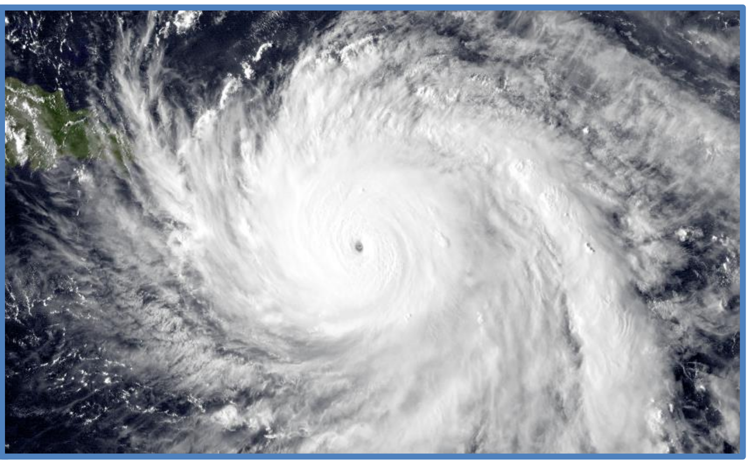
CCRIF SPC

The Caribbean Catastrophe Risk Insurance Facility

The CCRIF Tropical Cyclone Model



SPHERA: System for Probabilistic Hazard Evaluation and Risk Assessment

Caribbean and Central American countries face a number of natural risks which will almost certainly be exacerbated in the future by climate change. Among other impacts, climate change is expected to produce more intense hurricanes, and this is likely to cause increased damage to public and private assets such as infrastructure and buildings, accelerating the erosion of coastal beaches, flooding low-lying land and triggering the loss of protective mangroves.

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 totalling US$138.8 million, of which US$94.9 million were for tropical cyclone 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 called SPHERA (System for Probabilistic Hazard Evaluation and Risk Assessment). Starting in the 2019/20 policy year, 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 TC model is able to:

- Produce a probabilistic assessment of tropical cyclones risk, measured in terms of likelihood of TC-induced losses, to be used for parametric insurance policy pricing.
- Estimate in near real time the damages to buildings and infrastructure due to TC-induced wind and storm surge caused by events in the region.
- Compute the payout to the insured countries due to the occurrence of a tropical cyclone according to the event parameters defined by the United States National Oceanic and Atmospheric Administration (NOAA).

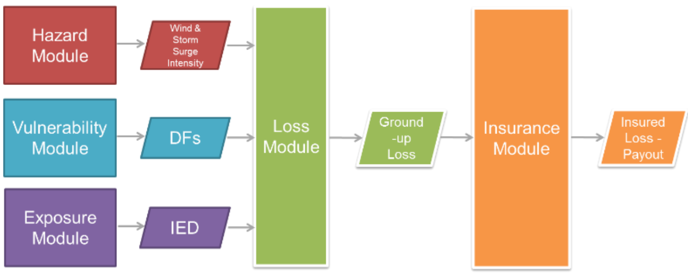
The hazard module was designed to provide a statistical representation of the economic impact of tropical cyclones, storms and depressions either by-passing or making landfall in any of the countries in the region. A probabilistic procedure was adopted to simulate potential storm tracks along with relevant storm parameters and for each simulated scenario to compute random fields of wind and storm surge intensities in the affected region.

Components of the Tropical Cyclone SPHERA model

The TC Model is composed 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 maximum wind speed and storm surge height induced by the occurrence of a tropical cyclone. The same hazard model is used to also estimate the long-term hazard through a probabilistic analysis.
- Vulnerability module, which defines the probability distribution of economic loss for different levels of wind speed and storm surge height induced by any tropical cyclone.
- Loss module, which estimates the ground-up losses based on the maximum wind speed and storm surge height, the exposure data and the vulnerability functions.
- Insurance module, which – based on the policy conditions, specifically the attachment point, exhaustion point and coverage limit – determines if a country's policy is triggered and if so, computes the payout to the country

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



The HAZARD module: How frequent are tropical cyclone events?

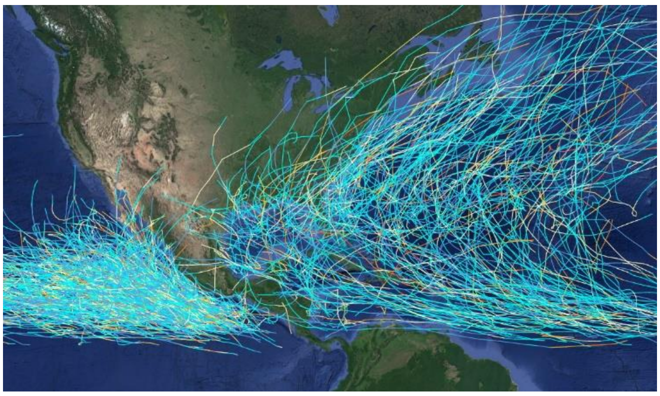
The hazard module can be used in two ways:

- Probabilistic mode: the aim is to estimate the impact of tropical cyclones, either by-passing or making landfall on any of the countries in the region. A probabilistic procedure was adopted to generate stochastic storm tracks along with relevant parameters and for each track to compute wind and storm surge fields.
- Hindcasting mode: the aim is to compute wind and storm surge intensities induced by the occurrence of a tropical cyclone in near real time, according to the parameters provided by NOAA.

To accomplish the above requirements an updated historical catalogue of tropical cyclones was compiled to statistically characterize the event frequency and the parameters of storm events in the Central American (both Atlantic and Pacific coasts) and Caribbean regions and the most up-to-date and adequate wind field and storm surge prediction models were selected to estimate their intensities.

Historical catalogue

An updated historical tropical cyclone catalogue was compiled to statistically estimate the frequency of occurrence of future events and their characteristics. The catalogue was built by collecting historical and instrumental information for the events that originated in the Central American (again both Atlantic and Pacific coasts) and Caribbean regions since 1850.



Track of tropical cyclones for the Caribbean Sea and Eastern North Pacific from 1998 to 2017, information from the HURDAT2 database

Characterization of tropical cyclone occurrence

This set of historical events was used to determine the annual frequency of occurrence of possible future storms in different regions of the Atlantic and Pacific basins.

Statistical models were used to characterize storm variables such as the minimum sea level pressure, the maximum wind speed and the radius of maximum wind.

Historical data were used to also determine the distributions of these variables.

Generation of the stochastic event set

To perform country-specific tropical cyclone loss assessments in the region, a stochastic catalogue of simulated events (events which did not occur but are statistically consistent with the historical events) was developed.

Records of cyclones in the region start in 1850. However, due to the nature of tropical cyclones, these records are not exhaustive enough to allow a comprehensive risk analysis which estimates the distribution of the losses caused by tropical cyclones to a given country, i.e. the assessment of the likelihood that losses will exceed a certain threshold. In these circumstances, the historical catalogue is limited, and it is necessary to extend it by simulating artificial (stochastic) events. The stochastic catalogue thus comprises a set of potential events in which the uncertainty in location and characteristics of the event have been taken into account. This catalogue is approximately equal to four thousand years of storm activity; this large number of events can help estimate more precisely and robustly the tropical cyclone risk in the region.

A set of stochastic events based on historical information for both the Atlantic and Pacific basins was generated. It consists of tens of thousands of tracks with defined parameters, such as intensity, size and shape, at regular intervals along the tracks of those cyclones.

Wind Field Estimation

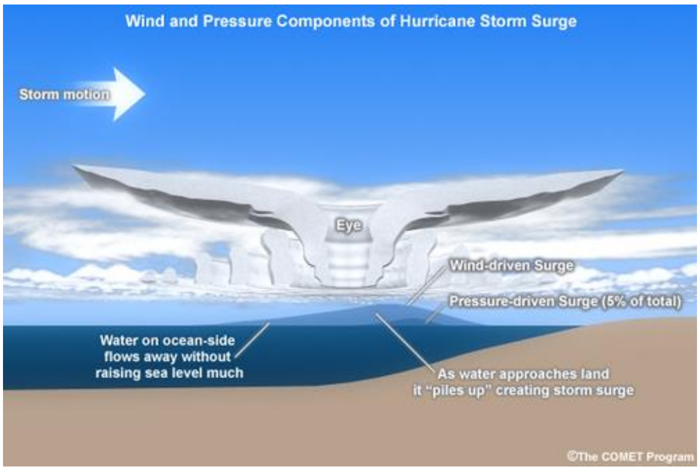
For each real or stochastic tropical cyclone, the model predicts a maximum wind field covering the whole region. This maximum wind field is then used to calculate losses, employing the vulnerability and exposure modules.

After a careful literature review of existing parametric tropical cyclone wind models, the model developed in 2002 by R. Silva and collaborators from the National Autonomous University of Mexico was selected as the most adequate for the region of study.

The model calculates the wind fields as a function of many variables such as radius of maximum winds, minimum sea level pressure, translational speed of the storm and geographic location. The effects of terrain roughness and topography on wind speed also are included in the model. For the former, information on land use and land cover at the appropriate resolution is collected and a friction coefficient calculated for each location to account for this effect. For the latter, the capacity of the model to detect greater detail in a range of wind speeds due to orographic obstacles depends greatly on the quality of topographical information available. A digital elevation model is used to evaluate the topographic effect on the wind. Finally, the model also considers the storm decay when the eye of the storm moves onshore (the filling effect).

Storm Surge

Storm surge is a natural phenomenon that occurs on the coast when atmospheric conditions cause water level oscillations in the time range of a few minutes to a few days (excluding wind-generated waves).



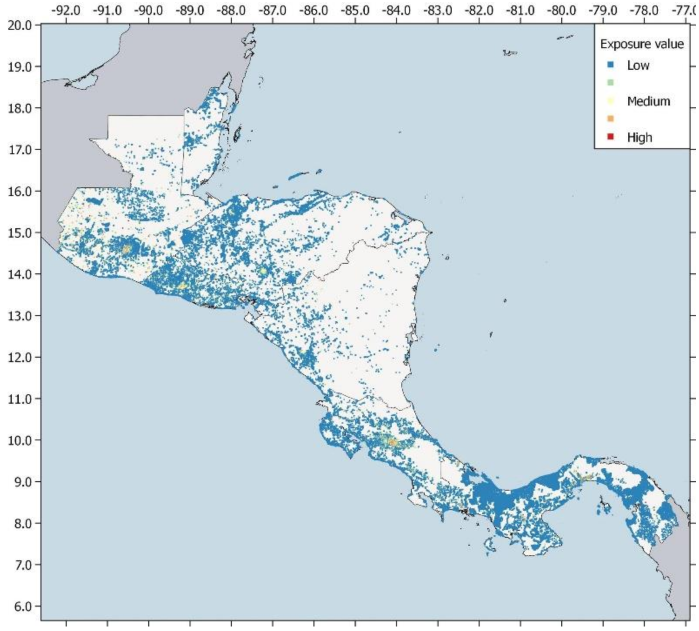
Scheme of the storm surge phenomenon (from COMET®, ©1997-2017 University Corporation for Atmospheric Research). All Rights Reserved.

Storm surges are classified as long waves, but their period and duration may vary considerably, depending on the topography/bathymetry of the water body and also on the characteristics of the storm (direction of movement and strength) and the characteristics of the water body. The wind field associated with the storm pushes the water towards the coast, thereby causing a pile-up of water at the coast and it is the main driving force of the storm surge. To forecast or reproduce storm surges on the coast it is necessary to account for many factors, such as meteorological conditions, characteristics of the storm, and characteristics of the location (bathymetry). Because of the complexity of the phenomenon, numerical methods are now the most widely used approach for storm surge prediction.

The model used for storm surge modelling in SPHERA is GeoClaw, a well-established model from the University of Washington and Columbia University. It requires as input the pressure and wind fields that are computed analytically from some specific storm parameters, such as cyclone track, maximum wind and radius, and minimum sea level pressure.

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 physical characteristics (e.g. construction type and material and height classification), geographic location, use and replacement cost (or production value for crops). The exposure dataset has been enhanced by collating several sources of data up to 2017 related to the built environment and 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
- Crops:
    - 6 different crops (banana, maize, coffee, rice, sugar cane, and generic)

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 distribution of exposure is estimated using independent data sources such as population. 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

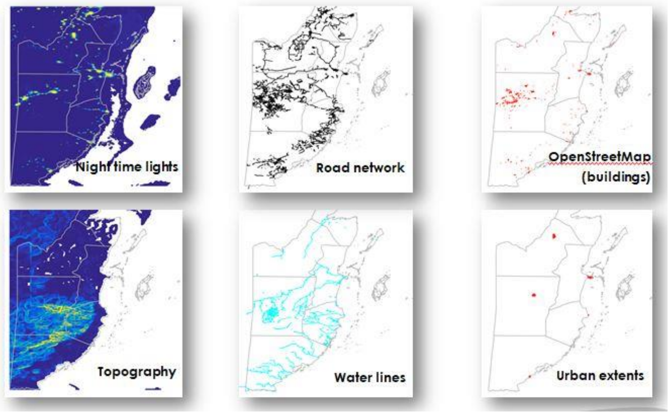
These datasets usually include categories such as residential, industrial, commercial, farmland (agriculture), infrastructure and government/public facilities. Land use datasets are usually produced at a local level for urban planning purposes, at a regional level by local governments, or at a national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

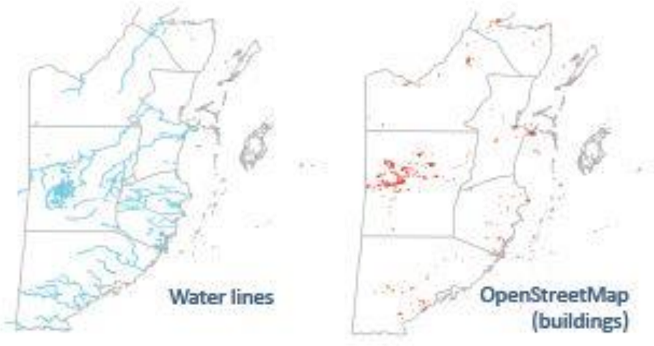
Datasets at the national level containing the transportation network for each country were collected. These datasets contain the spatial distribution of railways and roads, with the latter component usually sub-divided into primary, secondary and tertiary roads. With the exception of the first type of roads (which are usually used to connect large urban centres) 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 were 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 is 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 collected 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.

Assessment of Crops

The SPHERA model also aims at computing the losses caused by a tropical cyclone to the crop production of a country. In particular, SPHERA computes the direct losses in terms of lack of or reduction in annual harvest, i.e. the difference between the expected annual crop production and the actual annual production, given that a tropical cyclone has occurred and had an impact on agricultural areas. The implementation of a crop exposure database required a specific methodology that included three basic steps: identification and geolocalization of cultivated areas, estimation of the expected crop yield and estimation of the crop value.

The VULNERABILITY module: What would happen to the built environment after the occurrence of a tropical cyclone?

The vulnerability module provides a probabilistic relationship between the tropical cyclone intensity (wind speed and storm surge height) and the loss ratio (ratio between the damage and the total replacement cost) caused by the cyclone on an asset. Given the large size of the structure inventory and the lack of data to fully characterize each building individually, the vulnerability module considers classes of structures rather than individual buildings. These classes cover all the structures of the exposure database.

For the development of the module, construction typologies, occupancy classes, building code requirements, construction practices and other parameters are evaluated. The vulnerability model includes up-to-date empirical, expert-opinion-based analytical and hybrid fragility and vulnerability functions collected during an exhaustive search of peer-reviewed publications, public and private reports, and conference proceedings, among other sources.

The vulnerability functions are specific for each country and are defined as a function of structural system, height and occupancy. Other building characteristics such as roof shape and roof material that are not explicitly considered in the exposure database are accounted for with the use of country-specific modifiers that generate a country-specific function for every class of structure. Given the uncertainty associated with the estimation of losses for classes of assets, the vulnerability functions provide the mean loss ratio and its associated uncertainty for varying levels of wind speed. The vulnerability functions derived for the different building classes were validated and calibrated using country-scale post-disaster loss data from past tropical cyclones.

Methodology – Wind

The development of fragility and vulnerability models for a set of building typologies is based on the modification of existing vulnerability functions for other regions based on multiple criteria. The general procedure employed to develop the current vulnerability functions was based on the following steps:

- Identifying the existing models available in the literature for all the building typologies in the exposure database
- Fitting a vulnerability curve using a parametric form
- Homogenizing the available information (e.g., making all the curves dependent on the same wind intensity measure)

- Aggregating the country-specific functions for every building class based on their secondary modifiers
- Calibrating and validating the country-specific functions using damage/loss data

Methodology – Storm Surge

The storm surge vulnerability functions were developed using an in-house damage model (Dottori et al., 2016) for residential buildings. The model is based on a synthetic approach, which takes into account hazard properties at the building locations (e.g., water depth), the characteristics of the exposed buildings (e.g., structural type) and the replacement costs of its components, in order to compute damage values. The impact of different exposure characteristics on the storm surge flood vulnerability of residential buildings was taken into account in the development of the vulnerability module. More specifically, material, presence of a basement, number of stories in the building, and ground level height (i.e. whether the ground floor is more elevated than the street or the surrounding environment) were adopted as the main characteristics that define the storm surge vulnerability of buildings.

Dottori, F., Figueiredo, R., Martina, M.L.V., Molinari, D., Scorzini, A.R., 2016. INSYDE: a synthetic, probabilistic flood damage model based on explicit cost analysis. Nat. Hazards Earth Syst. Sci. 16, 2577-2591

The LOSS module: What are the losses caused by a TC event?

The loss module computes in near real time after the TC event has occurred whether the wind speed and the storm surge 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 wind speed and storm surge field value, exposure values in the event footprint and vulnerability functions, the SPHERA model computes the expected loss experienced by each country affected by the event under analysis.

In the case of a tropical cyclone risk model, multiple perils act simultaneously on every asset. In particular, wind and storm surge might both cause damages. The total losses are computed using a combination of the two perils (Ordaz, 2015).

Ordaz, M., 2015. A simple probabilistic model to combine losses arising from the simultaneous occurrence of several hazards. Nat. Hazards 76, 389-396

The INSURANCE module: Which parameters determine the payout of a TC?

The insurance module uses the modelled loss estimates to compute the payout to each country affected by a TC loss event. The payout depends on the values of a set of parameters selected by each insured country and specified in the TC 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.

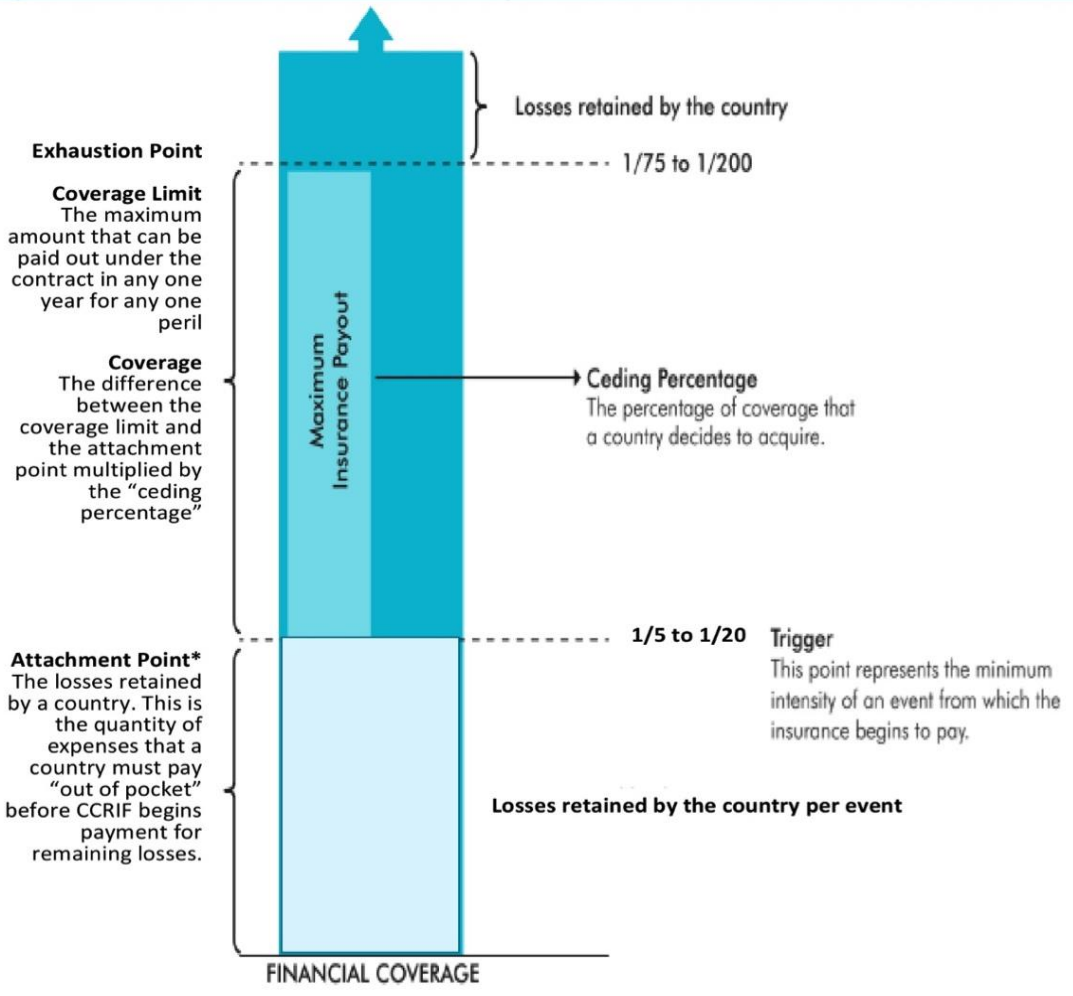
The **Ceding Percentage** is the fraction of the difference between the exhaustion point and the attachment point that the insured country transfers to CCRIF.

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 TC 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 TC 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 mitigation 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

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