CCRIF SPC

The Caribbean Catastrophe Risk Insurance Facility

The Evolution of CCRIF's Parametric Insurance Models

The Journey from EQECAT to SPHERA and Beyond


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The Evolution of CCRIF's Parametric Insurance Models

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Launched in 2007 as the world's first multi-country, multi-peril risk pool, CCRIF began providing parametric insurance coverage for tropical cyclones and earthquakes to 16 Caribbean governments. The development of CCRIF came at a critical time for developing countries, who were faced with growing exposure to hydro-meteorological risks as climate change signals started to become stronger. Risk management and risk transfer, through innovative pooling arrangements such as CCRIF, formed an important part of the UNFCCC Copenhagen Conference discussions and resulting climate change adaptation framework.

Caribbean countries are highly exposed to natural hazards and particularly vulnerable due to their small and undiversified economies. Caribbean nations whilst known globally for beautiful beaches, delectable cuisine and lush rainforests are now also globally known for leading the way with respect to the design and launch of CCRIF, using cost effective risk transfer and being able to access quick liquidity following natural disasters. Since 2007, Caribbean governments have been able to purchase unique parametric insurance coverage not available in the commercial markets at rates only achievable through the innovative pooled approach or risk pooling.

Today CCRIF provides parametric insurance coverage for tropical cyclones, earthquakes and excess rainfall and the fisheries sector to Caribbean and Central American governments and for tropical cyclones to Caribbean electric utility companies. The Facility is known as a sound financial institution and the Caribbean and Central America's development insurance company providing rapid payouts to governments within 14 days of a catastrophic event when policies are triggered, even for multi-country impact events causing millions of dollars in damage.

CCRIF's ability to provide parametric insurance coverage has always been underpinned by its parametric insurance models – which have evolved over the years... moving from off the shelf models, to CCRIF customized models and finally to models that are fully owned by CCRIF. From its inception, CCRIF has based its operations on continuous improvement, and this has emerged as one of the core principles underpinning its corporate governance framework.

How it Started!

The EQECAT Model

CCRIF's first loss model was based on EQECAT's then existing and proprietary hurricane and earthquake hazard models and stochastic event sets. However, new data had to be generated to represent the exposure of Caribbean governments to these hazardous events. Exposure data needed to take into account physical buildings, infrastructure and additional costs of operating (e.g. emergency relief) as well as the secondary effects of reduced revenue due to lower business activity (including tourism arrivals, which are a key component of many of the CARICOM governments).

EQECAT commissioned the University of the West Indies to undertake a data-gathering exercise for all 20 of the Caribbean countries the model covered. The aim of the exercise was to gather data which could be used as a basis for creating an exposure profile for each government. Unfortunately, much of the required data was unavailable, meaning that many proxies had to be used. A second major barrier was the lack of verification data available to help establish proxy relationships and to help validate the model outputs.

Once the loss model was completed, EQECAT used its proprietary stochastic event set to generate loss exceedance curves (curves plotting the amount of the modelled loss against the probability of that loss being matched or exceeded) for each of the 20 countries and for each of the two perils – tropical cyclone and earthquake – to be covered.

EQECAT then generated a template parametric index formula and based on the individual country loss exceedance curves, produced the two constants (alpha and beta) needed to solve the parametric equations for each country. The indexing had to strike a balance between producing a relatively simple parametric formulation and reproducing the underlying loss exceedance curve, which CCRIF directed EQECAT to focus on fitting the curve best at about the 100-year return period.

The loss modelling and indexing process enabled CCRIF to use a parameter of the hazard as a proxy for a loss, rather than the actual loss. The principle of indemnity (the covered party enduring a loss) still held, but instead of the loss being measured on the ground after an event, the loss was estimated using a series of formulae based in turn on catastrophe risk modelling.

Although inherent in insurance – both indemnity and parametric – the basis risk in this first model was at an undesirable level. Despite this, *CCRIF made payouts totalling US$7.3 million for 3 events (2 earthquakes and 1 tropical cyclone), to 3 member governments under the EQECAT model. In 2008, Turks and Caicos Islands received a payout of US$6.3 million.*

CCRIF's Second-Generation Modelling Framework - the Second Generation (2G) Hazard and Loss Estimation Model (HLEM)

As early as 2008, to address the deficiencies in the first model, CCRIF began work on the Second-Generation Modelling Framework which unlike the EQECAT model was designed for CCRIF. The new model was designed to address in large measure the issue of basis risk inherent in the loss indexing approach used in the first-generation model. The new model, the Second Generation (2G) Hazard and Loss Estimation Model (HLEM) included improvements in the hazard and loss modelling techniques, and the use of a modelled loss approach thereby making the model highly scalable and applicable at a wide range of modelling resolutions. This second-generation model was also designed to enable CCRIF to develop new products for perils other than tropical cyclones and earthquake. The Second Generation HLEM also utilized the same hazard modelling base as The Arbiter of Storms (TAOS) Real-time Impact Forecasting System (RTFS).

The main strengths of the Second-Generation Modelling Framework were:

- It was built on a strong, validated hazard modelling base at a 900m grid cell resolution.
- The same techniques/code were used for historical hazard/loss modelling and real-time event modelling/payout calculation.
- It was implemented using open modelling techniques from published scientific literature.
- It was highly scalable and was able to be applied at a wide range of modelling resolutions.
- It was implemented on a geographic base, enabling it to produce map outputs.

IMPROVEMENTS IN HAZARD AND LOSS MODELLING

FIRST GENERATION MODEL (EQECAT)	CCRIF SECOND GENERATION MODEL 2G HLEM
No terrain model used	Used digital terrain model at a 900m grid
Assets-at-risk (exposure) compiled from limited country data and assumptions made where data was lacking	Exposure constructed from satellite imagery and published population and economic data. Quality became uniform across all territories
Exposure was concentrated in one or a few points per territory	Used digital terrain model at a 900m grid
Used fixed wind attenuation factor over terrain	Wind attenuation based on actual terrain friction, delivered from satellite imagery
Storm surge not modelled	Storm surge hazard explicitly modelled
Seismic hazard modelled with fixed amplification factors	Seismic hazard modelled with amplification factors based on local geology
No hazard results available	Results of hazard modelling available
CCRIF was provided with loss index curves from EQECAT for each territory from which it could derive policy costing and event payouts	CCRIF now had access to a stand-alone loss model that allowed it to model any historic or real-time event, to price policies, and to calculate payouts based on events as modelled.

Under the HLEM, CCRIF made payouts totalling US$24.9 million for 5 events (1 earthquakes and 4 tropical cyclones), to 5 member governments. Recall the payout made to Haiti of US$7.7 million in 2010 following the devastating earthquake and in that same year the payout of US$8.6 million to Barbados for TC Tomas.

During 2010, CCRIF conducted reviews of the 2G HLEM Model through recalibration and configuration using upgraded data sets. The basis for these revisions were the updating of inputs, sensitivity analysis and revised parameter selection. The results of these reviews were detailed in the report, *"Verifying CCRIF's Tropical Cyclone Hazard and Loss Modelling"*, which presented the results of an analysis of the behaviour of the second-generation (2G) model after the 2010 Atlantic Hurricane Season. The goal of the analysis was to determine how the 2G model performed in terms of estimating the parameters of the hazard events and associated losses to assist in reducing the basis risk inherent in the loss indexing approach, compared with the first-generation EQECAT model.

The analysis addressed the following basic questions:

- How closely are the CCRIF model wind footprints matched to the National Hurricane Center's (NHC's) H*WIND and other modelled footprints?
- How does ground meteorological data fit with the CCRIF footprint for wind?
- Do the final losses generated by the model correspond with government and independent estimates?
- How does the breakdown of impact costs affect what can be considered government losses?

The report showed that, in general, the performance of the CCRIF 2G model was acceptable, with close correlations to the NOAA-NHC wind speed data and the TRMM rainfall data. Modelled losses were compatible with on-the-ground loss estimates where contributions to these losses from aspects not covered by CCRIF policies – such as rainfall and landslides – were excluded.

CCRIF Multi-Peril Risk Estimation System (CCRIF-MPRES)

In 2011, the 2G HLEM Model was revised based on the reviews conducted in 2010 and renamed the CCRIF Multi-Peril Risk Estimation System (CCRIF-MPRES), commonly referred to as MPRES. CCRIF created Country Risk Profiles for tropical cyclone and earthquake based on MPRES, for all member countries.

10 payouts totalling $71.9 million to 9 member governments under MPRES.
The largest payouts were:

- How closely are the CCRIF model wind footprints matched to the National Hurricane Center's (NHC's) H*WIND and other modelled footprints?
- How does ground meteorological data fit with the CCRIF footprint for wind?
- Do the final losses generated by the model correspond with government and independent estimates?
- How does the breakdown of impact costs affect what can be considered government losses?

Excess Rainfall (XSR) Model 1.0 and Coverage

CCRIF worked with Swiss Re and Kinetic Analysis Corporation (KAC) to develop an excess rainfall (XSR) product based on available NASA-processed satellite rainfall data to underpin a parametric policy. This product was first made available to Caribbean governments in policy year 2012/13. It was designed as a rainfall hedge rather than replicating actual loss from the various hazards related to heavy rainfall. This product was developed after CCRIF member countries and stakeholders expressed a strong interest in having available coverage for excess rainfall, both within hurricanes and in non-hurricane systems.

This parametric product was based on available NASA-processed satellite rainfall data from the NASA/JAXA Tropical Rainfall Measurement Mission (TRMM). It was aimed primarily at extreme high rainfall events of short duration (a few hours to a few days).

The CCRIF/Swiss Re XSR model used TRMM daily rain data to compile a 5-day running aggregate of rainfall measurements at all of the TRMM grid nodes across a given country. As used in other CCRIF products at the time, the Multi-Peril Risk Estimation System exposure database was utilized to map exposures across a country at 30 arcseconds (~1km) resolution. Remote sensing data, and economic and demographic

statistics for 2010 were used to generate the exposure database. The database was designed to provide acceptable estimates for losses to physical assets from hydro-meteorological and geophysical hazards. Since the TRMM nodes were at ~25 km resolution, the 1 km MPRES exposure data was mapped onto the TRMM grid. The value of each exposure node was distributed between the closest four TRMM grid nodes and weighted by distance. This provided a distribution of the total MPRES values between the rainfall measurement points

[1]Tropical Rainfall Measurement Mission - TRMM is a research initiative undertaken by the US National Aeronautics and Space Agency (NASA) and the Japan Aerospace Exploration Agency (JAXA).

covering each country. For scaling purposes, 1% of the total MPRES exposure value was used as the base XSR exposure.

As remains today, XSR 1.0 product triggers independently of the TC product, and if both policies trigger then two payouts are due. Also, while the excess rainfall product can be triggered by a tropical cyclone, it can also be triggered in non-cyclonic systems if the rainfall trigger thresholds are met.

CCRIF offered XSR policies to governments for the first time in 2013. Under XSR 1.0, 4 payouts were made to 3 member governments for excess rainfall, 1 associated with a tropical cyclone and 3 with trough systems. Payouts for these rainfall events amounted to US$3.4 million.

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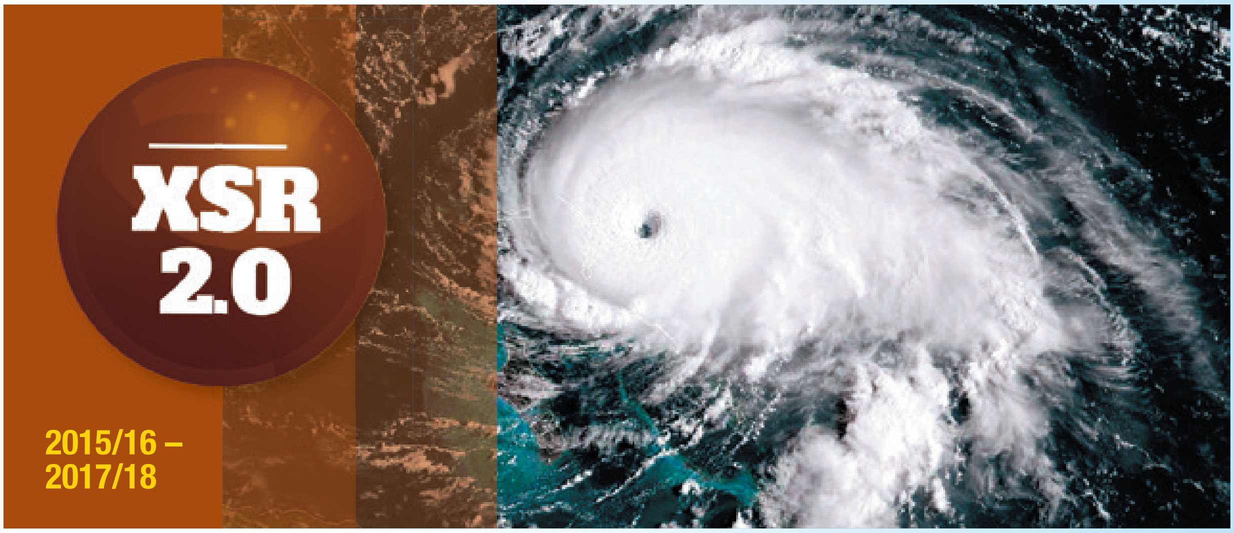


Excess Rainfall Model 2.0

CCRIF began modifications to XSR 1.0 in 2015. The new model – the CCRIF SPC XSR Parametric Rainfall Model – was based on the Global Forecasting System (GFS) model, which assimilated, when available, data such as rain, temperature, wind speed, humidity, and pressure to improve the modelled rain estimates. The choice of this GFS dataset was made based on the accuracy and reliability of future daily rainfall estimates and on the availability of a relatively long period of past/historical data, which is necessary to fine-tune a forecasting rainfall model. CCRIF computed the payouts for damages due to extreme precipitation events based on the following:

Computing payouts for damages due to extreme rainfall events

- the rainfall values as estimated by hydro-meteorological models
- the level of damage expected for different amounts of rainfall over an accumulation period of 2 or 3 days (depending on the country)
- each individual country policy conditions (attachment point, exhaustion point and ceding percentage)

These modifications to the model were made to address the anticipated termination of the Tropical Rainfall Measurement Mission (TRMM), which provided satellite rainfall data for the previous model XSR 1.0. Designed to monitor tropical/subtropical precipitation, the TRMM had been operative from 1998, but on 8 April 2015, the spacecraft depleted its fuel reserves and shortly thereafter fell out of the sky. Therefore, the satellite was no longer available for use in the CCRIF model. The new CCRIF XSR model, XSR 2.0 underpinned the 2015/2016 excess rainfall policies.

The modifications to XSR 1.0 enabled the CCRIF XSR Rainfall Model 2.0 to simulate in real time the precipitation over a country and rapidly estimate the potential consequential losses. The daily rainfall estimates were derived through a combination of climatic-meteorological models (2 configurations of the Weather Research and Forecasting or WRF model – WRF1 and WRF2)– which more accurately reproduced the intensity of the rainfall event – and a satellite-based precipitation model (Climate Prediction Center Morphing Technique or CMORPH) – which captured precisely, both spatially and temporally, the location of the rainfall caused by the event.

The exposure database comprised information (number, area, economic value) about the different types of structures: residential buildings, commercial buildings, industrial facilities, hotels and restaurants, healthcare facilities, education assets, airports and ports, and the transportation (road) network. The damage functions related to the aggregated rainfall and losses. The modelled losses due to the XSR event were calculated and the insurance module – based on the policy conditions (attachment point, exhaustion point and ceding percentage) – determined if a country's policy was triggered and computed the payout to the country.

Under XSR 2.0, 13 payouts were made under this model totalling $22.7 million to 9 member governments. The largest payouts were:

- $7.0 million – Trinidad and Tobago after a rainfall event in October 2017
- $3.8 million – Saint Lucia after TC Matthew
- $3.0 million – Haiti after TC Matthew
- $2.4 million – Dominica after TC Erika

In 2015, Dominica received a payout of US$2.4 million under its XSR policy following the passage of TC Erika, which severely impacted 10% of the country's population and resulted in damage and losses of about 90% of Dominica's GDP.

Excess Rainfall Model 2.1

At the beginning of 2018, CCRIF updated the Excess Rainfall (XSR) model to XSR 2.1. Changes to this version of the model included better estimation of losses due to shorter intense rainfall events, thus reducing the basis risk of the XSR parametric product.

The XSR 2.1 model was used for the 2018/19 policy year and included data on several important rainfall events that occurred in 2016 and 2017, such as tropical cyclones Earl, Matthew, Irma and Maria and other rainfall events not induced by tropical cyclones.

XSR 2.1 also included the additional exposure data collected during the development of the SPHERA TC/EQ model. The inclusion of the 2016 and 2017 events and the updated exposure database within the risk analysis of the countries provided a significant improvement in the assessment of the precipitation hazard in the region and allowed member governments to be able to obtain more accurate policies.

Under XSR 2.1, 2 payouts were made totalling $8.3 million to 2 member governments. The largest payout was:

- $5.8 m to the Government of Barbaods after TC Kirk

Excess Rainfall Model 2.5

During 2018-19, the XSR 2.1 model was further upgraded to XSR 2.5 for the 2019/20 policy year. The three main improvements of the XSR 2.5 version were:

- An updated hazard module: it included the assimilation of observed data (meteorological observations, such as temperature, pressure, humidity) into the WRF weather model (this new model set-up is called WRF7 and replaced WRF1) and it introduced a new weather model set-up, called WRF5, which replaced WRF2.
- An updated loss module: it included multiple primary triggers and a component that accounts for the soil saturation at the beginning of a rainfall event.
- An updated vulnerability module: the vulnerability functions were modified to account for the different behaviour of the three precipitation models.

CCIRF made 14 payouts under XSR 2.5 14 payouts totalling $31.7 million to 9 member governments. The largest payouts were to:

- $7.2 m – Haiti after TC Laura
- $5.1 m – Trinidad and Tobago after rainfall event in October 2022
- $3.6 m – Guatemala after TC Cristobal
- $3.5 m – Jamaica after TCs Zeta & Eta

The SPHERA Model

It is important to note that whilst HLEM and MPRES were developed specifically for CCRIF they were not fully owned by CCRIF. SPHERA is fully owned by CCRIF as well as XSR 2.0 and subsequent revisions to those models.

In the 2018/19 policy year, SPHERA was completed and approved by reinsurers. As of policy year 2019/20 CCRIF's TC and EQ policies have been underpinned by the SPHERA models which replaced MPRES.

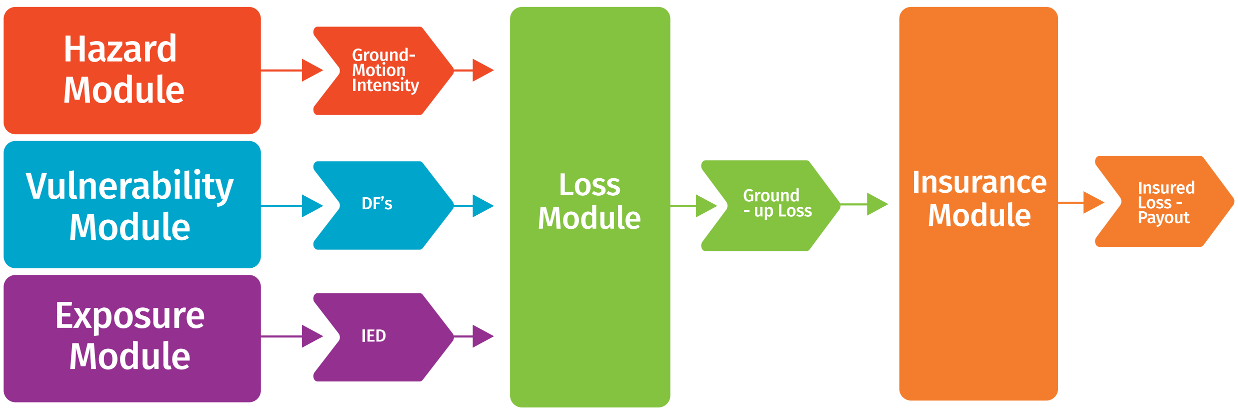
The SPHERA loss assessment models were designed to:

- Produce ex-ante estimates of future EQ- and TC-induced losses in the countries 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 and 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 an earthquake or a tropical cyclone according to the event parameters defined by United States Geological Survey (USGS) and the United States National Oceanic and Atmospheric Administration (NOAA)

SPHERA was based on a geo-referenced database of buildings and infrastructure that included building count, replacement cost and vulnerability classification of the different assets at a 1 km2 granularity (100 m2 along the coastline). Unlike the MPRES model, the SPHERA exposure database provided the economic value of the exposed assets disaggregated by sector (residential, commercial, industrial, hotels, education, healthcare, public, airports, ports, power facilities, road network etc.) and by building class (e.g., reinforced concrete, masonry, etc., of different age and height). By leveraging several sources of information, two additional databases were built, which included the related physical, human, and economic losses caused by a collection of historical EQ and TC events that had occurred in the Caribbean and Central America. These databases were used to validate and calibrate the two risk models.

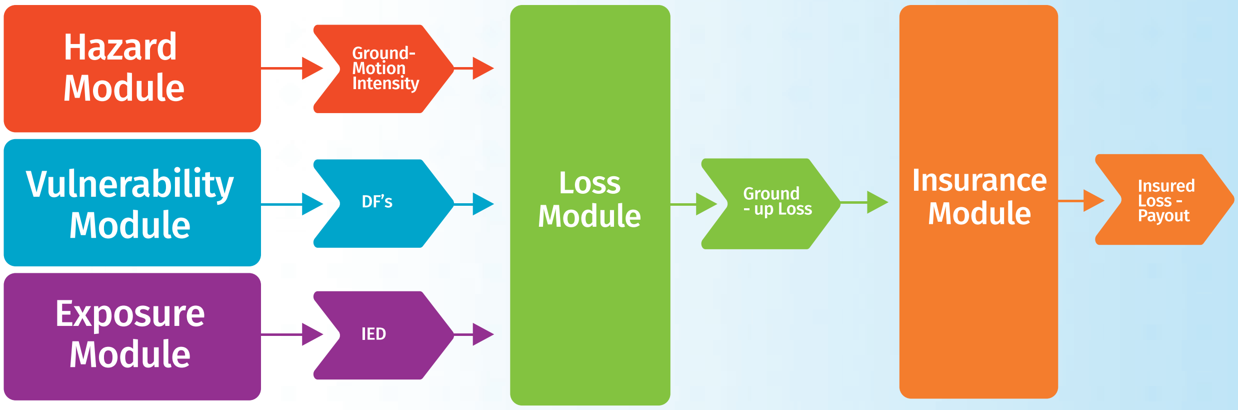
The EQ hazard module was designed to statistically estimate the possible impact that of future earthquakes through a probabilistic seismic hazard assessment (PSHA) technique that combines the frequency of occurrence of future earthquakes in time and space and the evaluation of the ground motion random fields generated by each event.

General Framework of the Earthquake Model



The TC hazard module was designed to statistically estimate the impact of future tropical cyclones, storms, and tropical depressions either by-passing or making landfall in any of the countries considered. A probabilistic procedure was adopted to simulate future 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 regions. For both perils, the hazard module allowed for computing of ground motion or wind and storm surge intensities induced by the occurrence of an earthquake or a tropical cyclone, respectively, according to the parameters provided by the USGS and NOAA.

General Framework of the Tropical Cyclone Model



Under SPHERA, 6 payouts totalling $89.4 million were made to 4 member governments. The largest payouts were:

- $40.0 m – Haiti after August 2021 earthquake
- $19.9 m – Nicaragua after TC Iota
- $11.5 m – The Bahamas after TC Dorian

These model revisions allow for an increasingly robust risk analysis and a continual reduction of the basis risk in the excess rainfall product.

How it's Going! 2023

Parametric index design seeks to minimize basic risk and CCRIF remains at the leading edge among risk pools of global progress in this regard.

2021-23 | Updates to SPHERA and XSR

In policy year 2021/22, CCRIF began updating the SPHERA and XSR models and the new models will be available in the 2023/24 policy year. For each of these models, the exposure, hazard, and vulnerability components have been analyzed and evaluated to include the most up-to-date data and model improvements. The main updates are listed below.

The SPHERA TC model is being updated to include:

- Revised wind and storm surge risk assessment based on a new stochastic catalogue which uses state-of-the-art techniques for stochastic tropical cyclone generation.
- New bathymetry data with higher resolution
- New data from the most recent tropical cyclones, including Elsa in 2021 and Dorian in 2019 etc., which will allow for a recalibration of the vulnerability functions; the current version of the model was calibrated using data up to 2017.
- An additional trigger for extreme localized events

The SPHERA EQ model is being reviewed and updated for Jamaica, Haiti, and the Cayman Islands. Work being undertaken includes:

- Review of existing seismic hazard studies in Jamaica and surrounding areas
- Preparing a new earthquake catalogue for Jamaica, Haiti, and the Cayman Islands
- Preparing new event loss tables for Jamaica, Haiti, and the Cayman Islands
- Conducting new risk sensitivity analyses

Updates to the XSR 2.5 model include:

- Using two new WRF configurations at high resolution (approx. 3.6 km) to replace those currently used; the WRF is a climatic-meteorological model developed by NOAA and is one of the sources of rainfall data used in the model.
- Inclusion of IMERG to replace CMORPH as one of the sources of data for the model; NASA's new IMERG system combines information from the current constellation of satellites to estimate precipitation. This algorithm is particularly valuable over the areas that lack precipitation-measuring instruments on the ground.
- Use of data from rainfall events that occurred over the period 2019 to 2021 in the risk analysis.
- Review of the loss calculation methodology
- Adjustment of the vulnerability curves
- Implementation of an additional trigger for extreme localized events
- Inclusion of a wet season factor in the loss calculation to reflect when rainfall events occur in quick succession.
- Use of the standardized precipitation index (SPI) to detect exceptionally dry periods.
- Inclusion of crops in the exposure module (previously these were only in the exposure modules for tropical cyclone and earthquake)

And Beyond - In Conclusion

CCRIF's policies do not obviate the need for Caribbean governments to continue to invest in disaster risk mitigation and climate change adaptation activities and in other financing mechanisms to cover relatively small losses, which occur in more frequent events such as minor earthquakes, flash floods, tropical storms, and heavy rainfall, which oftentimes do not cause catastrophic loss. CCRIF provides a cost-effective solution to one part of the larger comprehensive disaster risk management (CDRM) universe. CCRIF is increasingly supporting other aspects of CDRM in the region, in partnership with national governments, and international and regional institutions.

In A Nutshell

The Evolution of Parametric Models used by CCRIF – 2007 to 2023 and Beyond

Model and Policy Years Used	Perils	Main Features	Payouts on Policies using this Model (US$)
EQECAT Hurricane and Earthquake Models 2007/08 – 2008/09	TC EQ	• Proprietary model owned by EQECAT • Used exposure data from Caribbean governments – significant missing data • Used EQECAT stochastic event sets to generate loss exceedance curves (LECs) for TC and EQ • Used a template parametric index formula generated by EQECAT based on the individual country LECs • High basis risk due to loss-indexing approach • TC model based on wind speed Seismic hazard modelled with fixed amplification factors • Loss index curves from EQECAT could be used by to derive policy costing and event payouts	3 payouts totalling $7.3 million to 3 members Largest payout: $6.3 m - Turks and Caicos Islands after TC Ike
Second Generation Hazard and Loss Estimation Model (HLEM) 2009/10 – 2011/12	TC EQ	• Designed for CCRIF • Used modelled loss approach, using open modelling techniques from published scientific literature • Built on a strong, validated hazard modelling base at 900m grid cell resolution • Model was highly scalable and applicable at a wide range of resolutions • Implemented on a geographic base enabling it to produce map outputs • Facilitated the development of products for other perils • TC model based on wind speed and storm surge • Seismic hazard modelled with amplification factors based on local geology	5 payouts totalling $24.9 million to 5 member governments. Largest payouts: • $8.6 m – Barbados for TC Tomas • $7.7 m – Haiti after earthquake in January 2010

Model and Policy Years Used	Perils	Main Features	Payouts on Policies using this Model (US$)
		• Enabled CCRIF to access a stand-alone loss model that allowed it to model any historic or real-time event, to price policies, and to calculate payouts based on events as modelled	
CCRIF Multi-Peril Risk Estimation System (CCRIF MPRES) 2012/13 – 2018/19	TC EQ	• Revision of 2G HLEM	10 payouts totalling $71.9 million to 9 member governments. Largest payouts: • $20.4 m – Haiti after TC Matthew • $19.3 m to Dominica after TC Maria • $13.6 m to TCI after TC Irma • $6.8 m – Antigua and Barbuda after TC Irma • $6.5 m – Anguilla after TC Irma
Excess Rainfall Model 1.0 (XSR 1.0) 2012/13 – 2014/15	XSR	• Aimed primarily at extreme high rainfall events of short duration (a few hours to a few days) For rain events during cyclones or non-cyclonic systems[2] Based on available NASA-processed satellite rainfall data from the NASA/JAXA Tropical Rainfall Measurement Mission (TRMM)	4 payouts totalling $3.4 million to 3 member governments. Largest payouts: • $1.3 m – Barbados after a trough in November 2014

[2]Applies to all XSR models

Model and Policy Years Used	Perils	Main Features	Payouts on Policies using this Model (US$)
		• MPRES exposure database was utilized to map exposures across a country at 30 arcseconds (~1km) resolution. • Remote sensing data, and economic and demographic statistics for 2010 were used to generate the exposure database • 1% of the total MPRES exposure value used as the base XSR exposure • Policy triggered separate from TC policy[1]	• $1.1 m – St. Kitts and Nevis after a trough in November 2014
XSR 2.0 2015/16 – 2017/18	XSR	• Based on the Global Forecasting System (GFS) model • Rainfall estimates no longer used data from TRMM, which terminated in April 2015 • Rainfall estimates derived through a combination of climatic-meteorological models (2 configurations of the Weather Research and Forecasting or WRF model – WRF1 and WRF2) – which more accurately reproduces the intensity of the rainfall event – and the satellite-based precipitation model, Climate Prediction Center Morphing Technique or CMORPH – which captures precisely the spatial and temporal location of the rainfall caused by the event • Losses calculated based on the rainfall values estimated by hydro-meteorological models and the level of damage expected for different amounts of rainfall over an accumulation period of 2 or 3 days • Exposure database comprised information (number, area, economic value) about the different types of structures. • Damage functions related to the aggregated rainfall and losses • Hazard module based on rainfall data from 1998 to 2015	13 payouts totalling $22.7 million to 9 member governments. Largest payouts: • $7.0 m – Trinidad and Tobago after a rainfall event in October 2017 • $3.8 m – Saint Lucia after TC Matthew • $3.0 m – Haiti after TC Matthew • $2.4 m – Dominica after TC Erika

Model and Policy Years Used	Perils	Main Features	Payouts on Policies using this Model (US$)
XSR 2.1 **2018/19**	XSR	• Upgrade of XSR 2.0 • Changes included better estimation of losses due to shorter intense rainfall events, thus reducing the basis risk • Included rainfall data on events in 2016 and 2017 (e.g. TCs Earl, • Matthew, Irma, Maria) Improvement in the assessment of the precipitation hazard in the region • Exposure module included new data used in the SPHERA model – becoming aligned with SPHERA • Better estimation of losses due to shorter intense rainfall events	2 payouts totalling $8.3 million to 2 member governments. Largest payouts: $5.8 m – Barbados after TC Kirk
XSR 2.5 **2019/20 – 2022/23**	XSR	• Upgrade of 2.1 • Updated hazard module to include assimilation of observed data (meteorological observations, such as temperature, pressure, humidity) into the WRF weather model called WRF7, which replaced WRF1 and introduced a new weather model set-up, called WRF5, which replaced WRF2 • An updated loss module, which included multiple primary triggers and a component that accounts for the soil saturation at the beginning of a rainfall event • Vulnerability functions modified to account for the different behaviour of the three precipitation models (CMORPH, WRF5 and WRF7)	14 payouts totalling $31.7 million to 9 member governments. Largest payouts: • $7.2 m – Haiti after TC Laura • $5.1 m – Trinidad and Tobago after rainfall event in October 2022 • $3.6 m – Guatemala after TC Cristobal • $3.5 m – Jamaica after TCs Zeta & Eta

Model and Policy Years Used	Perils	Main Features	Payouts on Policies using this Model (US$)
System for Probabilistic Hazard Evaluation and Risk Assessment (SPHERA) 2019/20 – 2022/23	TC EQ	• Owned by CCRIF • Produces ex-ante estimates of future EQ- and TC-induced losses in the countries to be used for parametric insurance policy pricing • Estimates in near real time the modelled losses to buildings and infrastructure due to EQ ground motion and to TC-induced wind and storm surge caused by events in the region3 • Computes the policy payout to insured countries due to the occurrence of an EQ or a TC according to the event parameters defined by United States Geological Survey (USGS) and the United States National Oceanic and Atmospheric Administration (NOAA)3 • Based on a geo-referenced database of buildings and infrastructure that included building count, replacement cost and vulnerability classification of the different assets at a 1 km2 granularity (100 m2 along the coastline). • Provides the economic value of the exposed assets disaggregated by sector (not available under MPRES) • Supported by two additional databases, which include the related physical, human, and economic losses caused by a collection of historical EQ and TC events that have occurred in the Caribbean and Central America • Increased ability to validate and calibrate the risk models for TC and EQ • EQ hazard module statistically estimates the possible impact of future earthquakes through a probabilistic seismic hazard assessment technique that combines the frequency of occurrence of future earthquakes in	6 payouts totalling $89.4 million to 4 member governments. Largest payouts: • $40.0 m – Haiti after August 2021 earthquake • $19.9 m – Nicaragua after TC Iota • $11.5 m – The Bahamas after TC Dorian

		time and space and the evaluation of the ground motion random fields generated by each event • TC hazard module statistically estimates the impact of future hurricanes, tropical storms, and tropical depressions by-passing or making landfall in any of the countries considered. A probabilistic procedure was adopted to simulate future 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 regions	

Moving Forward - 2023/24 and Beyond

XSR 3.0	XSR	The new XSR model will: • Use two new WRF configurations at high resolution (approx. 3.6 km) to replace WRF5 and WRF7 • Use IMERG to replace CMORPH as one of the sources of data; NASA's new IMERG system combines information from the current constellation of satellites to estimate precipitation. This algorithm is particularly valuable over the areas that lack precipitation-measuring instruments on the ground. • Use data from rainfall events that occurred over the period 2019 - 2021 in the risk analysis • Be based on a review of the loss calculation methodology • Use adjusted vulnerability curves • Include an additional trigger for extreme localized events • Include a wet season factor in the loss calculation to reflect when rainfall events occur in quick succession • Use the standardized precipitation index (SPI) to detect exceptionally dry periods • Include crops in the exposure module (previously these were only in the exposure modules for tropical cyclone and earthquake)

<table>
<tr>
<td>SPHERA 2.0</td>
<td>TC
EQ</td>
<td>The upgraded TC model will use:

A revised wind and storm surge risk assessment based on a new stochastic catalogue that uses state-of-the-art techniques for stochastic TC generation
New bathymetry data with higher resolution
New data from the most recent tropical cyclones, including Elsa in 2021 and Dorian in 2019, which will allow for a recalibration of the vulnerability functions; the current version of the model was calibrated using data up to 2017
An additional trigger for extreme localized events

The upgraded EQ model is for Jamaica, Haiti, and the Cayman Islands. Work to support the revised model includes:

Review of existing seismic hazard studies in Jamaica and surrounding areas
Preparing a new earthquake catalogue for Jamaica, Haiti, and the Cayman Islands
Preparing new event loss tables for Jamaica, Haiti, and the Cayman Islands
Conducting new risk sensitivity analyses

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CCRIF SPC

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