. For each seismic source, a series of scenarios with different magnitudes compatible with the source-specific magnitude recurrence model was generated. The other characteristics of the stochastic events such as the rupture geometry and mechanism were simulated from the probabilistic distributions of the different parameters identified for the different seismic sources.

The EXPOSURE module: Which assets are at risk and what are their values?

The exposure database is a comprehensive and spatially-distributed list of vulnerable assets. Several attributes are associated with each asset, such as its characteristics (e.g. construction type and material and height classification), geographic location, use and replacement cost. The exposure dataset has been enhanced by collating several sources of data up to 2017 related to the built environment and to the surrounding topography, including the most recent available local data such as national building and population census surveys and land use/land cover maps, night-time lights maps, digital elevation maps and satellite imagery. The database has a resolution of approximately 1x1 km for inland areas and approximately 250x250 m to 120x120 m for coastal areas.



Methodology and datasets used

The SPHERA exposure module includes information about:

- Building stock:
    - Residential buildings
    - Commercial buildings
    - Industrial facilities
    - Public Buildings
    - Hotels and restaurants
    - Healthcare infrastructure
    - Education infrastructure
- Infrastructure:
    - Energy facilities
    - Airports and ports
    - Transportation (road) network

The process by which the building stock and infrastructure exposure database was developed involves a number of steps, many of which leverage GIS tools and datasets. First, construction types are identified in each country. Next, a building count is estimated and economic values are assigned by country. The economic value, defined as "replacement cost", which means the cost of returning the building to the conditions existing before the occurrence of an event, is usually not directly available and thus it is estimated through the use of proxies such as data from technical studies and post event reports. For example reports compiled by local or sub-regional institutions about costs of construction were used to estimate the unit replacement costs for residential assets. Lastly, the geographic distribution of exposure is estimated using independent data sources such as population and urban density mapping derived from satellite imagery. This process results in a gridded representation of the exposure distributed across each participating country.

Night-time lights

A common dataset to distribute buildings within a given region is the night-time lights layer (i.e., data regarding the light intensity during the night on a 30 arc second resolution grid). This dataset is particularly useful to spatially distribute the commercial and industrial building stock, as there is a strong correlation between electrification and industrialization.

Land use

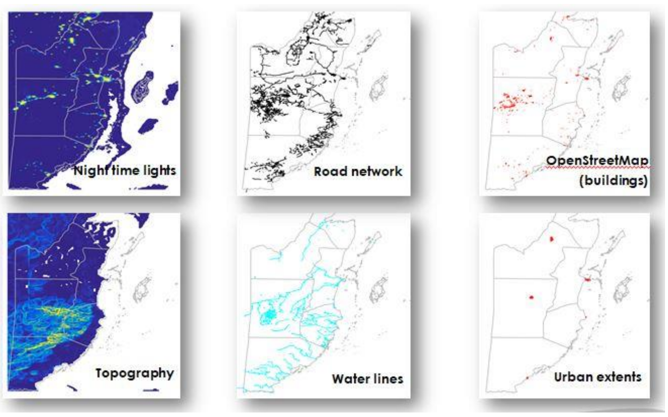
These datasets usually includes categories such as residential, industrial, commercial, farmland (agriculture), infrastructure and government/public facilities. Land use datasets are usually produced at a local level for urban planning purposes, at a regional level by local governments, or at a national level by open-access initiatives such as OpenStreetMap.

Digital Elevation Model (DEM)

The elevation is used to assess whether an asset is close to sea level (and thus potentially subject to storm surge) or far from it. The slope is used as a proxy for human activity, as urban settlements tend to exist in flat areas (e.g. valleys) as opposed to regions with steep slopes.

Roads

Datasets at the national level containing the transportation network for each country were collected. These datasets contain the spatial distribution of railways and roads, with the latter component usually sub-divided into primary, secondary and tertiary roads. With the exception of the first type of roads (which are usually used to connect large urban centers) there is a strong correlation between the density of these roads and the presence of buildings. Several sources for this type of information can be found, from private companies (usually responsible for updating GPS maps) to publicly open initiatives such as Bing, Google, Digital Chart of the World, and OpenStreetMap.

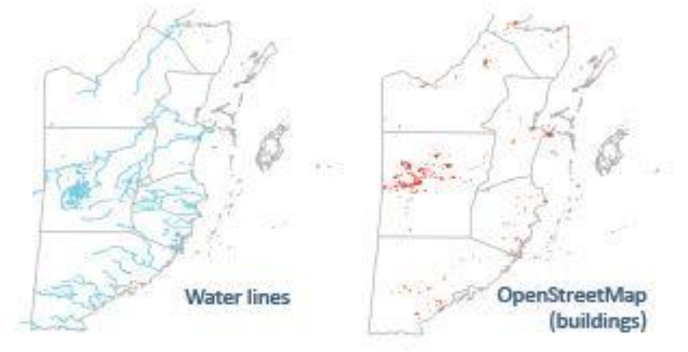


Satellite imagery

Remotely sensed data play a fundamental role in urban density mapping. The images used in the SPHERA model have been acquired by the optical 'Landsat-8' satellite.

These are composed of: 8 multispectral bands at 30m spatial resolution, 1 panchromatic band at 15m spatial resolution, and 2 further thermal bands at 100m spatial resolution (resampled at 30 m).

The method used to map urban density can be divided into three phases. The first one consists of collection of cloud-free data for the entire region of interest. In the second phase, the remotely sensed data are used to conduct the urban density mapping procedure. In the third phase, manual refining is performed over the entire region of interest.



OpenStreetMap data

OpenStreetMap (OSM) is a collaborative project begun in 2004 at University College London, with the aim of creating a free geographic database of the entire world. Because many sources of geographic data are provided with licenses restricting their use, OSM's data are distributed under the "Creative Commons Attribute-Share Alike 2.0 license", which allows freedom of use by the public. OSM is probably the most popular and successful volunteered geographic information initiative, as supported by recent investigations on its completeness and quality. OSM goes beyond mapping only the street network, as it contains a plethora of spatial data such as roads, buildings, land use areas and points of interest, emphasizing the potential of its use in the development of exposure models globally.

Rivers and inland water

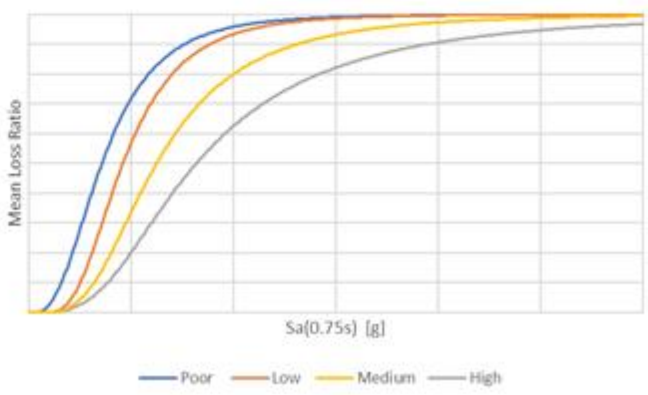
The procedure to spatially distribute the exposed assets also considers the areas where no buildings exist due to the presence of rivers or other inland water bodies (lakes, lagoons, etc.). This information is usually provided as part of country administrative boundaries, or through the Digital Chart of the World.

The VULNERABILITY module: What would happen to the built environment after the occurrence of an earthquake?

The earthquake vulnerability model of SPHERA comprises damage functions specific for the different typologies of assets in the exposure databases (e.g. buildings and infrastructure) for the countries covered by the model. For the development of the module, construction typologies, height, occupancy classes, building code requirements, construction practices and other parameters were evaluated.

The vulnerability model for buildings was developed using an analytical procedure that was designed to assess the structural behavior and fragility under seismic loading of the exposed assets. The use of an analytical methodology allows consideration of the differences among the several structural typologies and configurations that are common in the Caribbean and Central America. Moreover, it allows accounting for the differences among countries and overcoming the lack of reliable data and scientific studies about the seismic vulnerability of buildings in some of the countries covered by the model. Information about the building stock quality and structural characteristics were collected for each country to derive vulnerability functions specific for the Central America and Caribbean regions. Also, the damage functions obtained analytically were calibrated and validated comparing them with the results of vulnerability studies available for the region.

The vulnerability model for infrastructure was created from a database of fragility and vulnerability functions derived from the scientific literature. These functions were used to develop the vulnerability model, identifying the main characteristics of the infrastructure in the geographic area considered. An example of a damage function is shown in the figure below. These plots depict the expected loss associated to different hazard intensity measures for a given typology and the colors indicate the differences that can exist after considering different vulnerability levels.



Vulnerability curves related to reinforced concrete mid-rise infilled frames for different quality of building stock

The LOSS module: What are the losses caused by an EQ event?

The SPHERA loss module produces ex-ante estimates of possible future earthquake-induced losses in the countries covered by the model and also computes in near real time after an EQ event has occurred whether the ground motion intensity estimated by the hazard module could potentially cause significant losses to the exposure assets that are located within the footprint of the event. Based on ground motion field value, exposure values in the event footprint and vulnerability functions, the SPHERA model computes the expected ground-up loss experienced by each country affected by the event under analysis.

The INSURANCE module: Which parameters determine the payout of an EQ event?

The insurance module uses the modelled loss estimates to compute the payout to each country affected by an EQ loss event. The payout depends on the values of a set of parameters selected by each insured country and specified in the EQ insurance policy (see figure below):

The **Attachment Point** represents the loss that a country retains before any insurance payout begins and is equivalent to a "deductible" in a standard insurance policy.

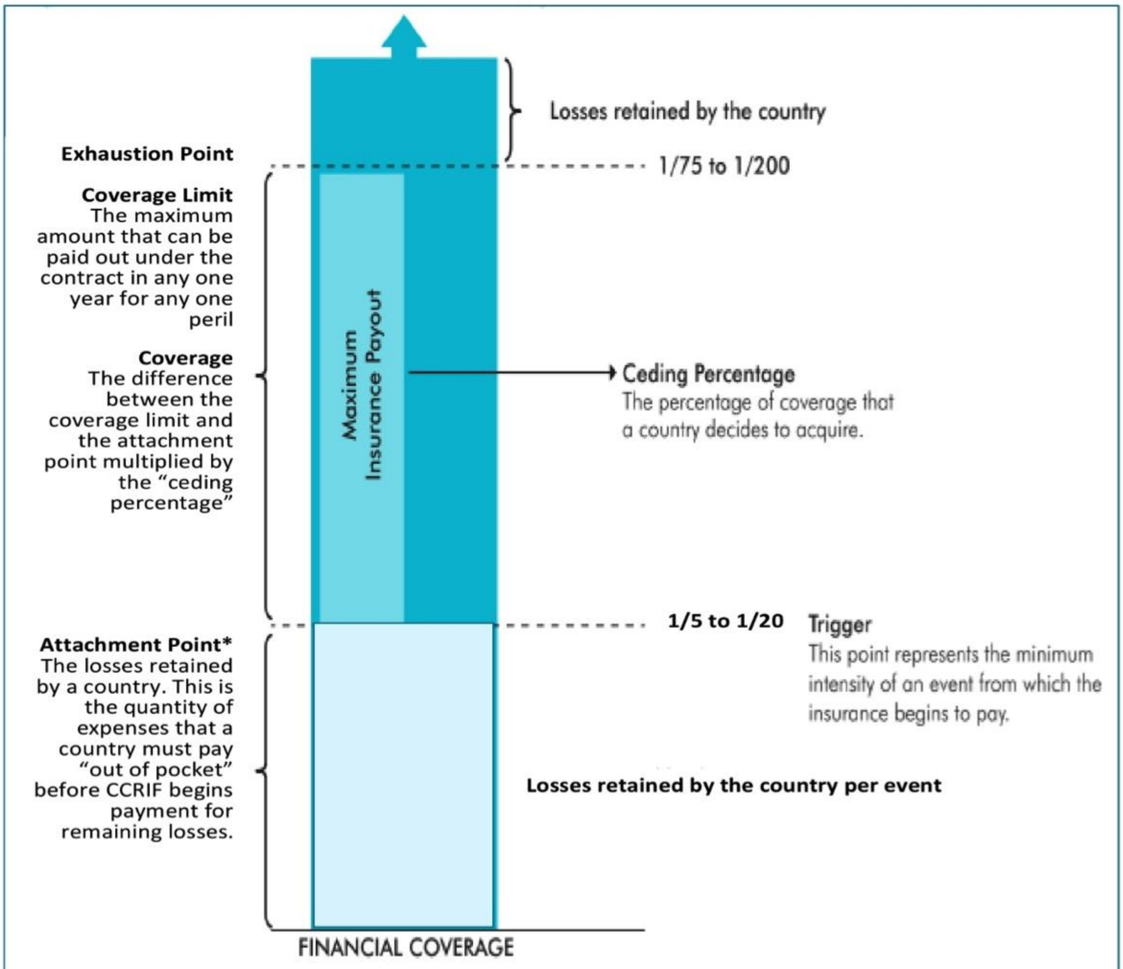
The **Exhaustion Point** is the loss value at which the full insurance payout is due.

The **Ceding Percentage** is the fraction of the difference between the exhaustion point and the attachment point that the insured country transfers to CCRIF.

The **Coverage Limit** is the maximum amount that can be paid out to an insured country in any one year of coverage.

A country's policy is triggered only when the modelled loss for the EQ event is equal to or exceeds the attachment point and therefore there is no payout for losses below this point.

The maximum payout that an insured country can receive after any EQ event is equal to the exhaustion point minus the attachment point times the ceding percentage. The values of these insurance policy parameters are crafted to provide the best possible coverage that meets the country's risk management needs within the desired premium budget. Once the attachment point and exhaustion point are chosen, there is a one-to-one relationship between the amount of premium paid and the ceding percentage – a higher ceding percentage means a higher premium. CCRIF insurance covers only the government losses, which are determined as a percentage of the national losses.



*The attachment point can be described as the minimum severity of the event loss which gives rise to a payment and therefore is the loss value at which the policy contract is triggered. The attachment point therefore functions like a deductible in a standard insurance policy.

Why are risk transfer tools becoming increasingly important?

Risk transfer mechanisms constitute an important part of disaster risk management (DRM) and climate resilience strategies. It is important for countries to engage in a range of strategies to reduce their vulnerabilities and to develop dynamic and first-class DRM policies and strategies. Risk transfer mechanisms should therefore be seen as one part of a country's broader and comprehensive DRM policy mix.

The use of risk transfer mechanisms constitutes pre-event planning and ensures that countries take a proactive, comprehensive and sustainable approach to DRM. These types of mechanisms are becoming increasingly important and an indispensable component of any economic policy and disaster risk management strategy, as countries seek to grow their economies, reduce poverty and become internationally competitive.

About CCRIF SPC

In 2007, the Caribbean Catastrophe Risk Insurance Facility was formed as the first multi-country risk pool in the world, and was the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. It was designed as a regional catastrophe fund for Caribbean governments to limit the financial impact of devastating hurricanes and earthquakes by quickly providing financial liquidity when a policy is triggered.

In 2014, the facility was restructured into a segregated portfolio company (SPC) to facilitate offering new products and expanding into geographic areas and is now named CCRIF SPC. The new structure, in which products are offered through a number of segregated portfolios, allows for total segregation of risk.

In 2015, CCRIF expanded to Central America, when CCRIF and COSEFIN (the Council of Ministers of Finance of Central America, Panama and the Dominican Republic) signed a Memorandum of Understanding to provide catastrophe insurance to Central American countries. Also, at that time, Nicaragua signed a Participation Agreement, becoming the first CCRIF member from Central America.

CCRIF currently offers earthquake, tropical cyclone and excess rainfall policies to Caribbean and Central American governments. Since the inception of CCRIF in 2007, the facility has made 38 payouts totalling approximately US$138.8 million to 13 member governments.

CCRIF was developed under the technical leadership of the World Bank and with a grant from the Government of Japan. It was capitalized 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, and membership fees paid by participating governments.

In 2014, another MDTF was established by the World Bank to support the development of CCRIF SPC's new products for current and potential members and facilitate the entry for Central American countries and additional Caribbean countries. The MDTF currently channels funds from various donors, including: Canada, through Global Affairs Canada; the United States, through the Department of the Treasury; the European Union, through the European Commission; Germany, through the Federal Ministry for Economic Cooperation and Development and KfW; and Ireland. In 2017, the Caribbean Development Bank, with resources provided by Mexico, approved a grant to CCRIF SPC to provide enhanced insurance coverage to the Bank's Borrowing Member Countries.

The current members of CCRIF are:
Caribbean – Anguilla, Antigua & Barbuda, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, Montserrat, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & the Grenadines, Sint Maarten, The Bahamas, Trinidad & Tobago and Turks & Caicos Islands
Central America – Nicaragua and Panama