Workshop II: Technical Issues towards effective Applications of Geospatial Technologies and Data in support of Disaster Risk Management in the Caribbean

September 6-8 2021

Use of Geospatial Technologies and Data in support of Disaster Risk Financing
Case Study: CCRIF SPC

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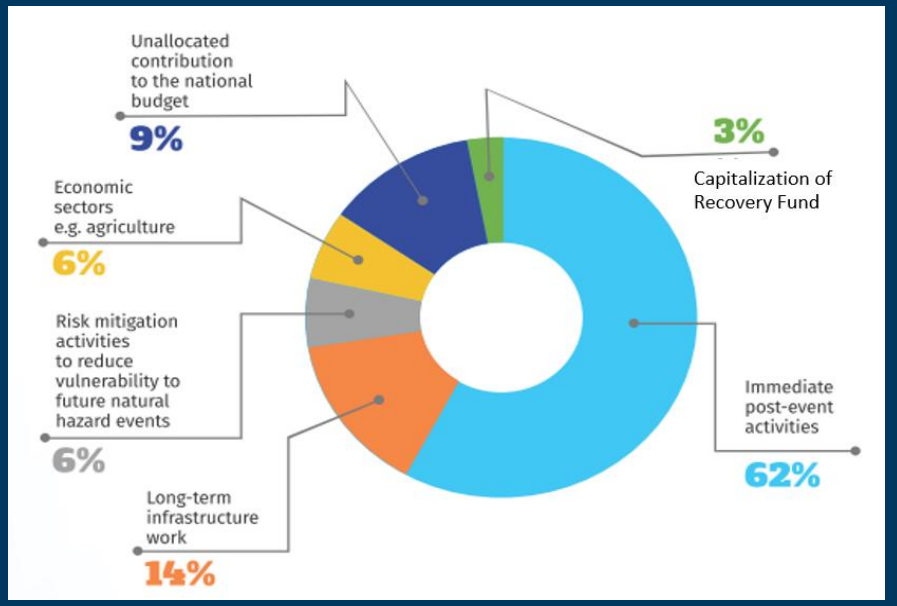
CCRIF…

- Is the world's first multi-country, multi-peril risk pool based on parametric insurance
- Provides parametric catastrophe insurance for Caribbean and Central American governments; and now for electric utility companies
- Provides quick liquidity following a natural disaster helping to close the liquidity gap
- Operates akin to a developmental insurance company – as the goods and services we provide are designed to enhance the overall developmental prospects of our members
- Has 23 members – 19 Caribbean governments, 3 Central American governments and 1 Caribbean electric utility company
- Offers products not readily available in traditional insurance markets
- Parametric insurance products are a key component in a country's disaster risk financing strategy and are designed to pre-finance short-term liquidity helping to close the protection gap, reduce budget volatility, allow countries to respond to their most pressing needs post disaster, including support to the most vulnerable

CCRIF Parametric Insurance Products, Payouts and Use of Payouts

54 payouts totalling US$245 million made to 16 member governments… within 14 days of the event

Approximately 3.5 million persons have benefitted from CCRIF payouts since 2007.



CCRIF Products, Current and In Development and the Perils Covered

CCRIF Products	Perils											Add. Info
	ES	Wind	Rain	Flood	Drought	Heat Wave	Landslide	Vol Er	Tsunami wave	Storm surge	Wave Height	
Earthquake	◆											
TC		◆								◆		
XSR			◆									
Products under Development												
Drought					◆							
Run-Off				◆								
Eco Sectors Covered												
Electric Utilities		◆								◆		
Fisheries		◆	◆							◆	◆	
LPP (microins)		◆	◆									Adaptive Social Protection
Eco Sectors under Consideration												
Agriculture		◆	◆	◆	◆					◆		Including Livestock
Tourism	◆	◆	◆							◆		
Gov. Buildings and other Infra.	◆	◆	◆	◆						◆		Schools, hospitals, offices, PS, houses
Housing Stock	◆	◆	◆	◆			◆			◆		

How CCRIF Parametric Insurance Policies Work

Parametric insurance disburses funds based on the occurrence of a pre-defined level of hazard and impact	Policy triggered on the basis of exceeding a pre-established trigger event loss
	Estimated based on wind speed and storm surge (tropical cyclones) or ground shaking (earthquakes) or volume of rainfall (excess rainfall)
	Hazard levels applied to pre-defined government exposure to produce a loss estimate
	Payout amounts increase with the level of modelled loss, up to a pre-defined coverage limit

CCRIF makes payouts within 14 days after an event.

Catastrophe (Cat) Modelling

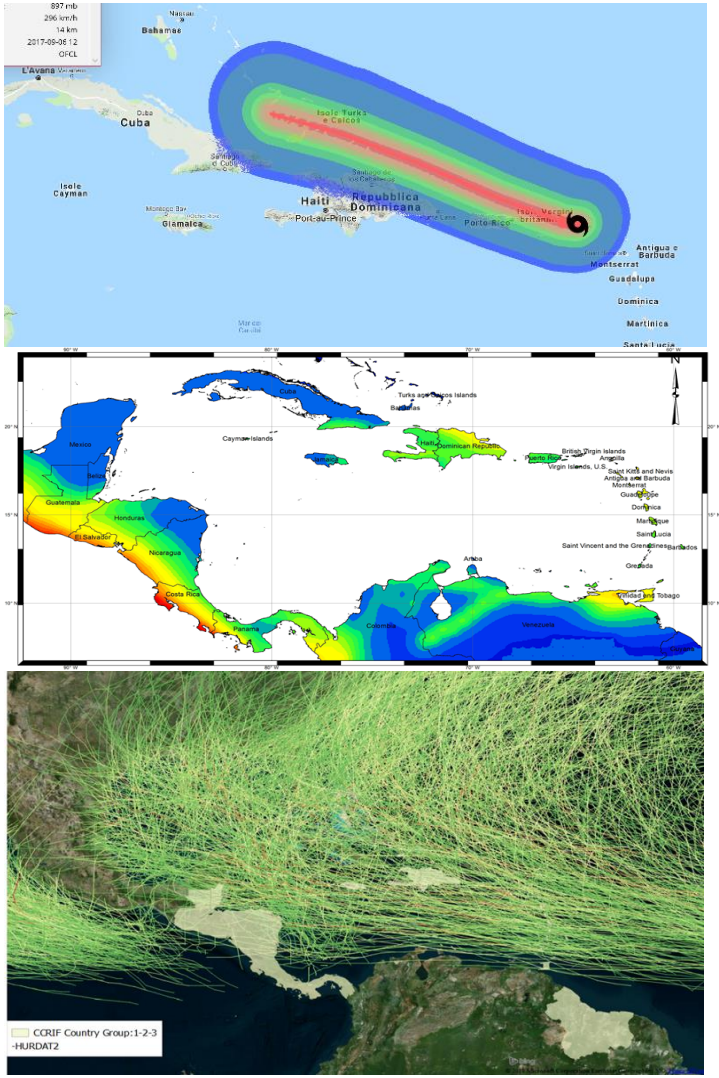
Catastrophe (Cat) modelling uses computer-assisted calculations to estimate the losses that could be sustained due to a catastrophic event

Catastrophe modeling allows insurers and reinsurers, financial institutions, corporations, and public agencies to evaluate and manage natural catastrophe risk.

A combination of science, technology, engineering knowledge, and statistical data is used to simulate the impacts of natural and man-made perils in terms of damage and loss.

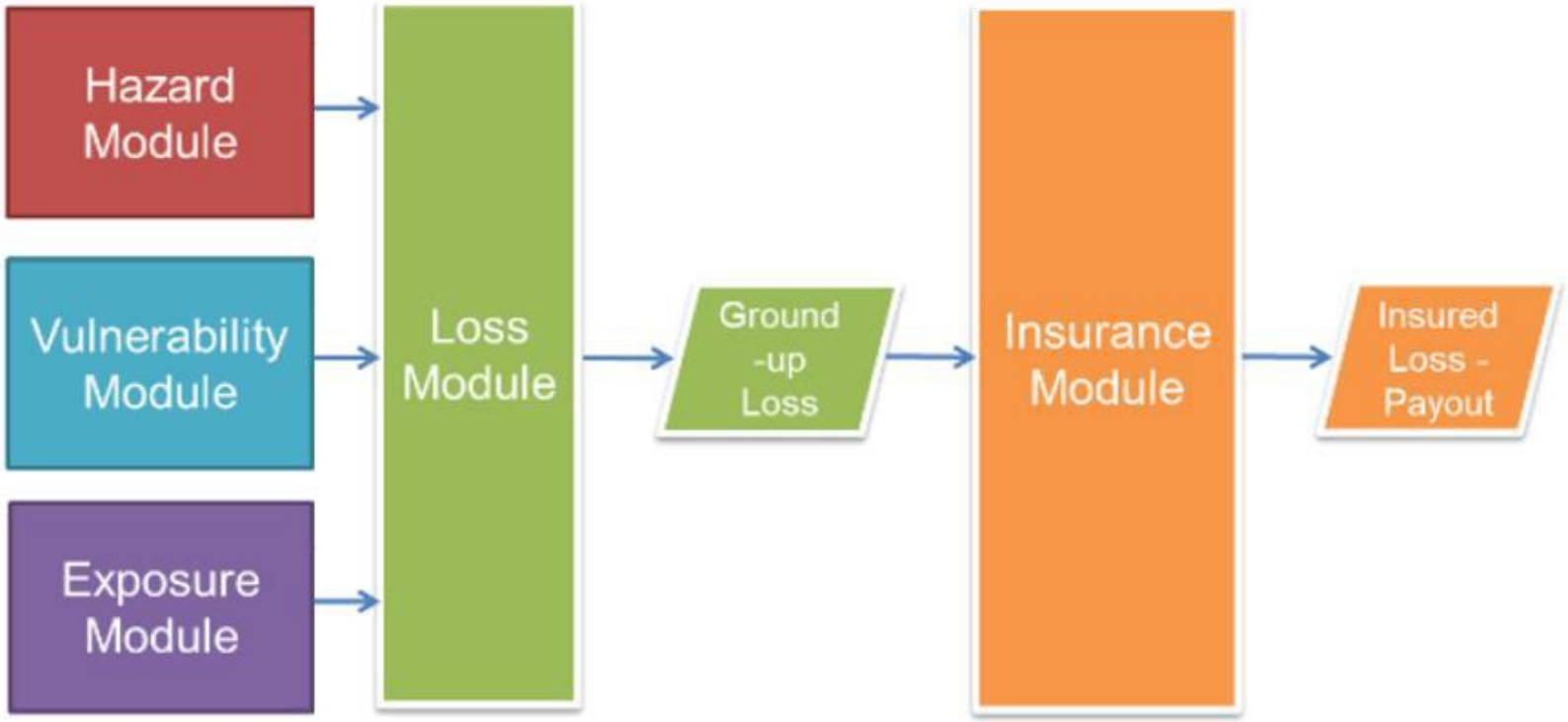
The Role of Loss Estimation and Cat Modelling

- **Before an event-** What might happen if…? What will we need? What areas will be impacted?
- **During an event-** Where is this hurricane going? Who should be evacuated? What assistance is needed?
- **After an event-** What happened? Where is the most damage? Where are people without food and shelter?
- **In general:** Where should we build stronger, higher, or farther away? Where should we retrofit, acquire property, or replace facilities? What should be insured? (insurers- how much should that cost?)



CCRIF's Parametric Model Construct

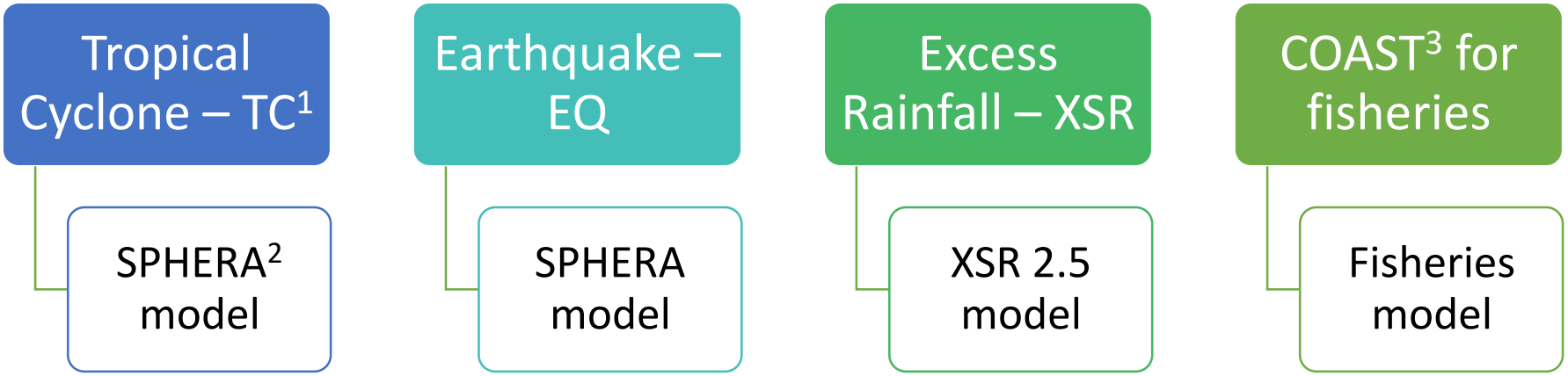
CCRIF's parametric policies are based on a loss modelling approach. The objective of the loss modelling approach is to equip CCRIF with the capacity to estimate loss probabilities for individual countries, price contracts for specific countries, and estimate site-specific hazard levels and losses for specific events during the contract period.



CCRIF's Parametric Models – The Modules

Hazard	Exposure	Vulnerability	Loss	Insurance
• Defines the expected frequency and severity of a hazard event at a specific location • Based on a database of historical events and simulated events • EQ: 1520-2017 TC: 1850-2017 XSR: 1998-2018	• Provides a comprehensive and spatially-distributed list of vulnerable assets e.g. buildings, airports/ports, power facilities, road networks, crops	• Assesses the vulnerability of the assets in the exposure module to the hazards defined in the hazard module	• Uses the Hazard, Exposure and Vulnerability modules to calculate a modelled loss for a current hazard event	• Applies the modelled losses to the conditions of the country's CCRIF policy to determine if the policy is triggered and computes the payout to the country.

CCRIF's Parametric Products and Models

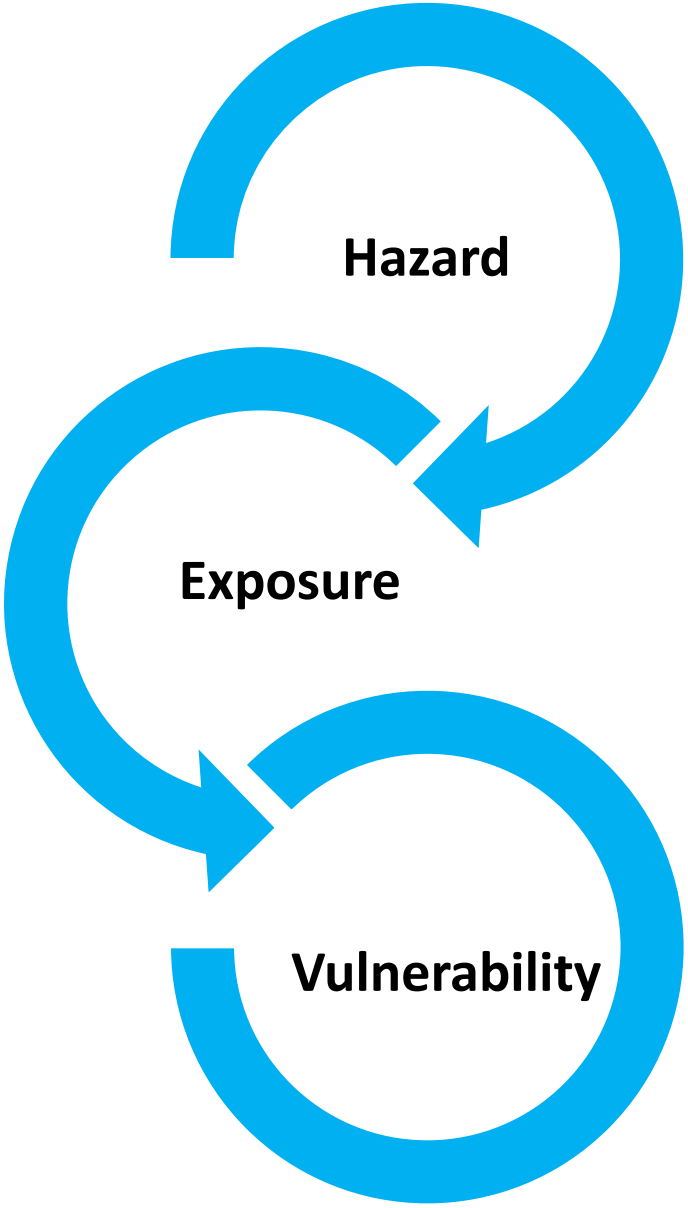


1. Used in Electric Utilities product also
2. System for Probabilistic Hazard Evaluation and Risk Assessment
3. Caribbean Oceans and Aquaculture Sustainability Facility

TC: wind speed > 39 mph (62.7 km/h)
EQ: magnitude >= 5.0 which generates a peak ground acceleration of at least 0.01g
XSR: amount of daily average rainfall during an accumulation period greater than a specified threshold over at least a specified percentage a country's area

SPHERA Model

TC
EQ



- **Tropical Cyclone:** Tropical cyclone data from NOAA within geographic region (wind and storm surge)
- **Earthquake:** Earthquake data from USGS (peak ground acceleration)

Buildings, airports/ports, power facilities, road network, crops

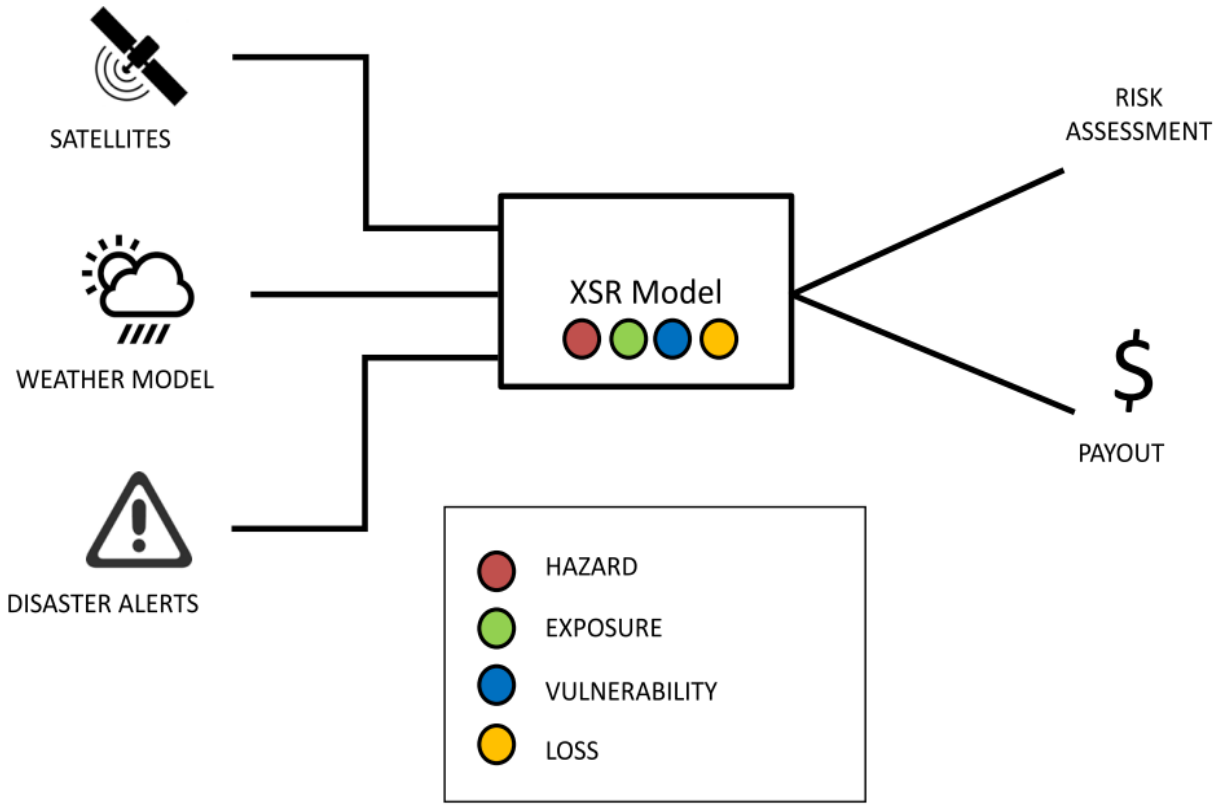
- Location
- Economic value (replacement cost/estimated income)
- Physical attributes (materials, dimensions)

- **Tropical Cyclone:** Relates wind/storm surge intensities to infrastructure damage ratios
- **Earthquake**: Relates ground shaking values to infrastructure damage ratios

XSR 2.5 Model

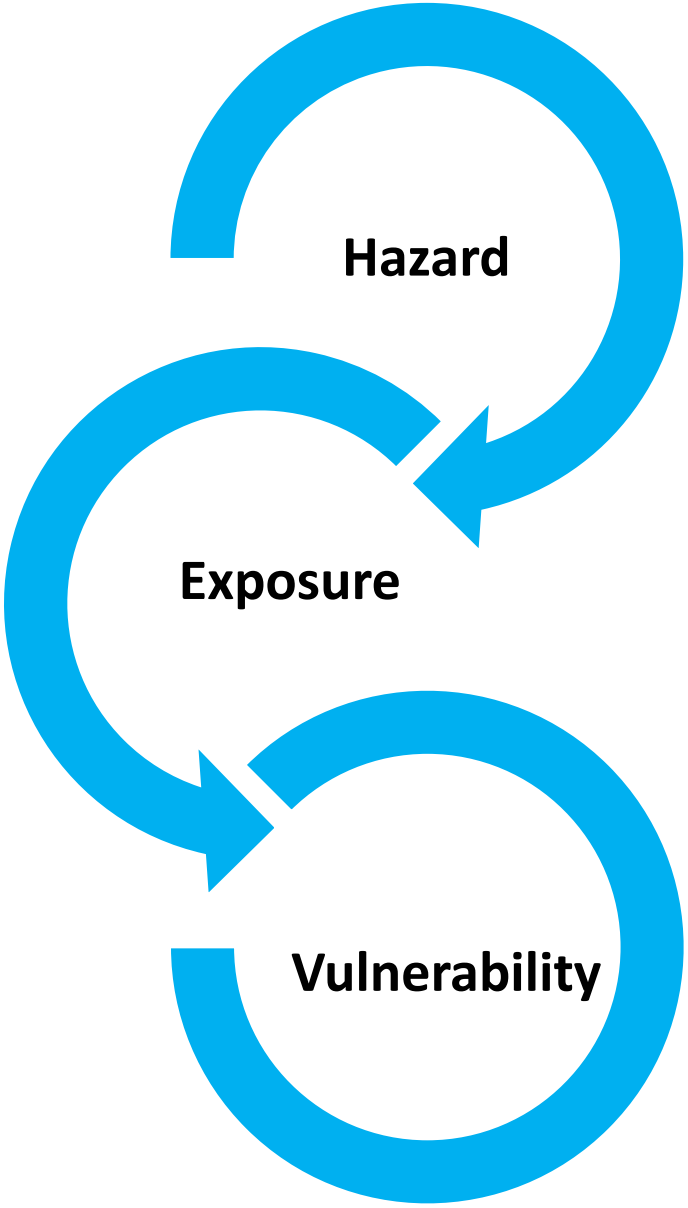
CMORPH: developed by NOAA Climate Prediction Center. It is low-orbiter satellite-based precipitation model which captures more precisely the ***spatial and temporal location*** of the rainfall caused by the event.

WRF: Weather forecasting models developed by the US National and Oceanic and Atmospheric Administration (NOAA), which computes the amount of rainfall based on climate conditions. This weather forecast model reproduces the ***intensity*** of the rainfall event.



From Reliefweb

COAST Fisheries Model



- **Adverse Weather Component:** Wave height and strong rainfall (for at least 3 consecutive days)
- **Tropical Cyclone Component:** Wind speed and storm surge

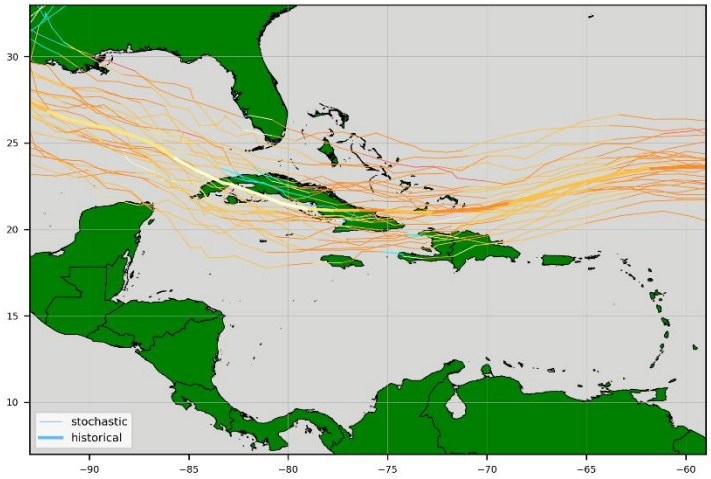
Comprises infrastructure, boats and fisherfolk characteristics such as:

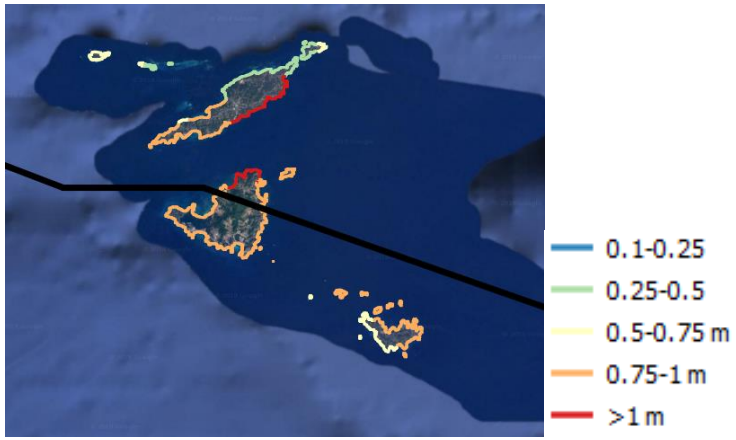
- Location
- Economic value (replacement cost/estimated income)
- Physical attributes (materials, dimensions)

- **Adverse Weather Component:** relates rainfall depth or wave height levels to daily lost revenues
- **Tropical Cyclone Component:** Relates wind/storm surge intensities to infrastructure damage ratios (%)

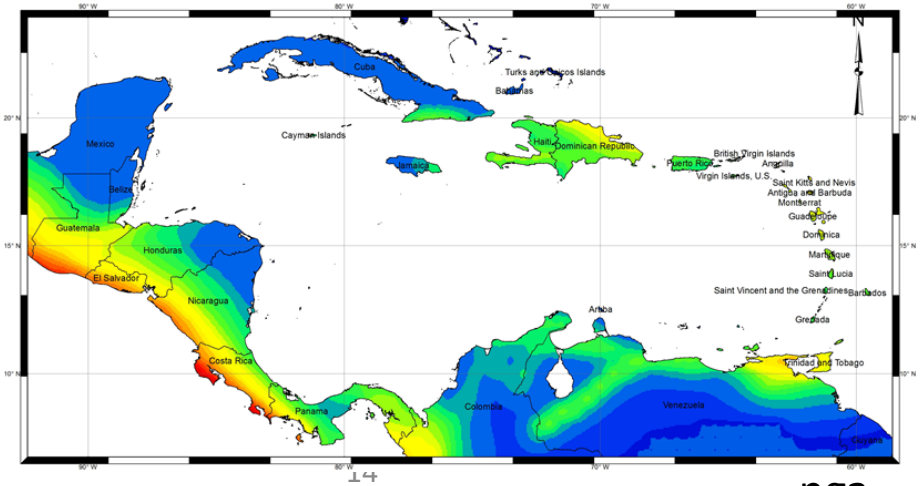
Hazard Module

Tropical Cyclone





Earthquake



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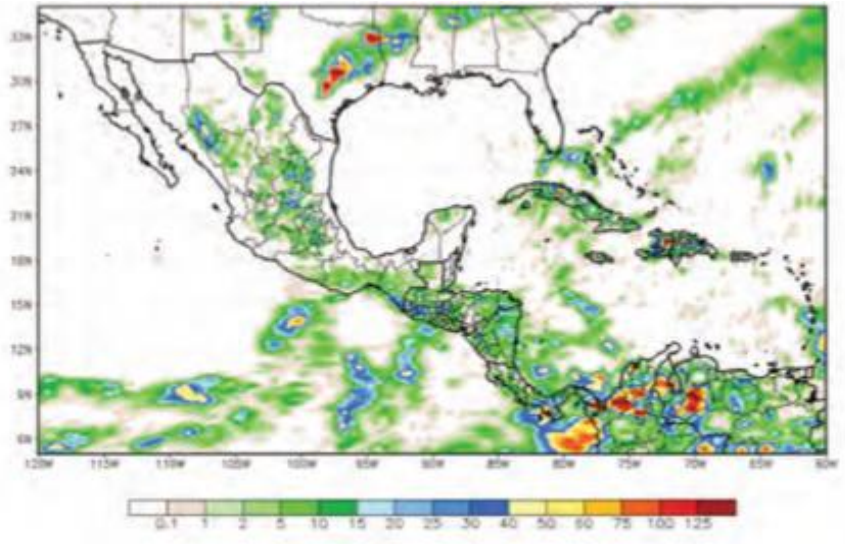
Excess Rainfall

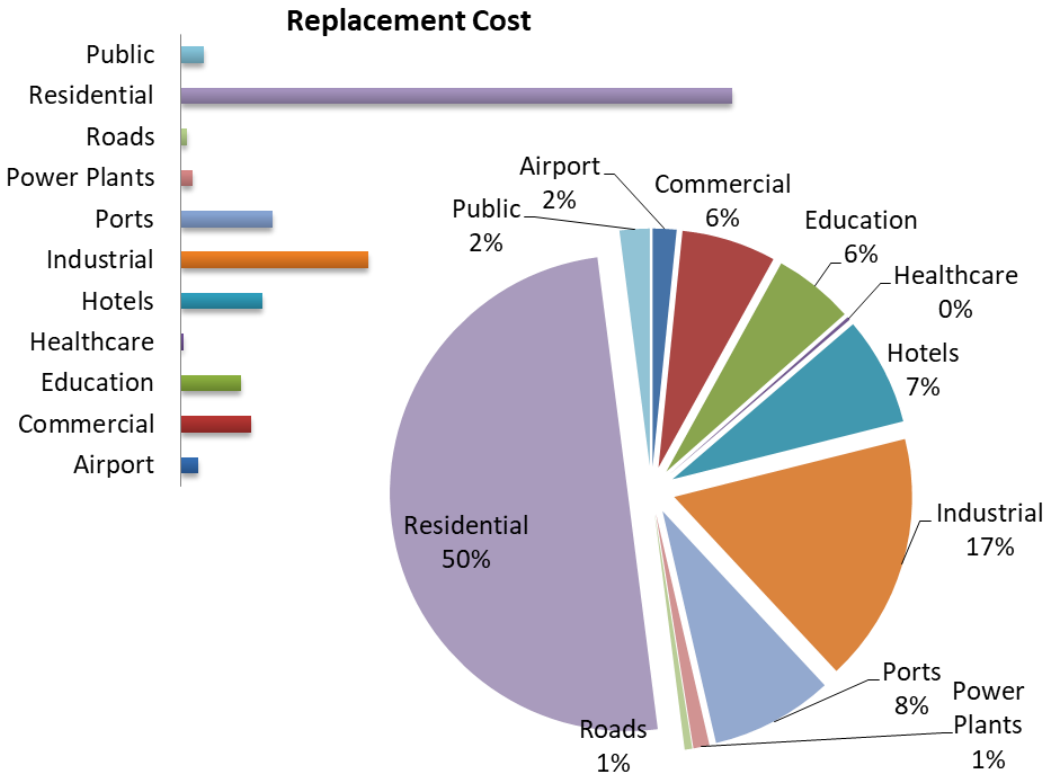


Exposure Module

- Using remotely sensed data and economic statistics from various sources, valuation estimates of the country's exposure are determined.

Categories included:

- Residential buildings
- Commercial buildings
- Public Buildings
- Industrial facilities
- Hotels and restaurants
- Healthcare infrastructure
- Energy Facilities
- Education infrastructure
- Airports and ports
- Transportation (roads) network



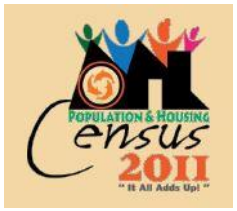
Exposure Module

- Using remotely sensed data and economic statistics from various sources, valuation estimates of the country's exposure are determined.

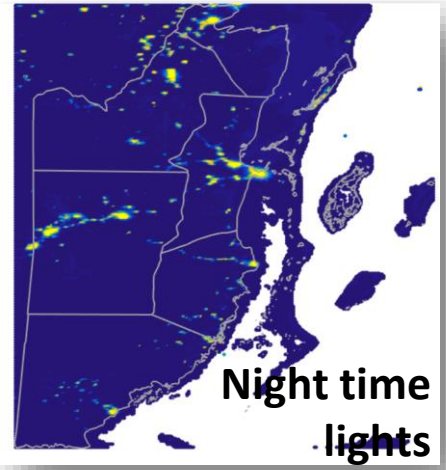
Exposure	Geographic Distribution Source	Valuation Derivation
Residential buildings	Census data and earth observation-based datasets	Number of dwelling units and their distribution calculated based on wall material and dwelling type
Commercial buildings and industrial facilities	Work force by sector	Required area per employee was consulted when available to estimate the total sector area.
Public buildings	Work force by sector	Required area per employee was consulted when available to estimate the total sector area.
Hotels, education and healthcare infrastructure	Public datasets	Since the number of assets by type was available at national level mostly, they were distributed across administrative divisions using the fractional labour share at this level as proxy.
Airports	Open Flights (country and region)	Estimated from airport location density and distribution as well as from airport capital development cost.
Ports	National, port size and type distribution	Port replacement costs per unit depending on the port dimension
Power facilities	Electricity generation detection algorithms.	Statistical use of energy and replacement costs per kind of energy.
Road Network	Satellite imagery	Cost per Km for different work type category and roads
Crops	Spaceborne remote sensing and ground-based data	Average production from historical records of crop yield.

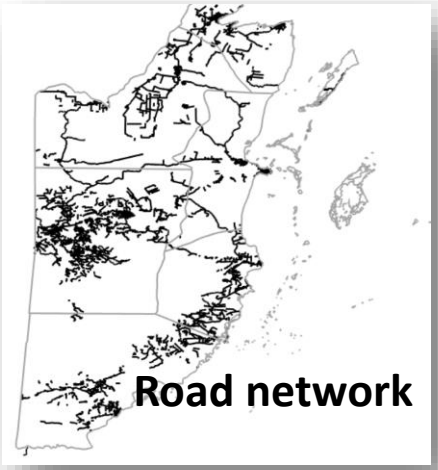
Exposure Module

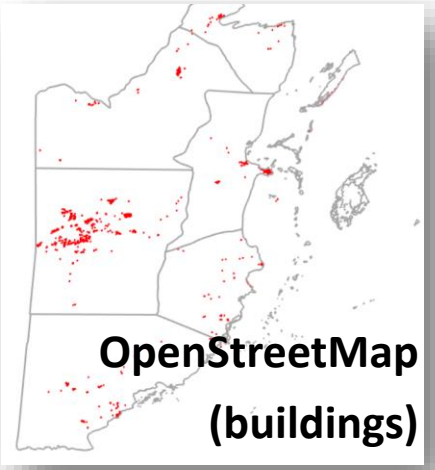
- The SPHERA IED is built and validated on country level census data, technical documentation, international peer-reviewed literature, publicly available reports and databases, and satellite images

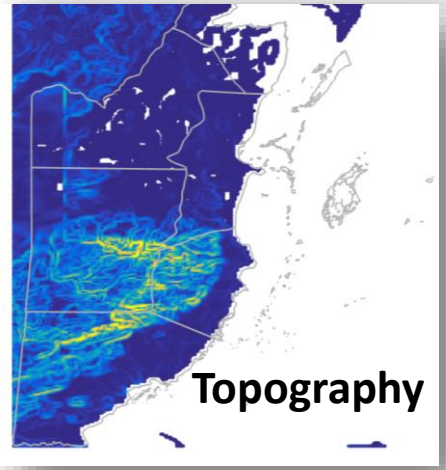


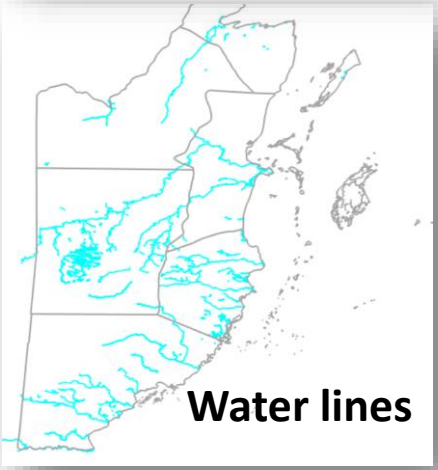
Exposure Database





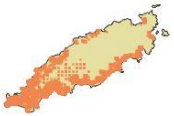




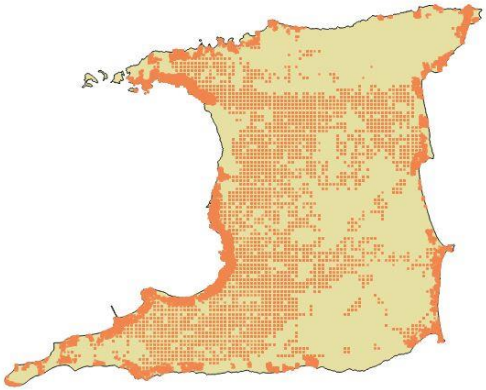


Exposure Module

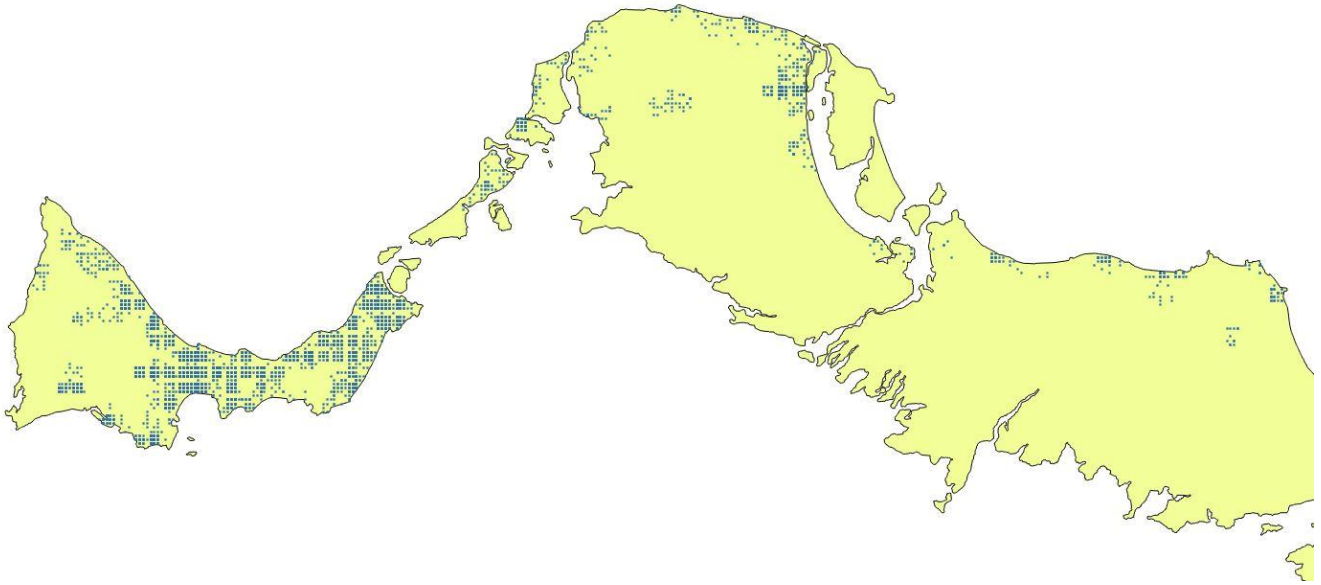
- 1x1 km resolution for internal areas
- 100x100m or 200x200m (depending on the info available) for coastal areas



Example: Trinidad and Tobago



Example: Turks and Caicos



Exposure Module

- Identification of the most common types of construction in each country
- Taxonomy defined to be used for different perils

Building Classes		
Code	**Number of stories**	**Description**
WL	1 - 2	Light wood members, low-rise
WS	1 - 2	Solid wood members, low-rise
WWD	1 - 2	Wattle and Daub, low-rise
A	1 - 2	Adobe construction, low-rise
UFM+LR	1 - 2	Unreinforced masonry, low-rise
SM	1 - 2	Stone masonry, low rise
MCF+ND+LR	1 - 2	Confined masonry, non-ductile, low-rise
MCF+D+LR	1 - 2	Confined masonry, ductile, low-rise
RM+ND+LR	1 - 2	Reinforced masonry, non-ductile, low-rise
RM+D+LR	1 - 2	Reinforced masonry, ductile, low-rise
S+ND+LR	1 - 2	Steel frame, non-ductile, low-rise
S+ND+MR	3 - 6	Steel frame, non-ductile, mid-rise
S+D+LR	1 - 2	Steel frame, ductile, low-rise
S+D+MR	3 - 6	Steel frame, ductile, mid-rise
S+INF+ND+LR	1 – 2	Steel frame, masonry infills, non-ductile, low rise
S+INF+D+LR	1 – 2	Steel frame, masonry infills, ductile, low rise
RC+INF+ND+LR	1 – 2	Reinforced concrete infilled frame, non-ductile, low-rise
RC+INF+ND+MR	3 – 6	Reinforced concrete infilled frame, non-ductile, mid-rise
RC+INF+ND+HR	> 7	Reinforced concrete infilled frame, non-ductile, high-rise
RC+INF+D+LR	1 – 2	Reinforced concrete infilled frame, ductile, low-rise
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RC+PC+LR	1 – 2	Pre-cast concrete
CR+LWAL+LR	1 – 2	Concrete wall and Covintec panel wall structures
UNK	ND	Unknown and informal construction



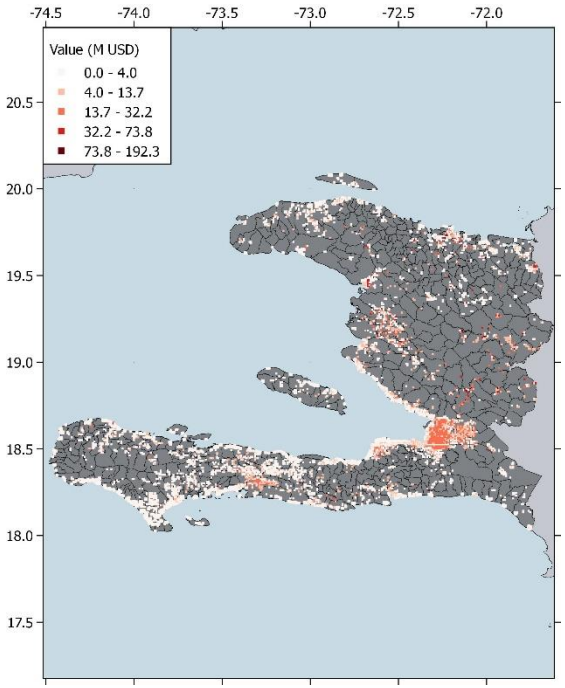




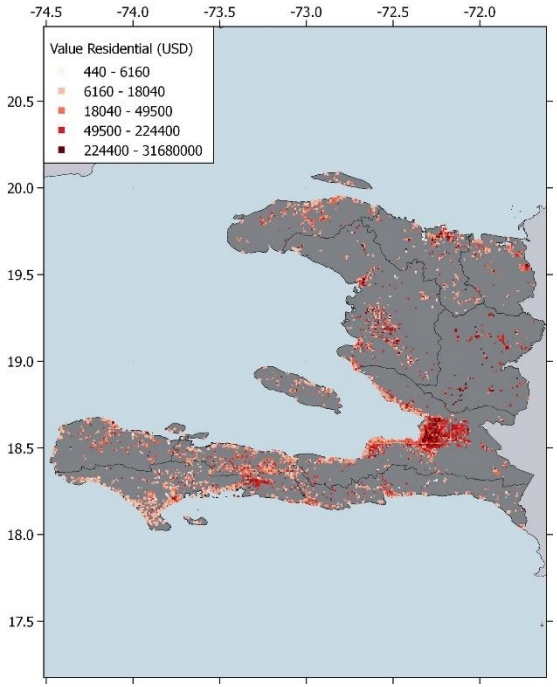

Exposure Module

- Example: Spatial distribution of economic value (Haiti)

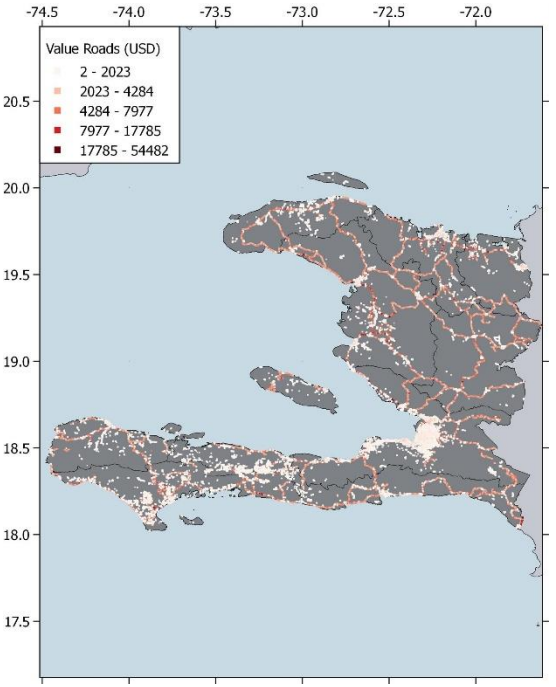
Total Exposure



Residential

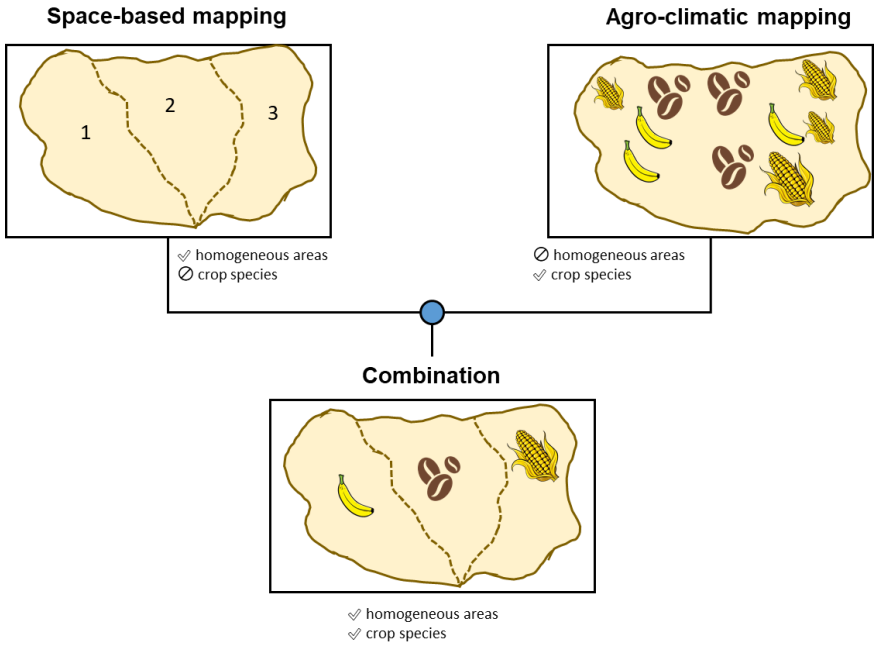


Road Network



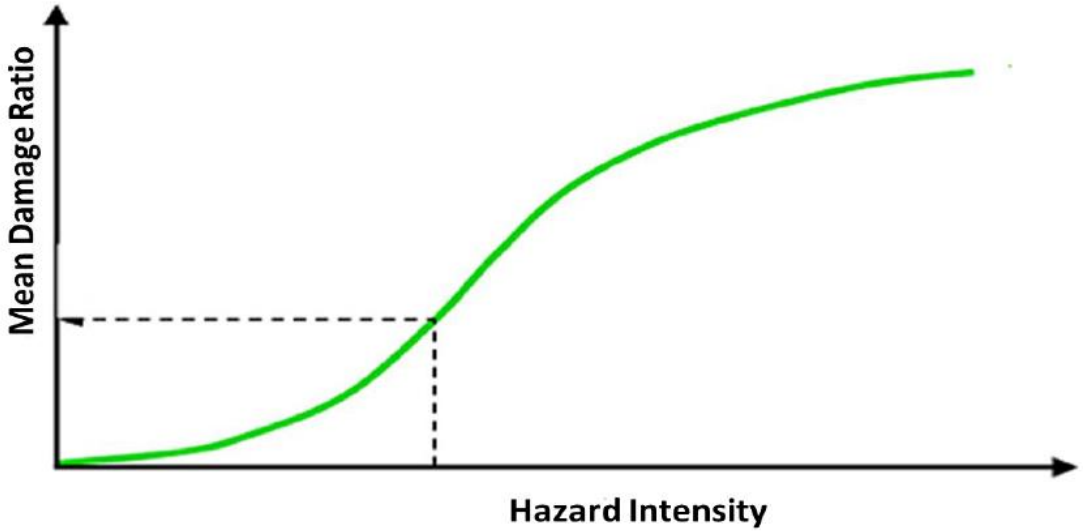
Exposure Module

- Crop exposure
  - MODIS-MCD12Q1 used to identify homogeneous zones (histogram analysis)
  - A crop type is assigned to each homogeneous zone, based on climate (precipitation and temperature), soils, elevation and land-use/vegetation maps.
  - Final results are compared with FAO statistics
  - Final resolution: 250 m



Vulnerability Module

- Susceptibility of an asset (building, infrastructure, crop) to be damaged by a tropical cyclone (wind, storm surge)
- Usually expressed through damage curves



- Mean damage ratio (MDR): repair cost divided by replacement cost of the structure

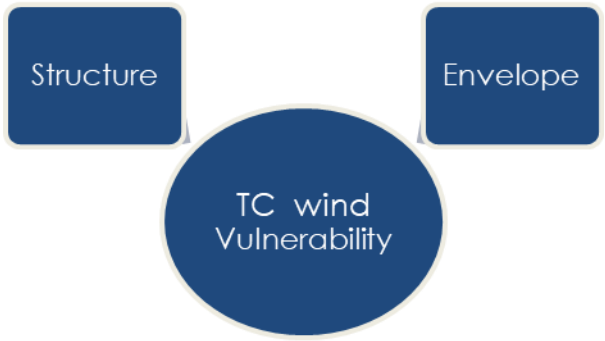
SPHERA – Vulnerability

- Damage functions assess the structural behaviour and fragility of the assets in the exposure
- For TC: Two damage mechanisms, hence two sets of damage functions:
  - **Wind** damage functions
  - **Storm surge** damage functions
- For EQ: damage based on ground shaking

- Literature review of existing fragility and vulnerability functions

SPHERA TC – Vulnerability

- Wind vulnerability



Types of envelope

Roof_shape	Arch
	Gable
	Hip
	Complex
	Flat/Monopitch
Roof_material	Sheet Metal/Eternite
	Shingle/Tiles
	Concrete
	Makeshift/Thatched
	Unknown
Shutter	None
	Present
Wall Opening	Windows <70% of walls
	Windows >70% of walls
	Walls without windows
	Open walls

Types of structure

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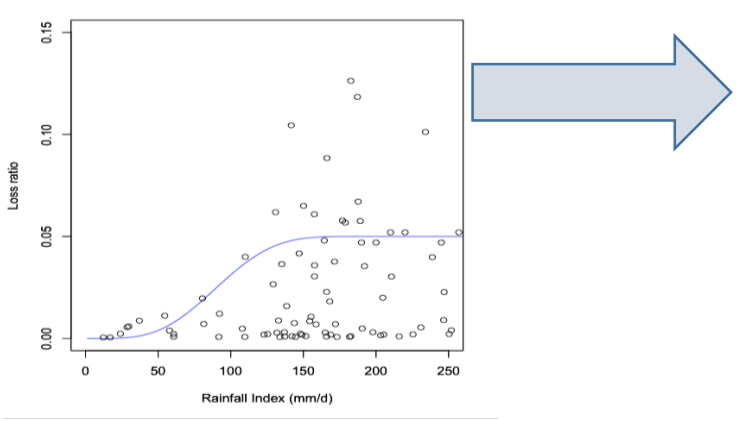
SPHERA TC – Vulnerability

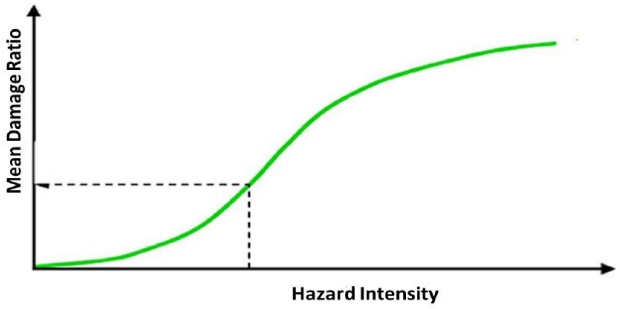
- Storm surge vulnerability
  - Dottori, F., et al., 2016. INSYDE: a synthetic, probabilistic flood damage model based on explicit cost analysis. Nat. Hazards Earth Syst. Sci. 16, 2577–2591
  - It takes into account:
    - hazard properties at the building locations (e.g., water depth)
    - characteristics of the exposed buildings (e.g., structural type)
    - replacement cost
  - Damage mechanisms of each building component described through a what-if analysis

XSR 2.5: Vulnerability Module

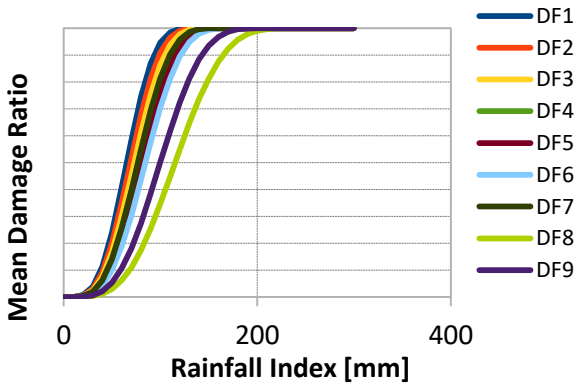
Vulnerability Module

- The vulnerability module provides a probabilistic relationship between event intensity and loss ratio (ratio between the damage and the total replacement cost).



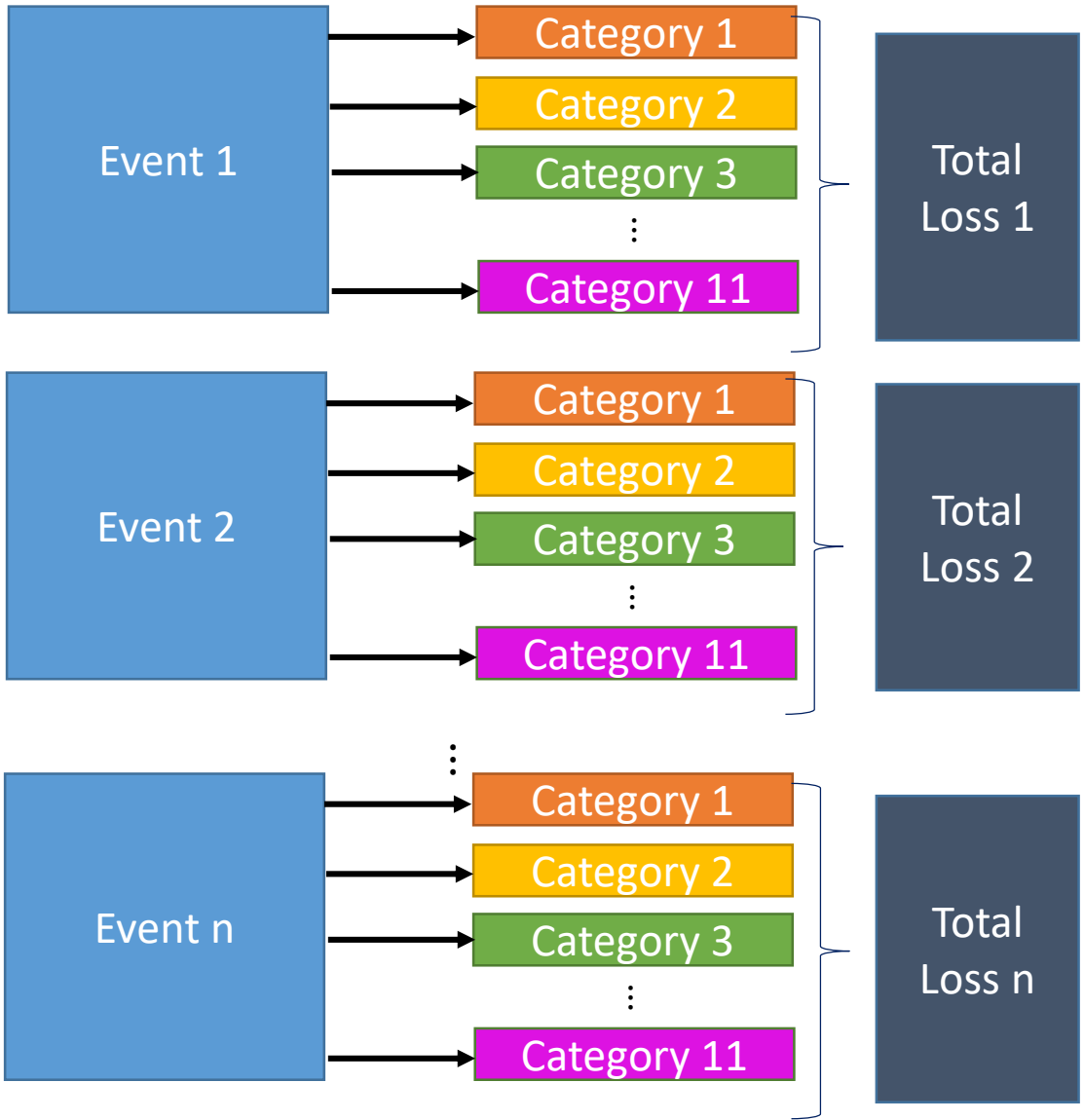


- Given the large size of the structure inventory and the lack of data to fully characterize each building individually, the vulnerability module considers classes of structures rather than individual buildings.



- The vulnerability functions derived for the different building classes were validated and calibrated using country-scale post-disaster loss data from past events.

Loss Assessment



$$L_i = V_i(H_i) \times E_i$$

The loss module translates the damage ratio derived in the vulnerability module into a dollar loss by multiplying it by the value at risk for each asset class across the country.

Losses are then aggregated at the level governed by the policy (national or sub-national).

Loss assessment

Event	Loss
1	Loss $_1$
2	Loss $_2$
3	Loss $_3$
⋮	⋮
n	Loss $_n$

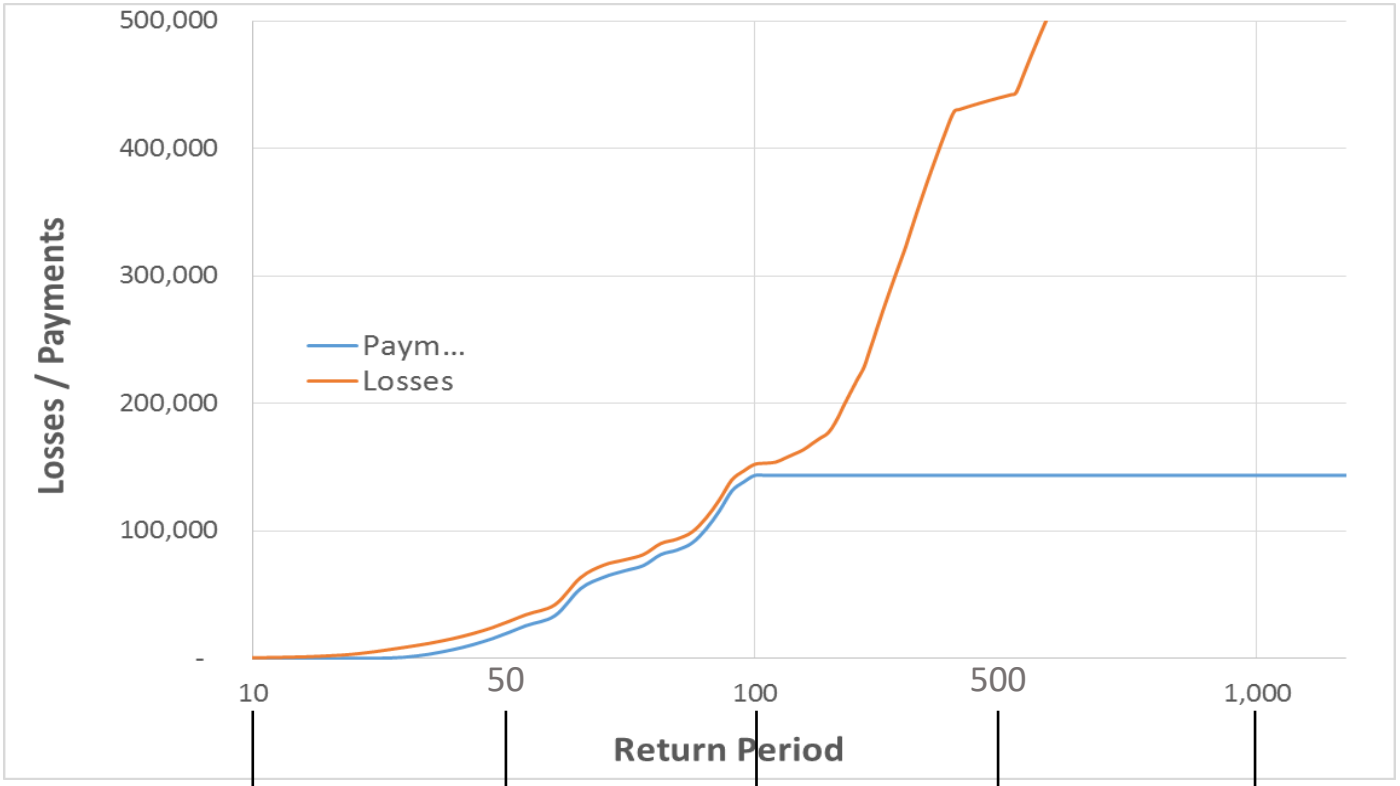
$$\textbf{Annual Probability of Exceedance of "Loss A"} = \frac{Number\ of\ times\ Loss\ A\ has\ been\ exceeded}{Number\ of\ Years}$$

$$\textbf{Return period of "Loss A"} = \frac{Number\ of\ Years}{Number\ of\ times\ Loss\ A\ has\ been\ exceeded}$$

Loss probability curves are generated from the results in the long-term loss event set.

Loss probability curve

Loss probability curve for a sample country



$$\text{Annual Probability of exceedance} = \frac{1}{\text{Return Period}}$$

10%	2%	1%	0.2%	0.1%

Insurance Module

The insurance module compares the modelled losses from the event to the conditions of the country's policy to determine if the policy is triggered and calculates the value of the payout.

A CCRIF policy is triggered when the modelled loss for an event in a member country equals or exceeds the attachment point specified in the policy contract.

The claims verification, administration and payout process

The main steps are:

- CCRIF uses **automated systems** which allows us to monitor every possible event that may trigger a payout under the terms and conditions of a country's policy. The system detects **earthquakes, tropical cyclones and rainfall** events.

- For XSR, according to the policy conditions, there is a **minimum number of days** required to compute the accumulation of rain: for example, **two days** with **one day tolerance**. Also, a rainfall event is not considered complete until the rainfall has fallen below a given threshold (**for example: 30 mm**) for **two consecutive days**.

- CCRIF issues an **event briefing** after an event has been completed if there has been a loss above a certain value across most of the country.

- If a country's policy is triggered by an event (i.e. if the country losses are greater than the policy's Attachment Point), **CCRIF will automatically contact the Ministry of Finance** about the next steps required to receive payment.

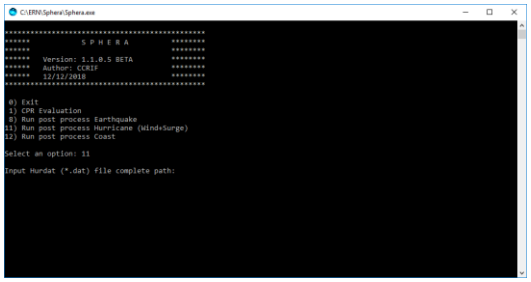
TC: Real-time operation

1 - NOAA activates a tropical cyclone alert

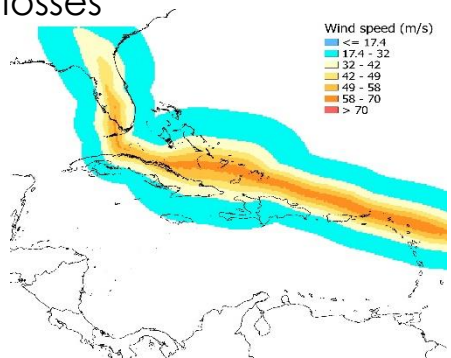
2 - NOAA produces a best track file

```
AL, 11, 2017082806, 01, CARQ, -24, 117N,  174W,  25,    0, DB,  34,
AL, 11, 2017082806, 01, CARQ, -18, 118N,  179W,  25,    0, DB,  34,
AL, 11, 2017082806, 01, CARQ, -12, 119N,  184W,  25,    0, DB,  34,
AL, 11, 2017082806, 01, CARQ,  -6, 120N,  190W,  25,    0, DB,  34,
AL, 11, 2017082806, 01, CARQ,   0, 120N,  195W,  25, 1009, DB,  34,
AL, 11, 2017082806, 01, CARQ,   0, 120N,  195W,  25, 1009, DB,  50,
AL, 11, 2017082806, 01, CARQ,   0, 120N,  195W,  25, 1009, DB,  64,
AL, 11, 2017082806, 03, CLP5,  12, 123N,  209W,   0,    0,  ,   0,
AL, 11, 2017082806, 03, CLP5,  24, 128N,  224W,   0,    0,  ,   0,
AL, 11, 2017082806, 03, CLP5,  36, 134N,  242W,   0,    0,  ,   0,
AL, 11, 2017082806, 03, CLP5,  48, 141N,  263W,   0,    0,  ,   0,
AL, 11, 2017082806, 03, CLP5,  60, 147N,  286W,   0,    0,  ,   0,
```

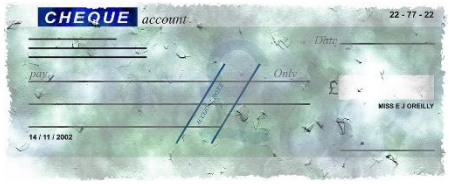
3 – CCRIF's calculation agent runs SPHERA using the best track file as input



4 - SPHERA produces estimates of wind speed, storm surge and economic losses



5 – Given the country's policy parameters, if the losses are above the attachment point, a payout is computed

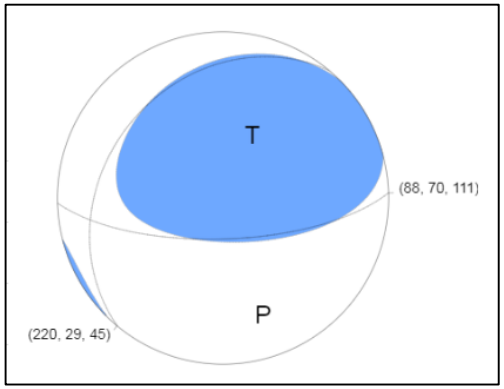


How CCRIF Policies are Triggered and Payouts Calculated – EQ

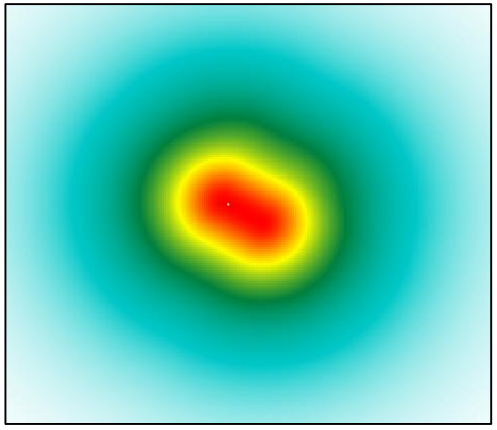
1 - USGS reports an EQ

2 – USGS reports magnitude, depth and moment tensor solution

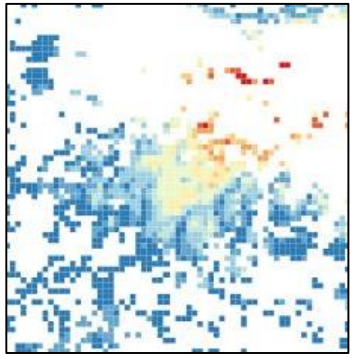
M=7.3
10.773° N
62.902° W
Depth=146.8km



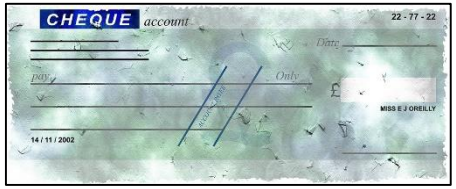
3 – CCRIF's calculation agent runs SPHERA using the USGS parameters as input



4 - SPHERA produces estimates of ground motion intensities and economic losses

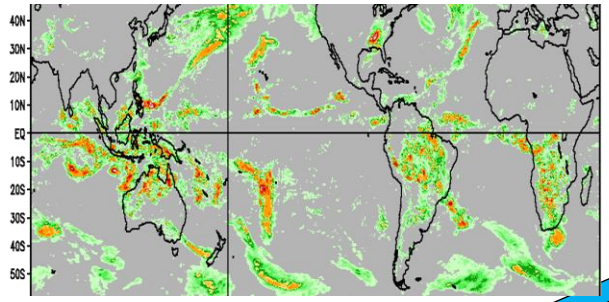


5 – Given the country's policy parameters, if the losses are above the attachment point, a payout is computed



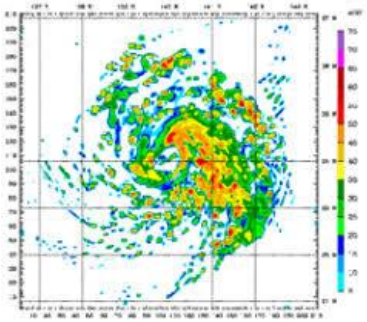
XSR 2.5 Real Time Operation

1 - NOAA provides global data of CMORPH, GFS FNL and ADP

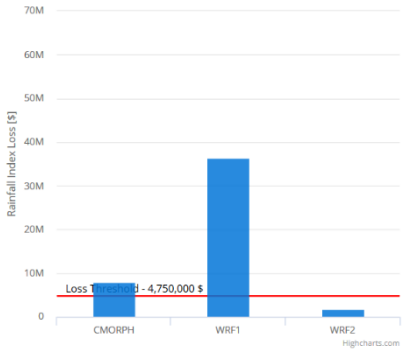


2 – The data are downloaded and cut over the geographical domain

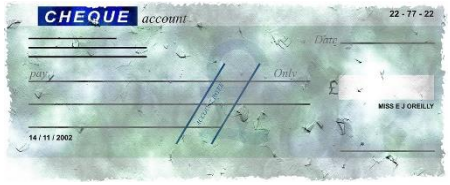
3 – CCRIF's calculation agent runs the WRF model



4 – XSR produces estimates of economic losses



5 – Given the country's policy parameters, if the losses are above the attachment point, a payout is computed



SPHERA Tropical Cyclone Risk

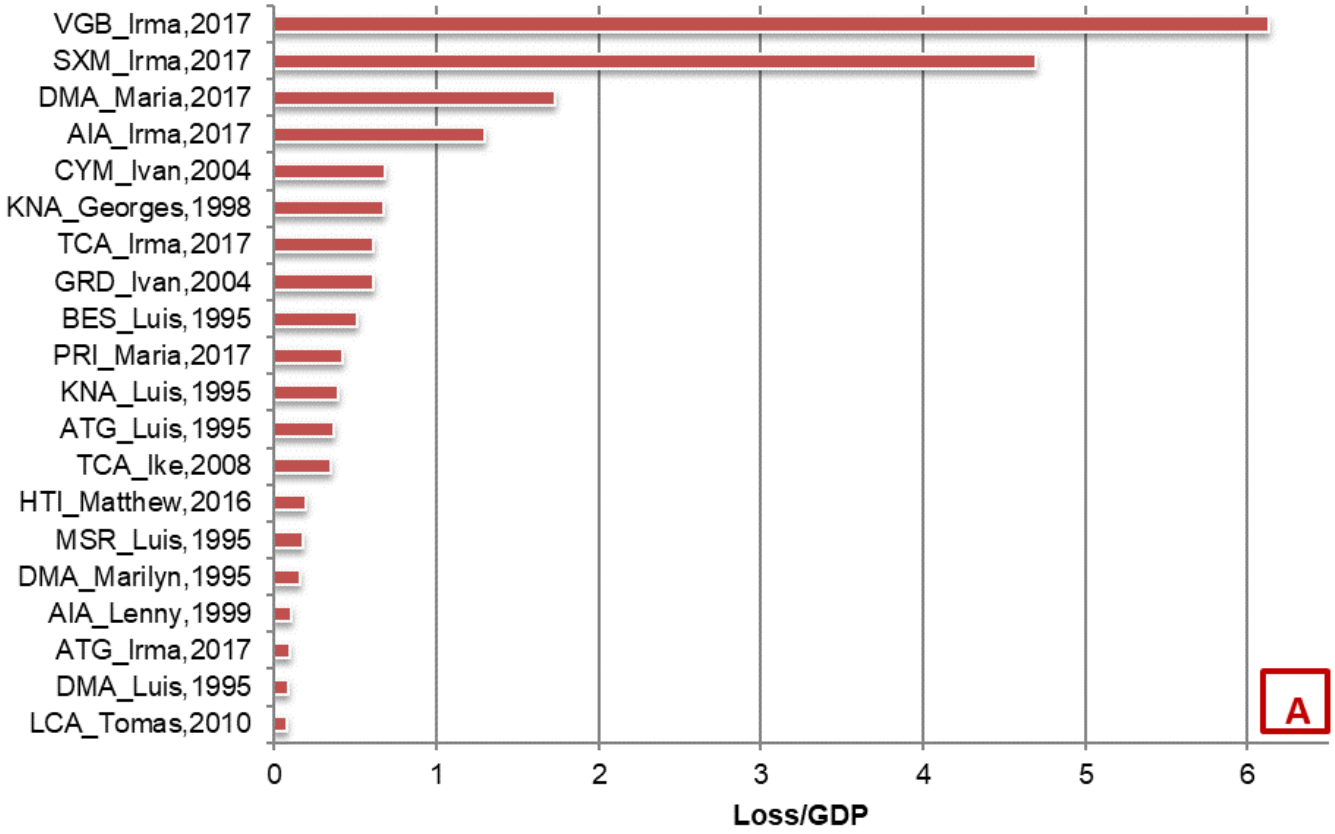
Model validation

SPHERA TC – Consequence database

- Consequence database: database of 700+ country-scale events and their corresponding loss assessment (from DALA, PDRA or other post-disaster assessment methodologies)
- From disaster databases (**EM-DAT**), international agencies (**ECLAC**), meteorological agencies (**NOAA**),local agencies (**CDEMA**), insurance/re-insurance companies (**MunichRe**, **SwissRe**, **AON**), …
- Purpose: **model validation**

SPHERA TC – Consequence database

- Consequence database
  - Most harmful events (1990-2018) in CCRIF's member countries

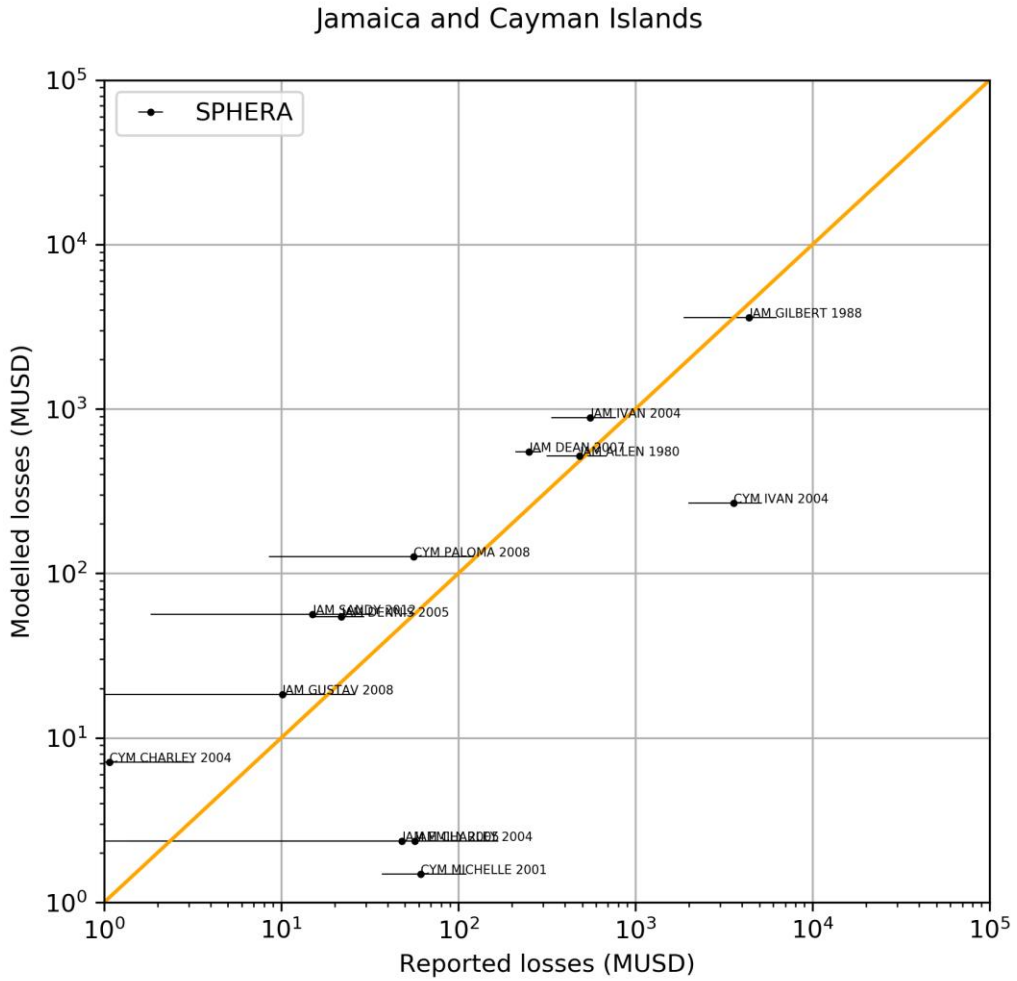


SPHERA TC – Consequence database

- Consequence database limitations
  - Rainfall losses removed (SPHERA only computes direct losses) -> uncertainty!
  - Trending to 2016 USD -> uncertainty!
  - Different sources give very different values -> uncertainty!
  - What do the reported values include? Business interruption, contents, …? -> uncertainty!
- In many cases, reported losses only give a very approximate indication of the “real” losses

SPHERA TC – Validation

- Validation: reported losses vs modelled losses



Understanding the role of country risk profiles

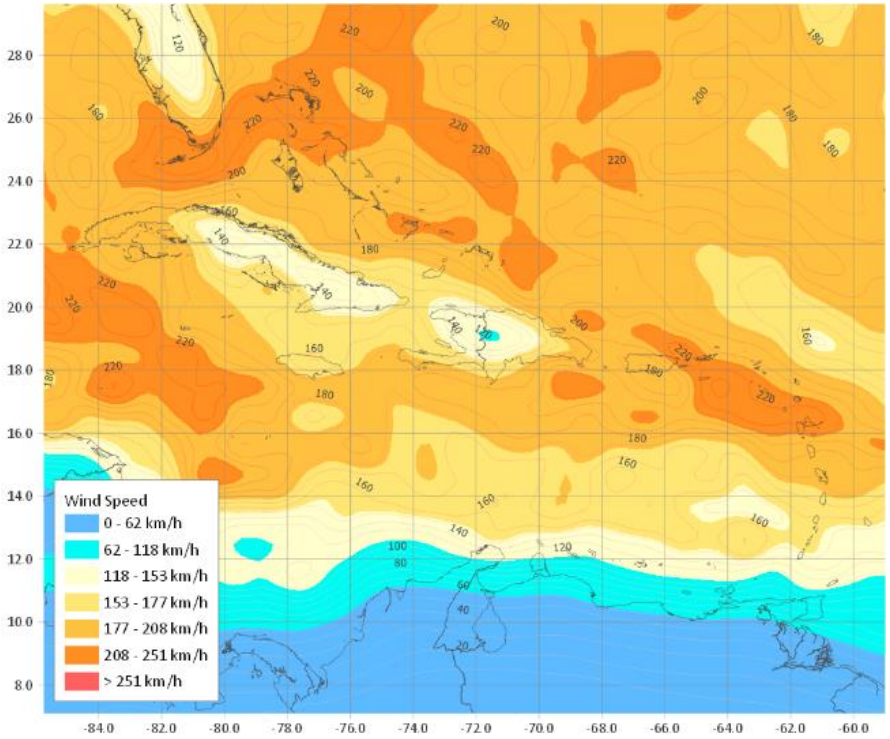
AIM

- ✓ **Provide information to the Country Risk Managers with simplicity, accuracy and robustness** about the demographical, geological, economic characteristics of their territories.
- ✓ **Assess the impact of historical losses** which may have caused damages, both to the infrastructure, population and economy
- ✓ **Illustrate and facilitate the risk transfer decisions.**
- ✓ **Help decision-making process**, but not substitute it. A country risk manager has to make his/her own decision and decide what is best for the country, given the combination of exposure to risk, risk proneness and also considering budgeting restrictions.

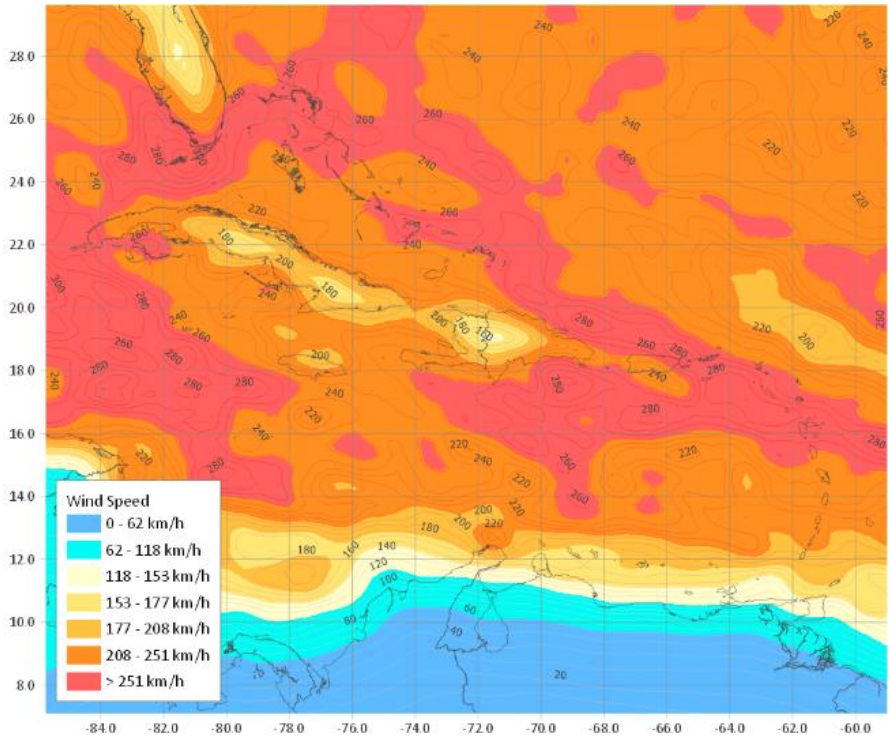
CONTENT

- ✓ Hazard Profile
- ✓ Exposure Profile
- ✓ Risk Profile
- ✓ **Most severe historical events and their estimated economical loss**, (give to a country risk manager a range of amounts by peril to help him/her to make decisions)

Tropical Cyclone - Hazard

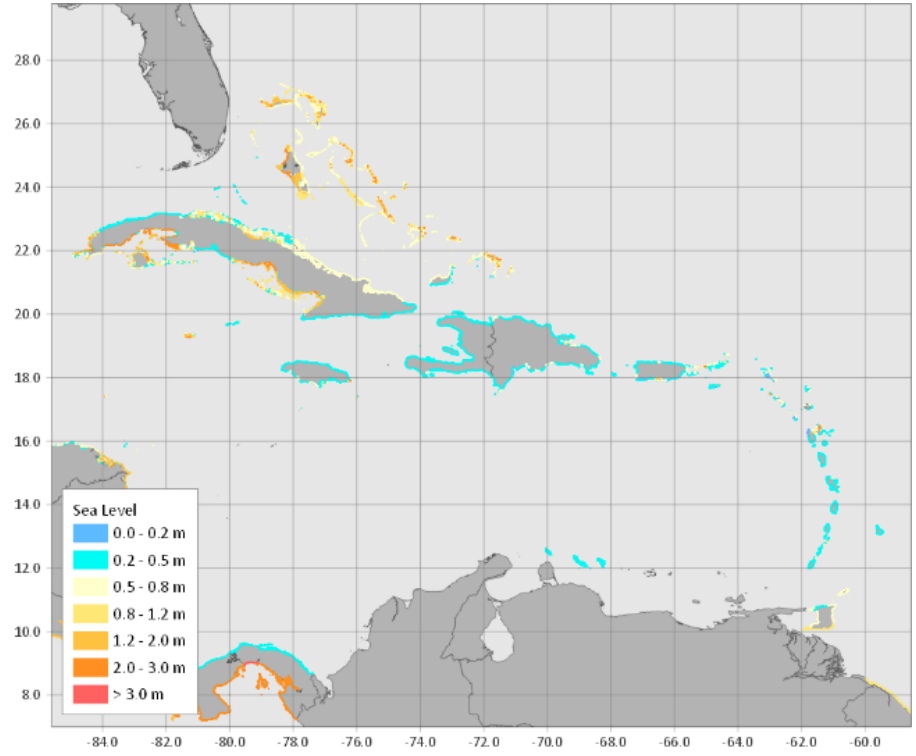


Wind speed for return period of 50 years

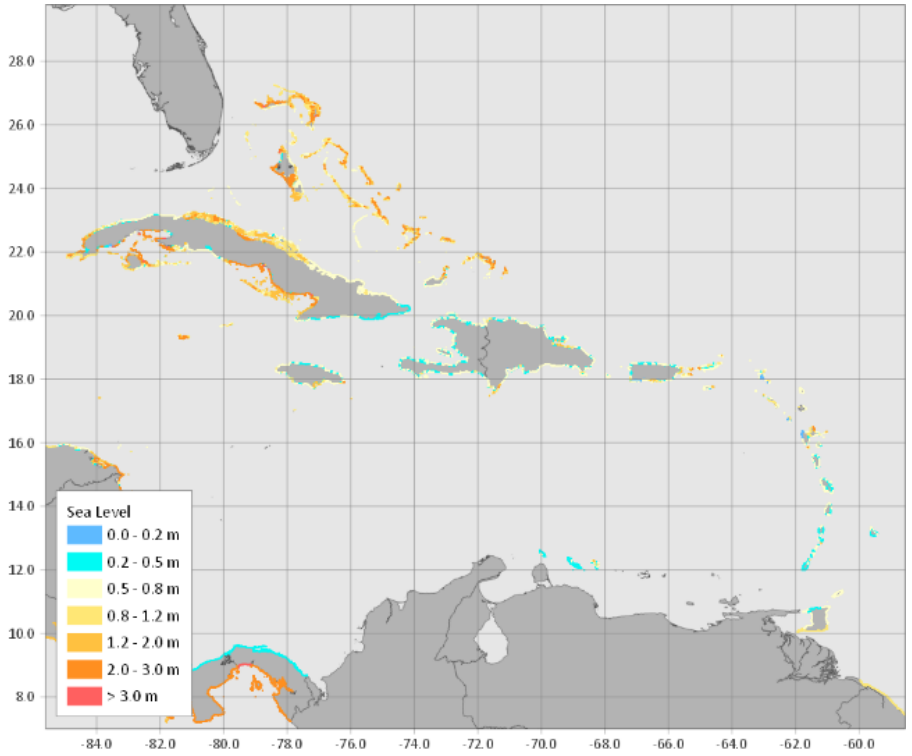


Wind speed for return period of 250 years

Tropical Cyclone - Hazard

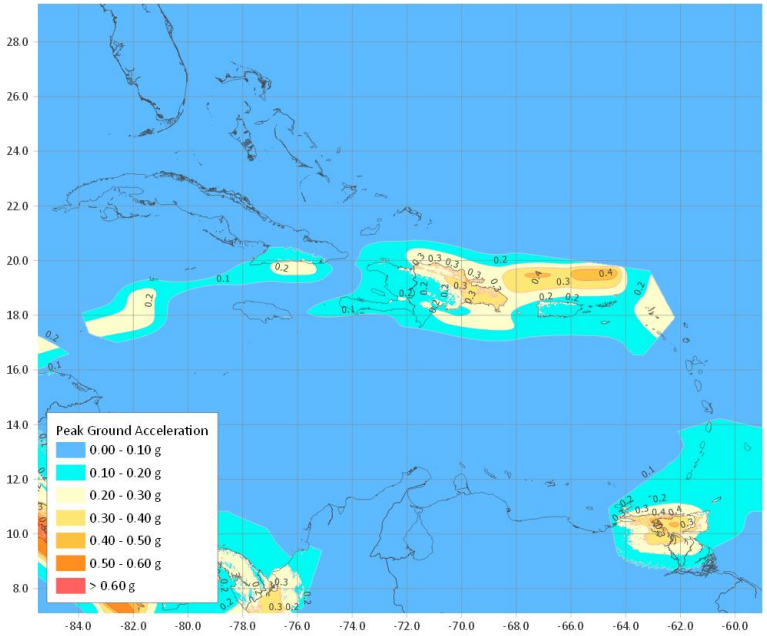


Sea level for return period of 50 years
storm surge + astronomical tide

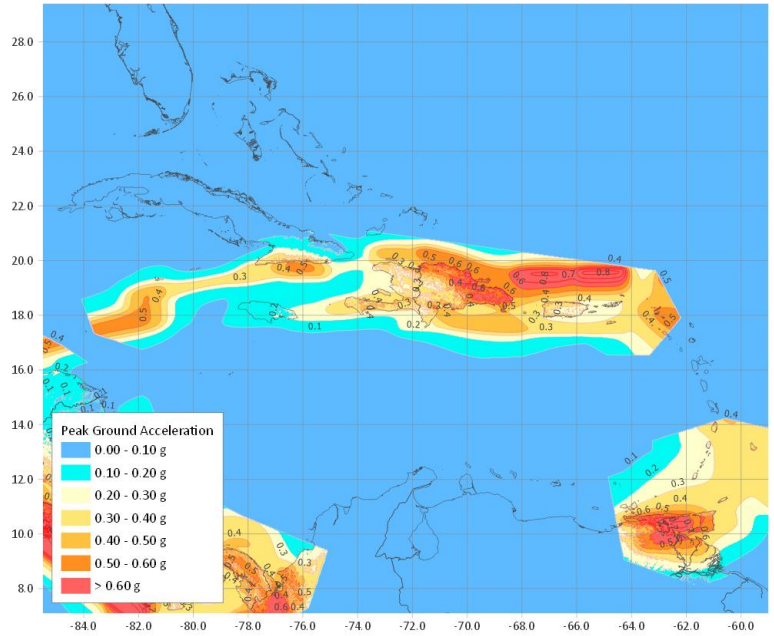


Sea level for return period of 250 years
storm surge + astronomical tide

Earthquake- Hazard

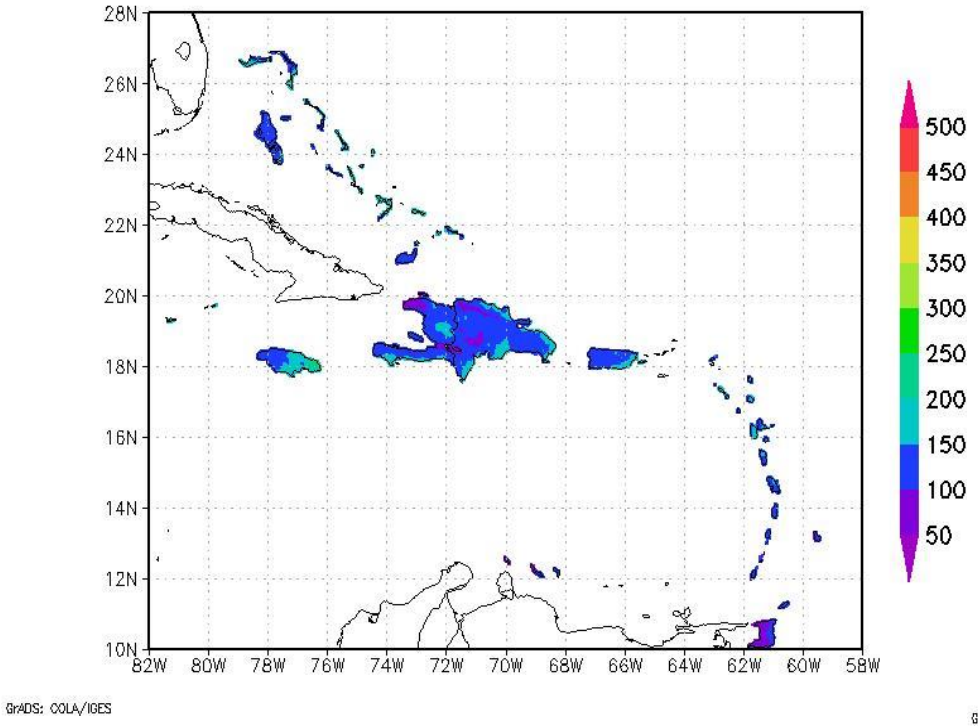


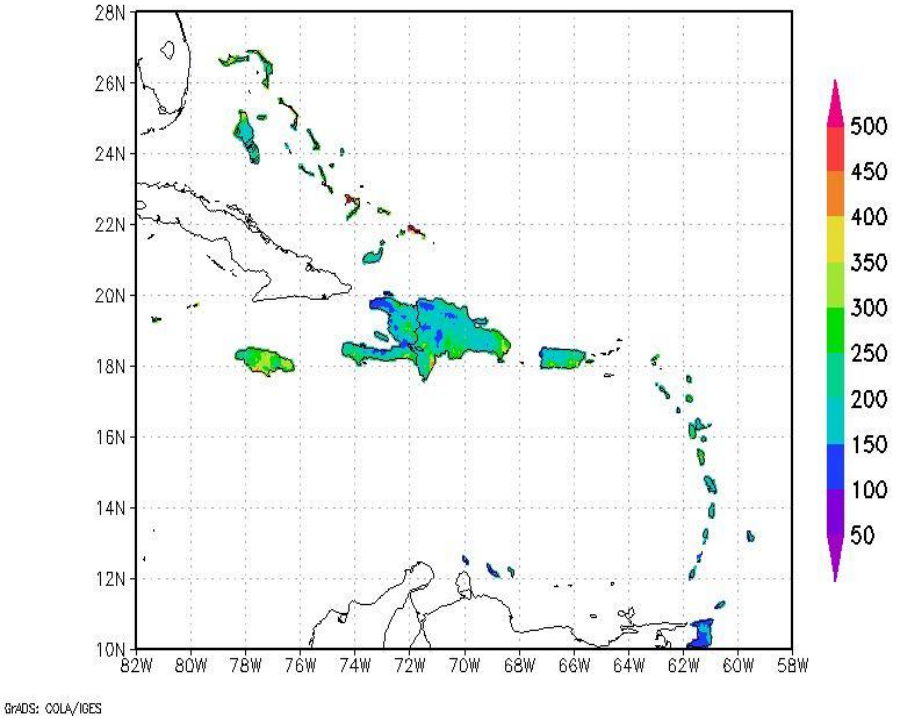
Peak Ground Acceleration (g) with an average return period of 95 years



Peak Ground Acceleration (g) with an average return period of 475 years

Excess Rainfall- Hazard

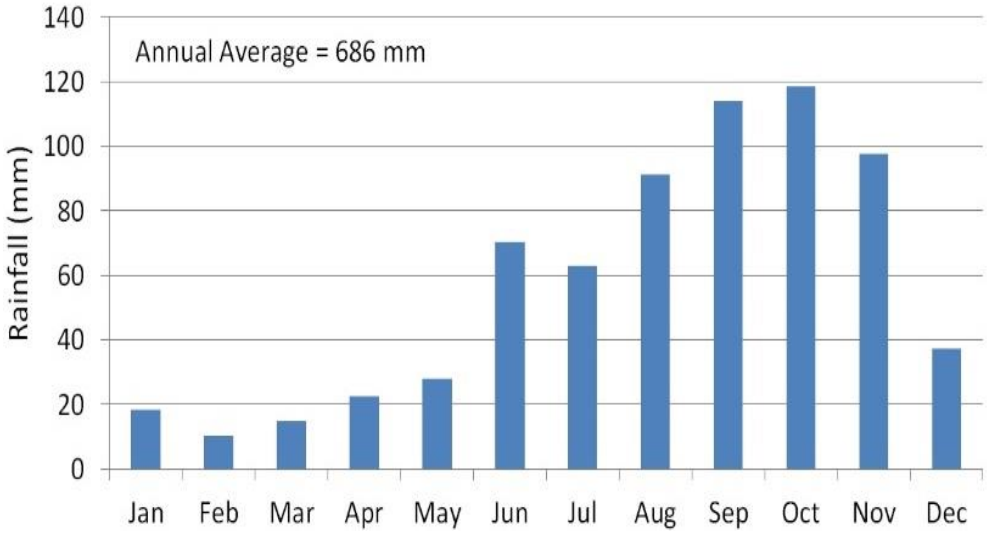




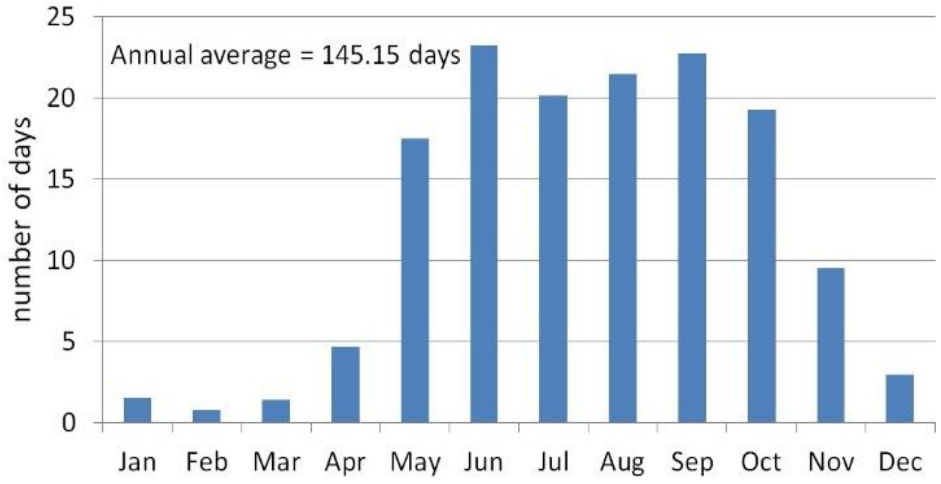
Hazard maps with return period 5 years for the country (amount of daily rainfall in mm)

Hazard maps with return period 25 years for the country (amount of daily rainfall in mm)

Excess Rainfall- Hazard



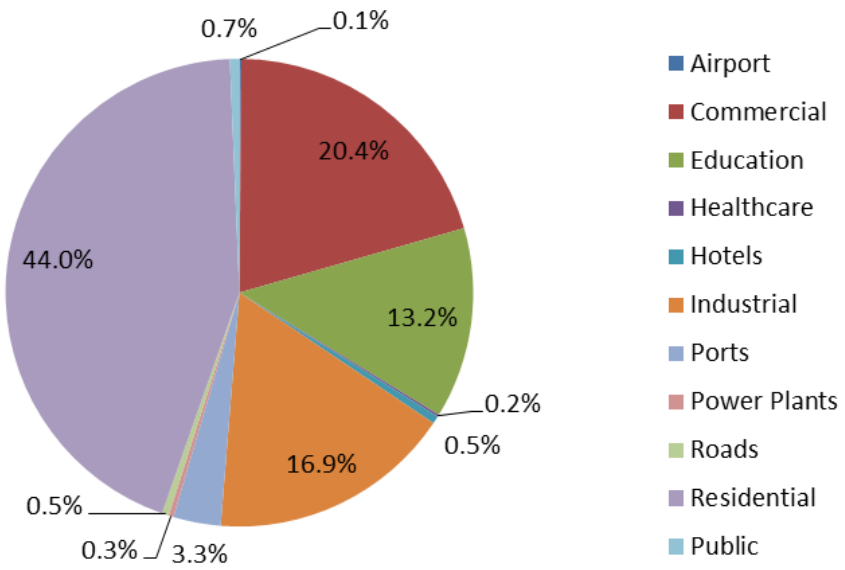
Average monthly rainfall in Country "A" for the period 1998-2018. Excess rainfall events are expected to occur almost exclusively during the wet season (between May and November)

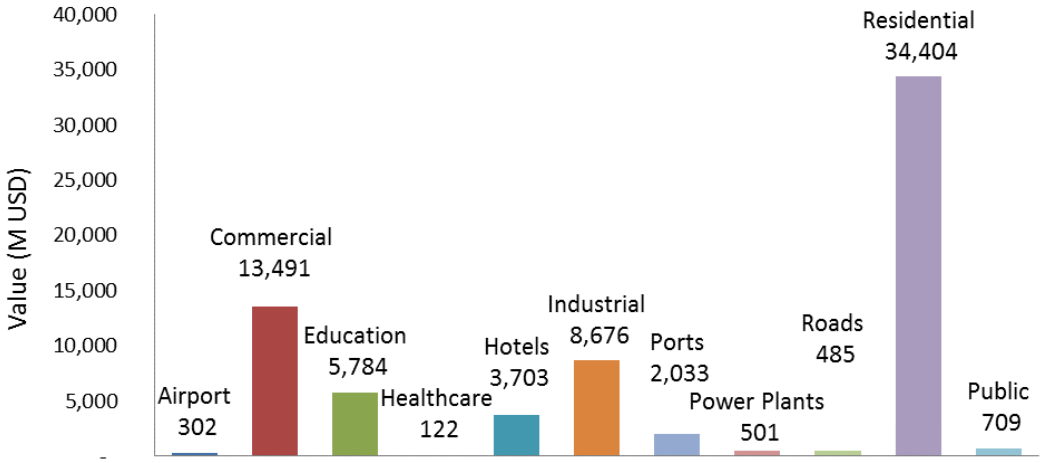


Monthly average number of days with extreme precipitation (over 50 mm/d at least at one location) in Country "A" for the period 1998-2018

Exposure

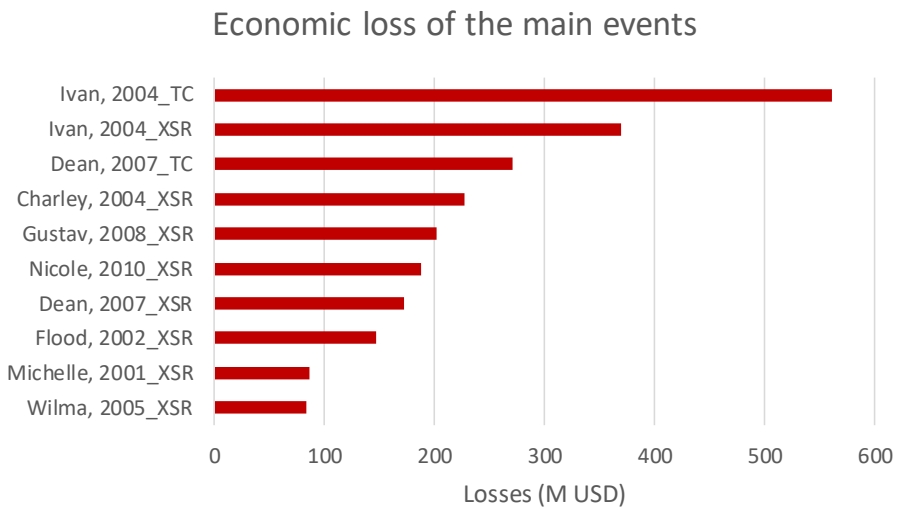
The two graphs show the breakdown of the replacement value of the assets at risk, classified by occupancy class, in terms of percentage (top) and absolute value (bottom).



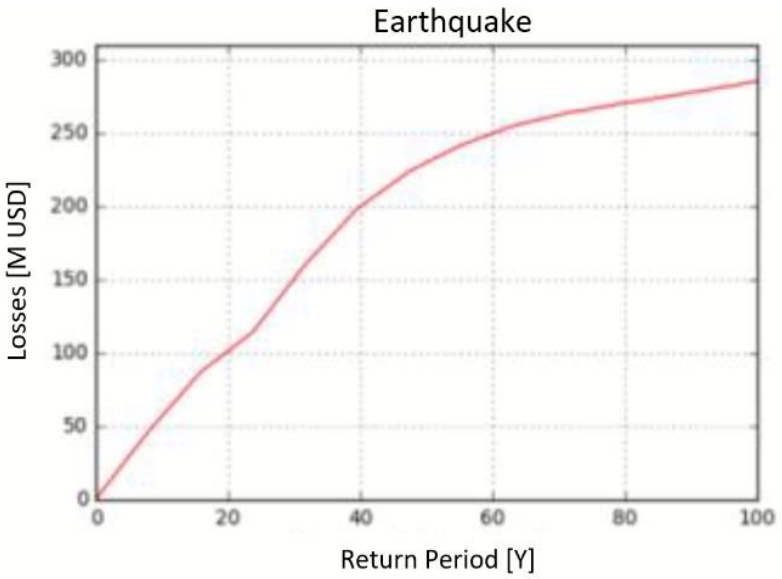


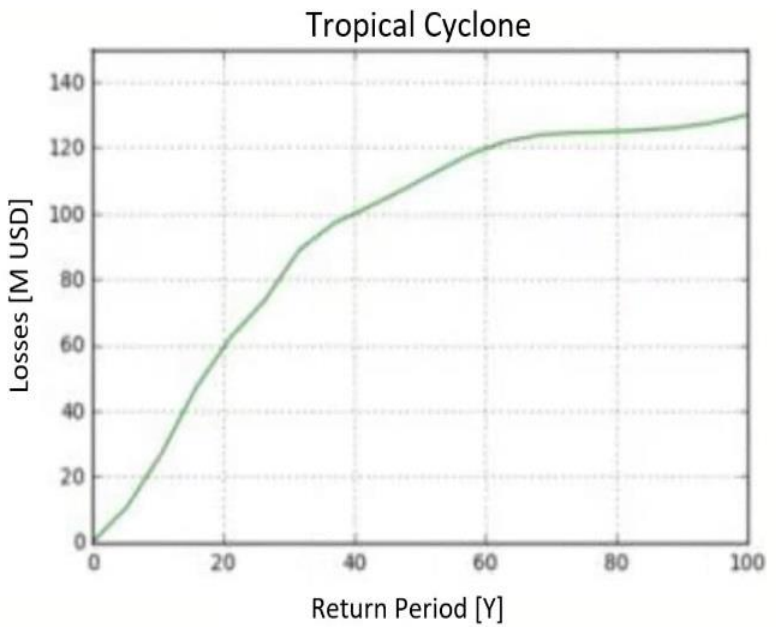
Historical Losses

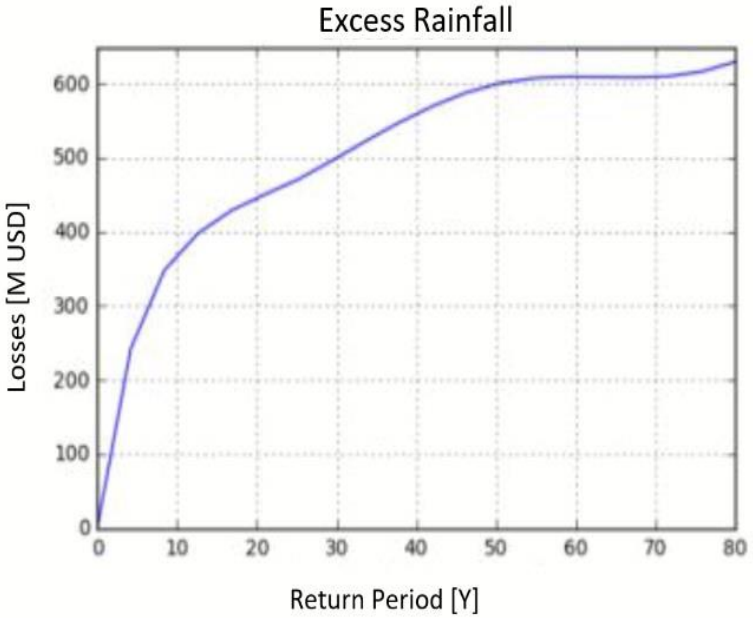
Event	*Hazard*	*Start Date*	*End Date*	*Hurricane Category*	*Number of fatalities*	*Losses (M USD)*
Ivan, 2004	TC	10/9	12/9	HU4	17	560.875
Ivan, 2004	XSR	10/9	12/9	HU4	17	370.36
Dean, 2007	TC	19/8	20/8	HU4	4	270.548
Charley, 2004	XSR	11/8	12/8	HU1	1	226.8
Gustav, 2008	XSR	28/8	30/8	TS	14	202.22
Nicole, 2010	XSR	28/9	29/9	TS	13	187.55
Dean, 2007	XSR	19/8	20/8	HU4	4	172.75
Flood, 2002	XSR	22/5	30/5		9	147.1
Michelle, 2001	XSR	2/11	4/11	TS	3	86.43
Wilma, 2005	XSR	15/10	20/10	TD	1	82.69



Risk

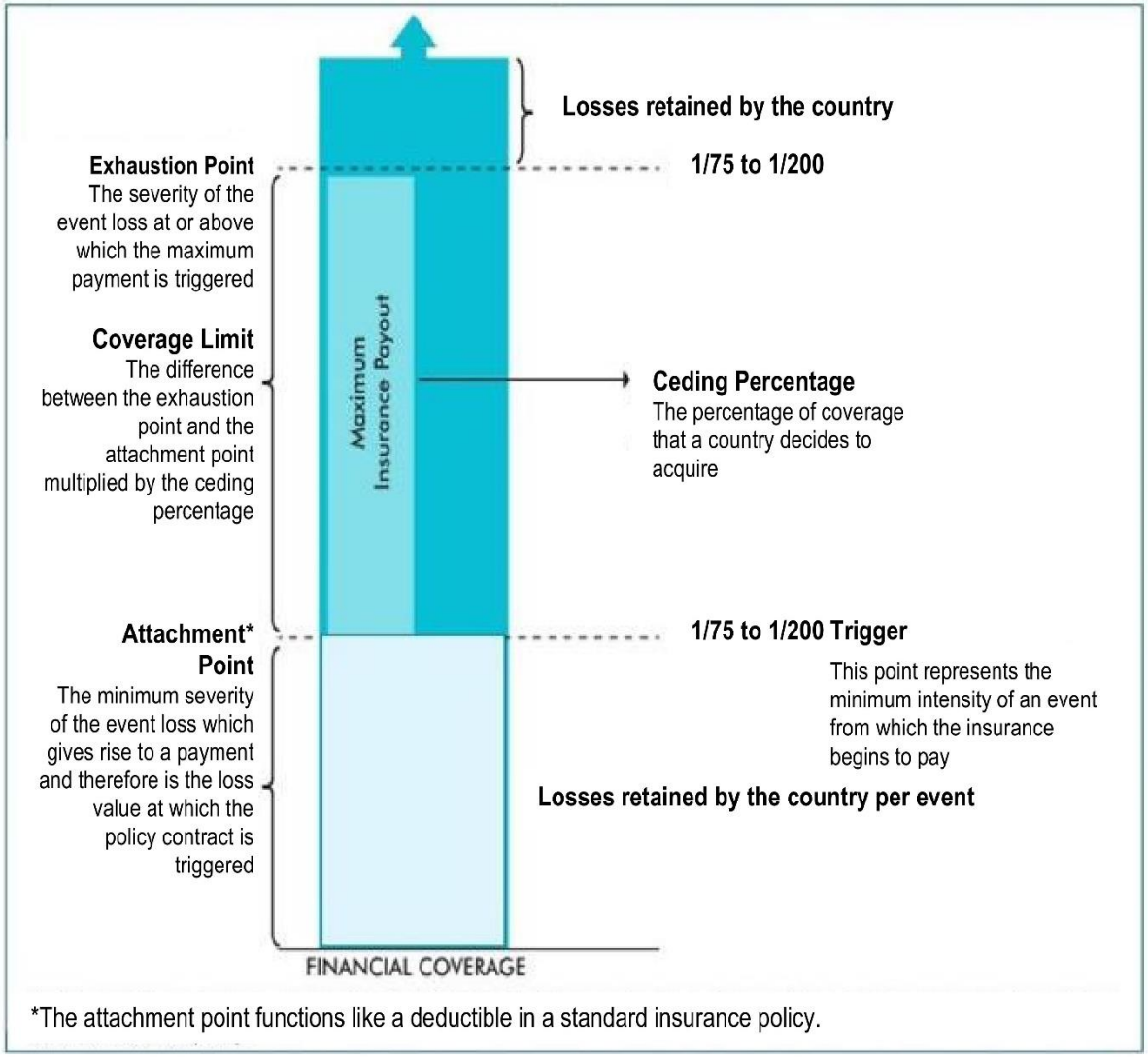






Return Period (Years)	Loss (M USD) EQ	Loss (M USD) TC	Loss (M USD) XSR
5	25	10	270
10	60	25	370
25	120	70	470
50	230	110	600
Average Annual Loss	75	55.5	295

Elements of CCRIF Policies



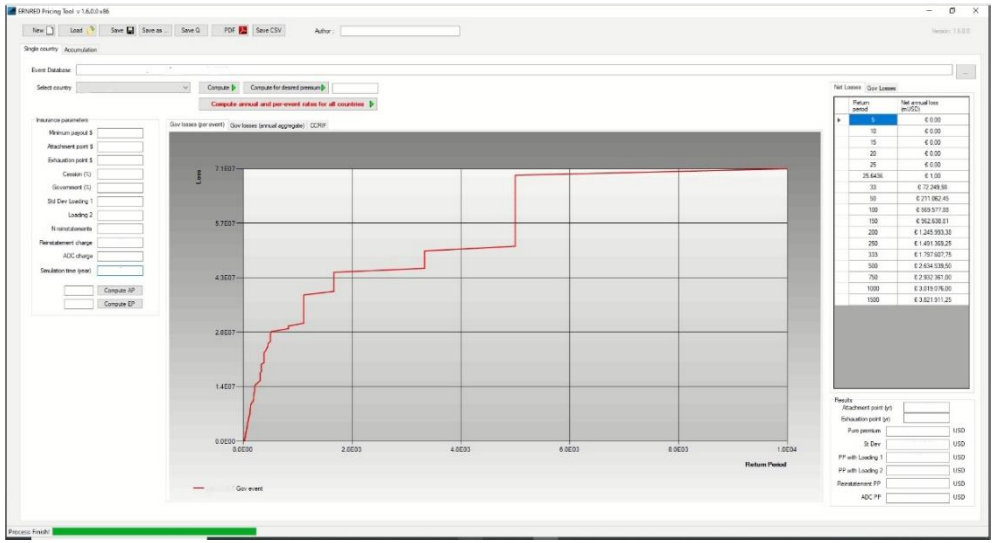
CCRIF policy premiums depend on the selection by Governments of 3 elements:

- **Attachment Point**
- **Ceding Percentage**
- **Exhaustion Point**

These are informed by the country's risk profiles

A CCRIF policy is triggered when the modelled loss for an event in a member country equals or exceeds the attachment point specified in the country's policy contract.

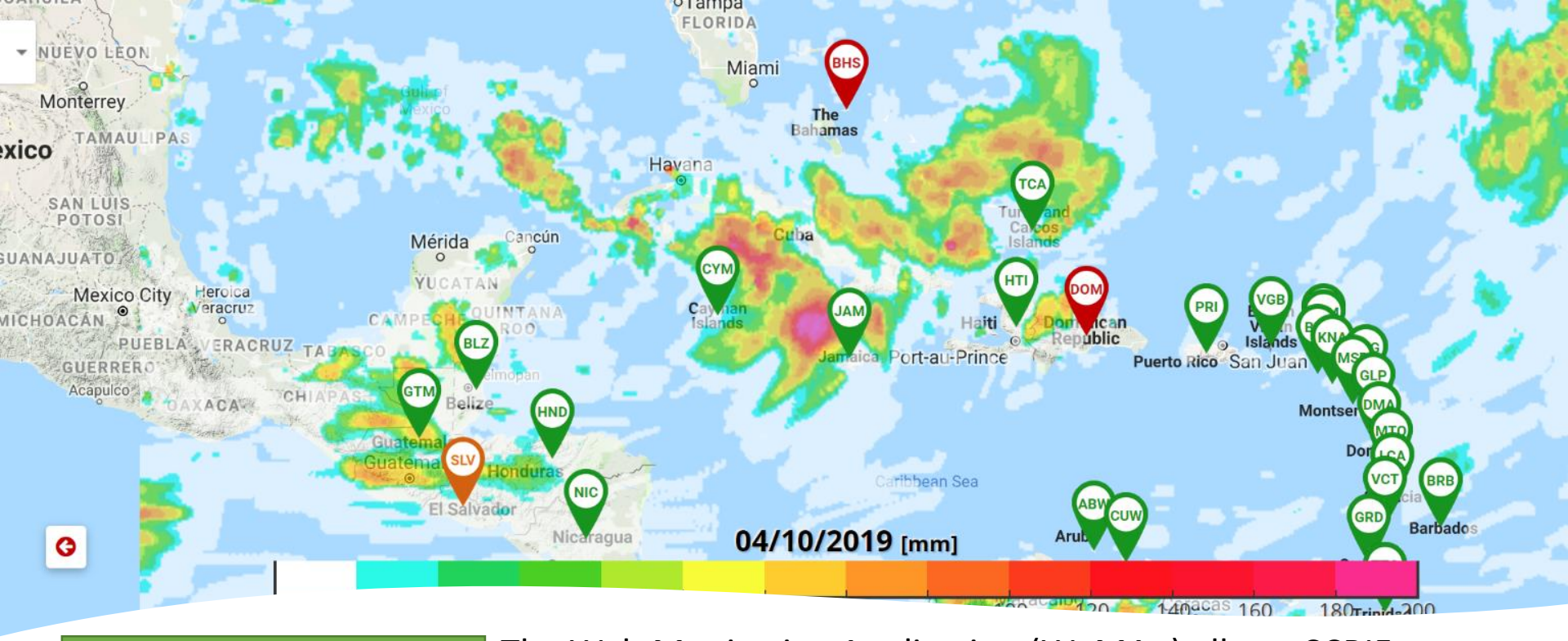
Determination of Premium Cost



- The cost of coverage for a country is directly proportional to the amount of risk being transferred by that country to CCRIF.
- It is based on:

  - the frequency with which the modelled losses are expected to exceed the selected attachment point.

  - the selected attachment point, exhaustion point and ceding percentage.
- Standard pricing approaches are used.
- CCRIF does not charge any “earnings” component as it operates as a not-for-profit organization.

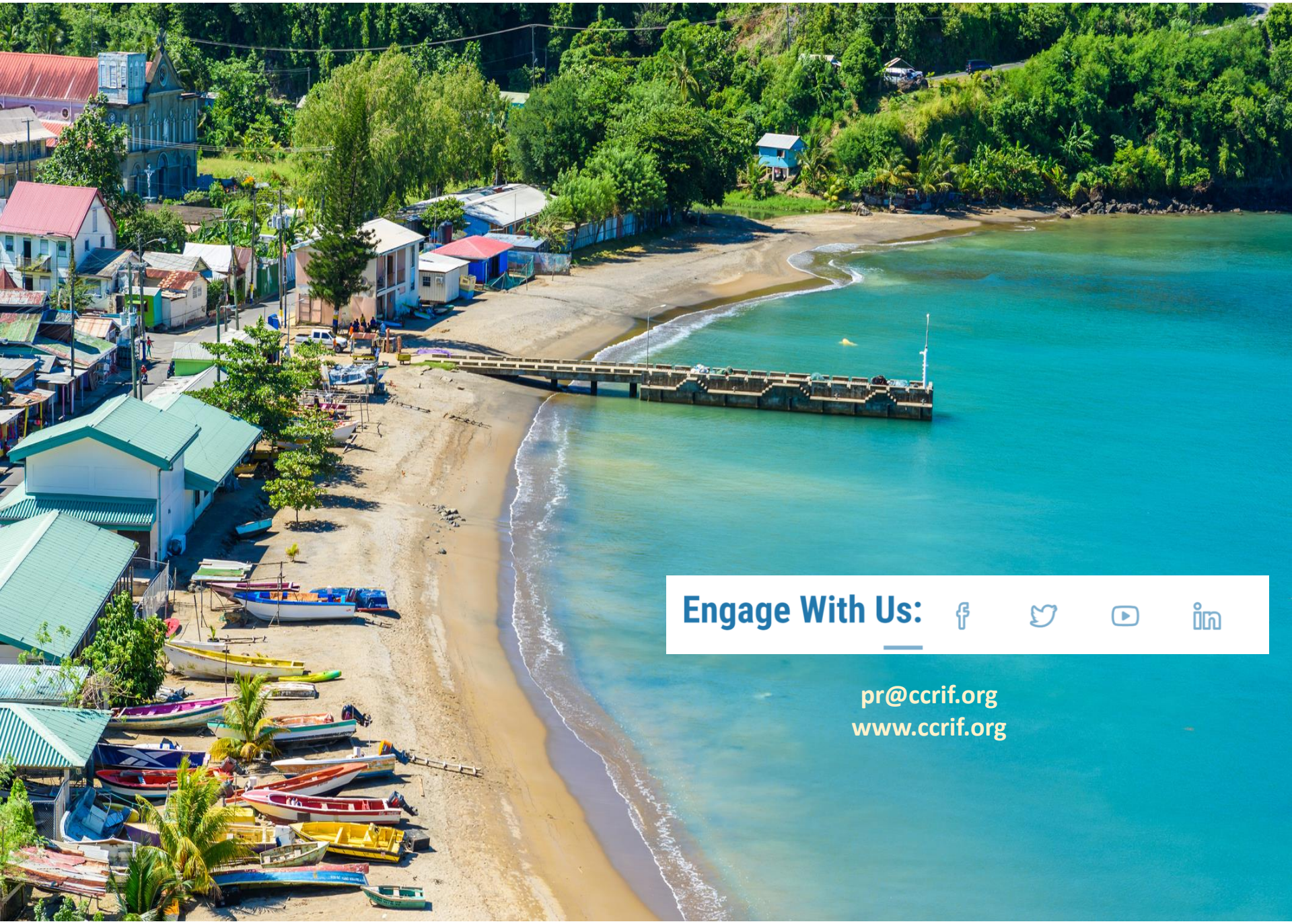


WeMAp

wemap.ccrif.org

The Web Monitoring Application (WeMAp) allows CCRIF members and other users to monitor earthquakes as well as the development of potentially damaging heavy rainfall, tropical cyclones, and earthquakes and analyze their intensity and assess their impact, as well as check whether an active insurance policy with CCRIF is likely to be triggered.

It has 4 components: the Real-Time Forecasting System (RTFS) for tropical cyclones (an update of the original CCRIF RTFS) and Monitoring Tools for tropical cyclones, earthquakes and rain events (including but not limited to cyclonic events).



Engage With Us:

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www.ccrif.org