CCRIF SPC

The Caribbean Catastrophe Risk Insurance Facility

Caribbean Regional Technical Workshop on CCRIF Models

Session:
The XSR model

With financial support from the European Union in the framework of the Caribbean Regional Resilience Building Facility, managed by the Global Facility for Disaster Reduction and Recovery (GFDRR)

CARIBBEAN REGIONAL RESILIENCE BUILDING FACILITY

A partnership funded by EUROPEAN UNION

GFDRR Global Facility for Disaster Reduction and Recovery

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Outline

- Introduction
- Hazard Module
- Exposure Module
- Vulnerability Module
- Loss Module
- Real-time operation
- Updates 2023

XSR – Introduction

A near-real time excess rainfall risk model for the Caribbean and Central America

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XSR Model - Introduction

In 2012/2013 CCRIF introduced a new product to cover against damages caused by excess of rainfall

Since then, CCRIF has made efforts to reduce the uncertainty in the model and improve its ability to estimate losses due to extreme rainfall events

XSR 1.0 (2012)

↓

XSR 2.0 (2016)

↓

XSR 2.1 (2018)

↓

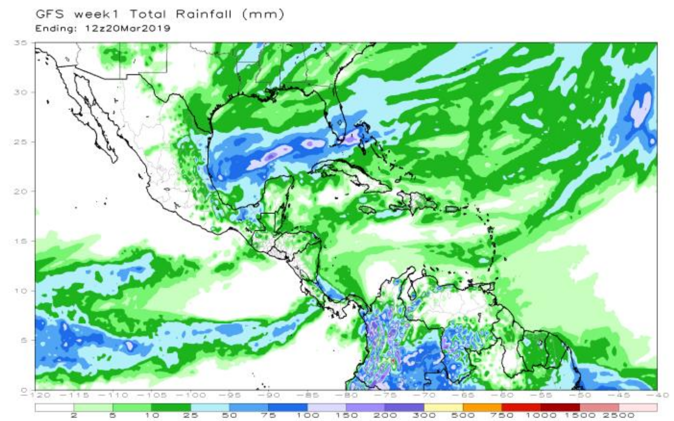
XSR 2.5 (2019)

↓

XSR 3.0 (2023)

XSR Model - Introduction

- ✓ Precipitation data are uncertain
- ✓ Risk models for parametric insurance have strict data requirements:
  - ✓ Real time availability
  - ✓ Reliability
  - ✓ Long historical records
  - ✓ Consistency between historical and real time data



Many sources of data with different characteristics, but not all can be used at this stage:

- ✓ Rain gauges
- ✓ Radar
- ✓ Satellite
- ✓ Weather Models

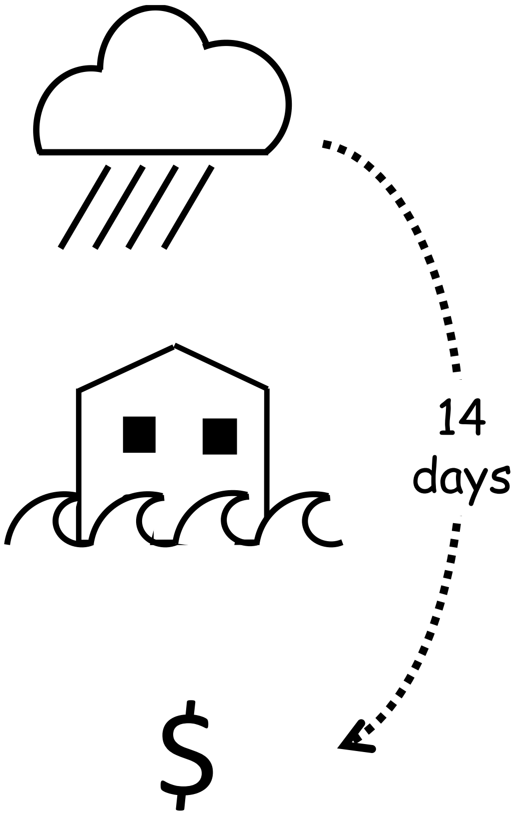
XSR Model - Introduction

The Excess of Rainfall (XSR) Model is aimed at

simulating in real time the precipitation over a country

rapidly estimating the potential consequent losses

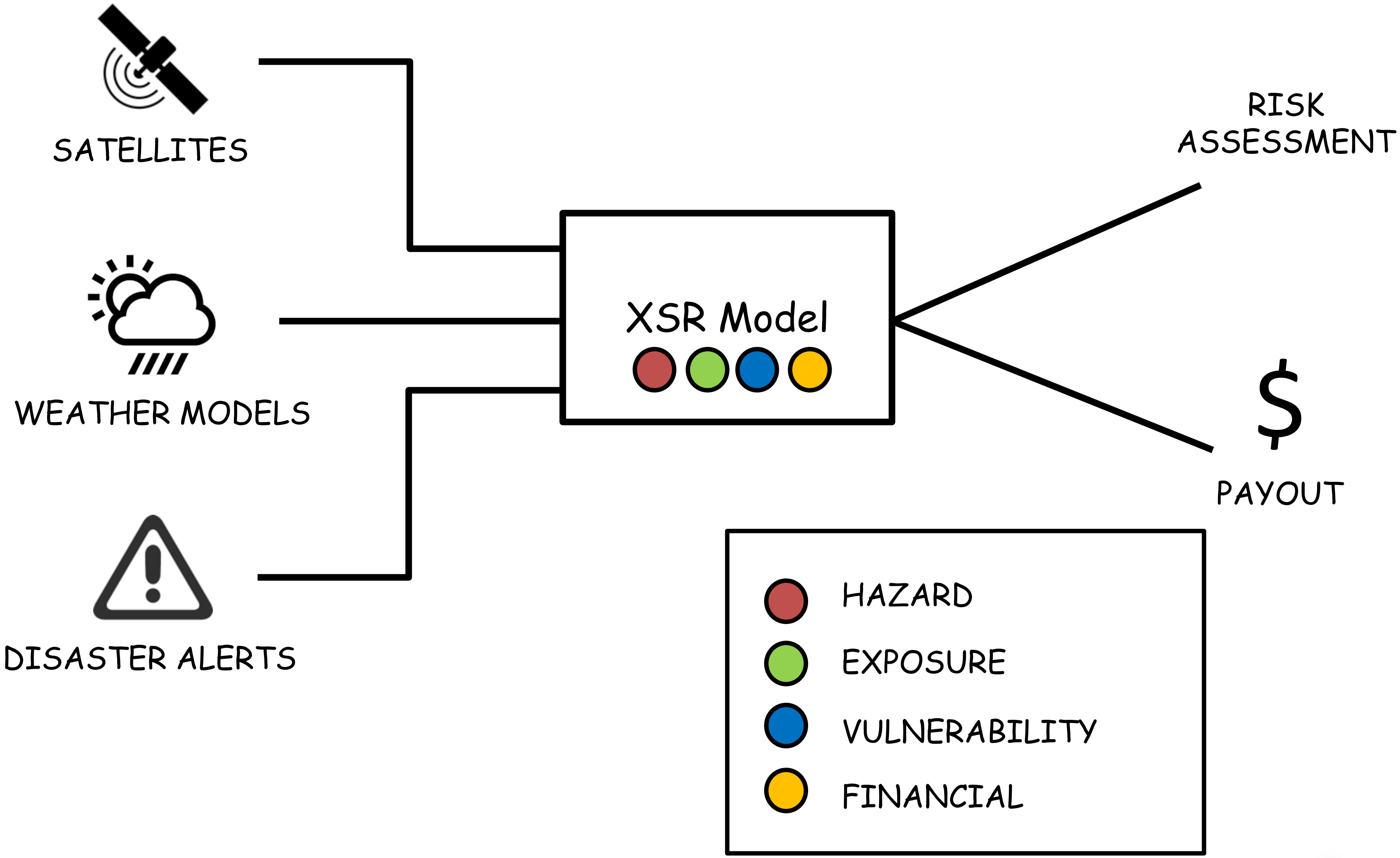
allowing the country to receive a payout consistent with the insurance policy conditions within 14 days after the end of the XSR event



XSR Model - Introduction

Application Domain: Caribbean and Central America

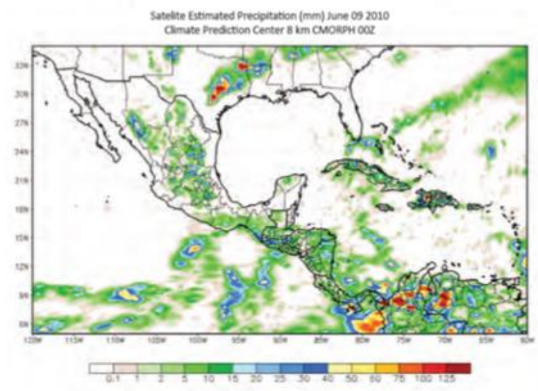
XSR Model - Introduction



XSR Model - Introduction

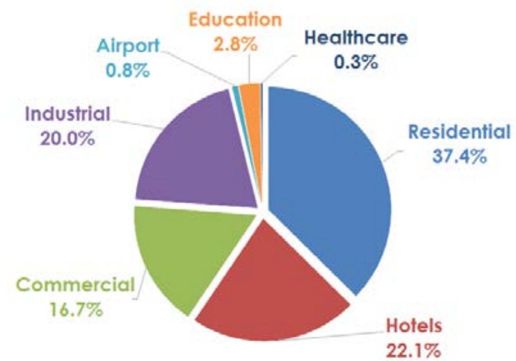
HAZARD Module

The rainfall estimates are derived in near real time from:
- Satellite data: precipitation estimated from remote sensing data
- Weather models: precipitation estimated from numerical weather prediction models



EXPOSURE Module

Several sources of data related to the built environment and to the surrounding topography are used. The final exposure database comprises information about the number of different types of structures, their area and their economic value for different sectors



Breakdown of the value of the assets at risk by occupancy class for Nicaragua.

XSR Model - Introduction

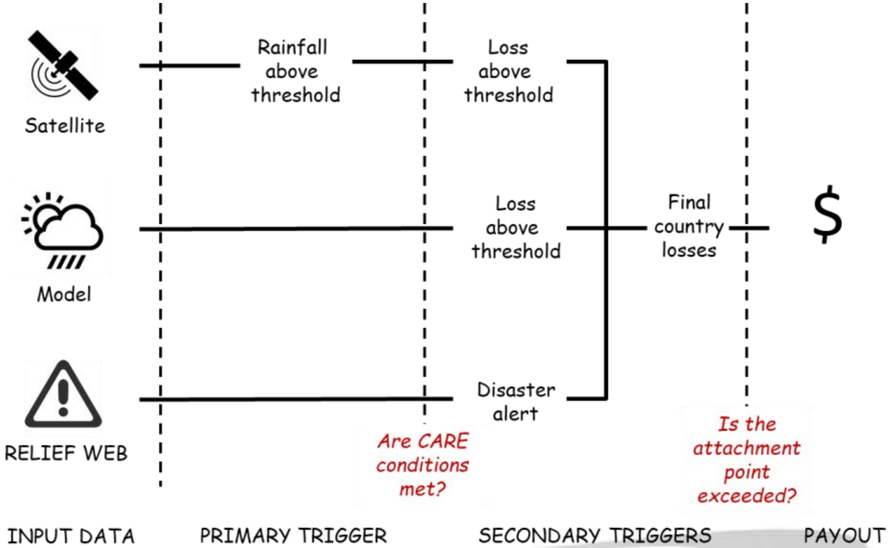
VULNERABILITY Module

Vulnerability analyses are conducted to identify the consequences for the built environment when an excess rainfall event occurs. The vulnerability functions are calibrated to be consistent with reported losses for historical events

LOSS Module

Simplified Primary trigger based on few parameters to identify the intensity of the event over the country

Secondary trigger to reduce basis risk

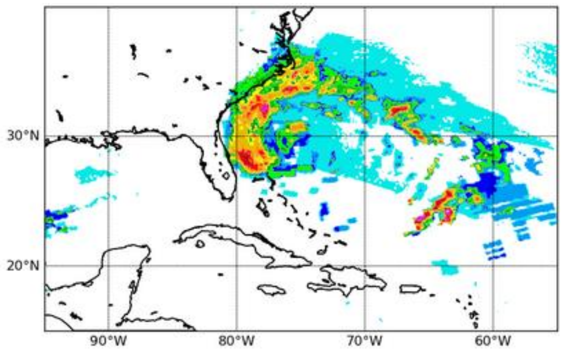


XSR – Hazard Module

A near-real time excess rainfall risk model for the Caribbean and Central America

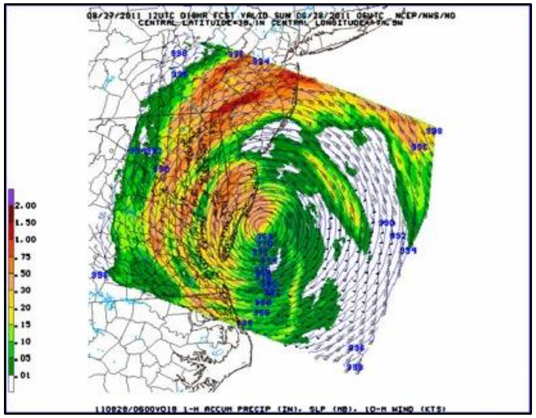
XSR Model - Hazard module

Rainfall estimates from satellite data



Global products provided by international agencies (NOAA, NASA):
- Rain estimates obtained by applying some algorithms to microwave observations produced by several low-orbit satellites
- Cloud tracking: monitoring of clouds by means of geostationary infrared satellites

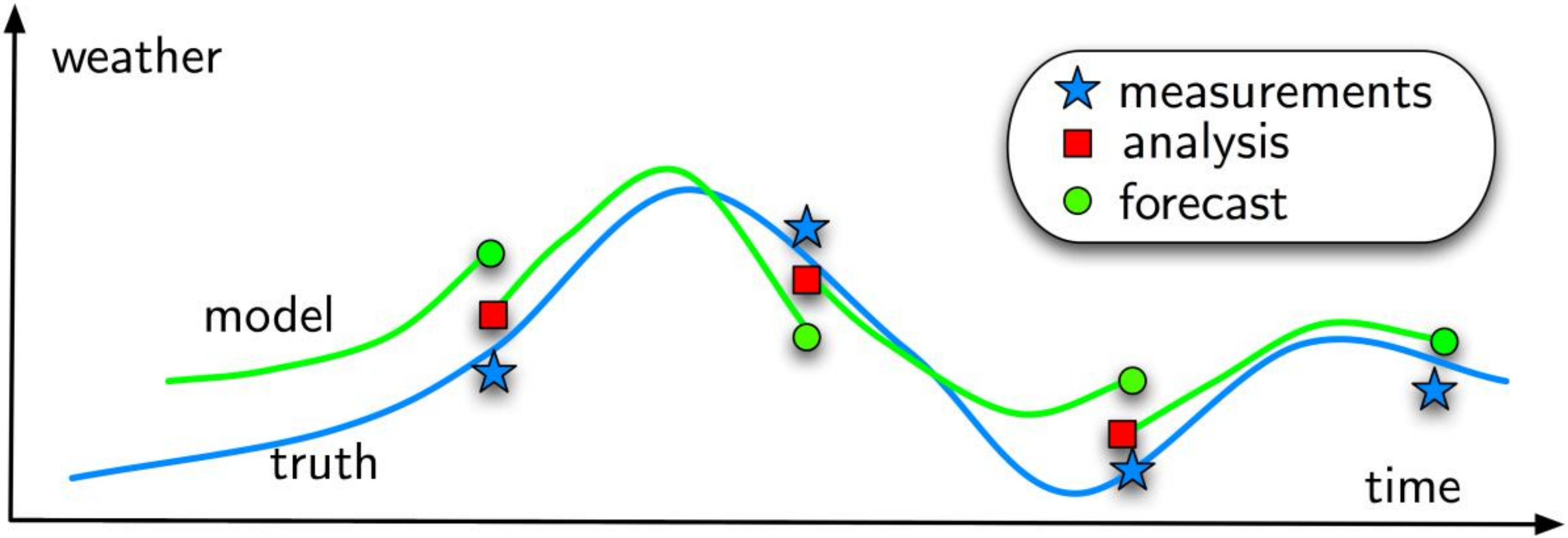
Rainfall estimates from numerical models



- Numerical calculation system for atmospheric simulation for the local scale
- Model: Weather Forecasting System (WRF)
- WRF has a large community of registered users worldwide (more than 30,000 in more than 150 countries)
- WRF is operational at NCEP, AFWA and many other agencies

XSR Model - Data Assimilation

A set of observations of wind, pressure, temperature and humidity collected both at the surface and in the atmosphere are used by the WRF model to correct its simulation, at each update time



XSR Model - Data Assimilation

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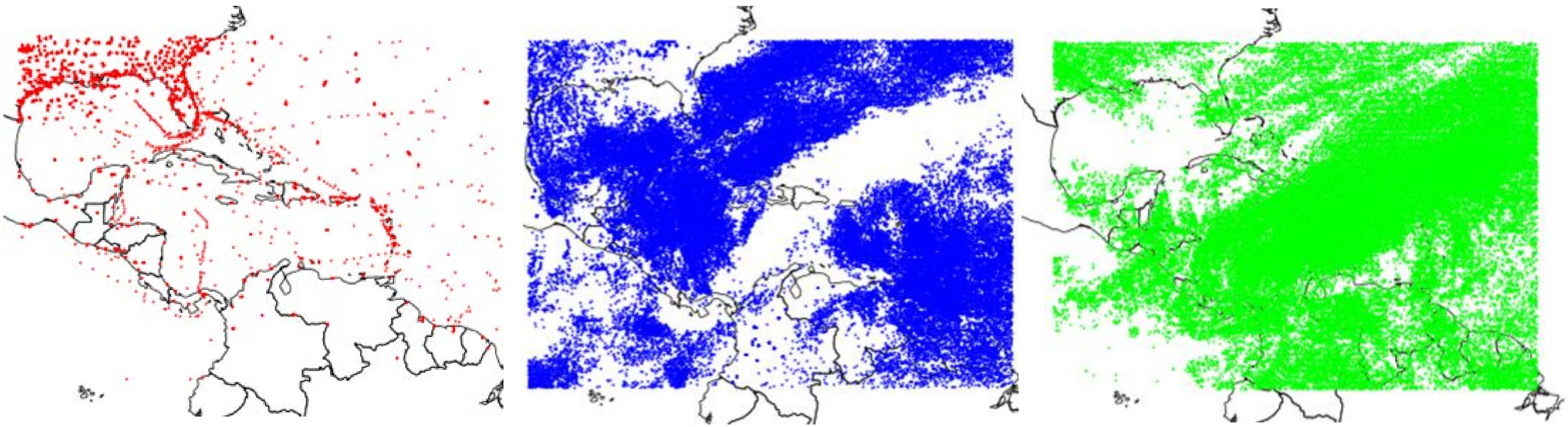
Observations assimilated in WRF for 22 November 2017

0 m | Middle Atmosphere | Upper Atmosphere



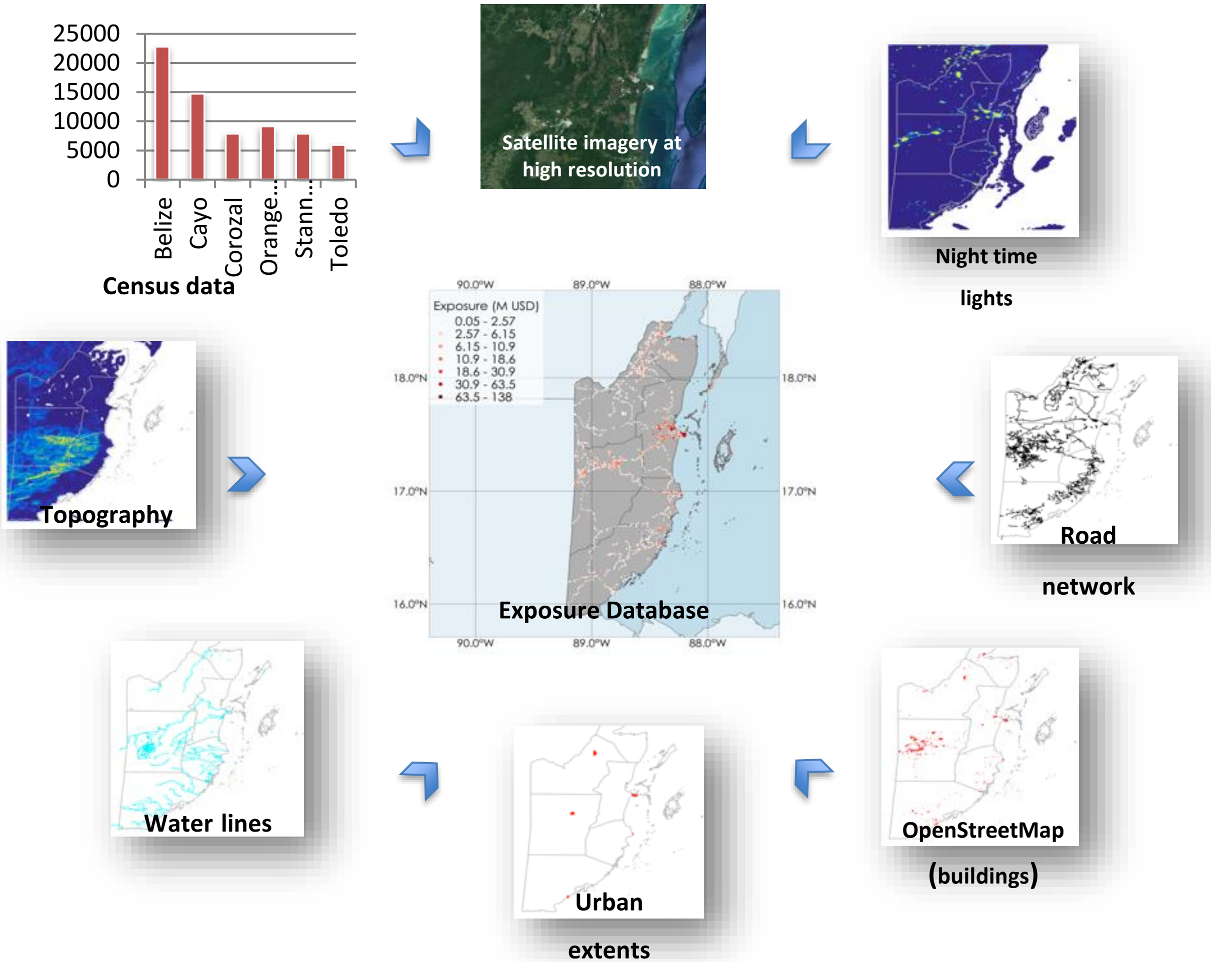
	Pressure	Wind	Temperature	Humidity
#Obs ass. In 1 day	~150,000	~150,000	~25,000	~25,000

XSR – Exposure Module

A near-real time excess rainfall risk model for the Caribbean and Central America

XSR Model - Exposure module

Several sources of information are used:



XSR Model - Exposure module

- Categories included:

Residential buildings

Commercial buildings

Industrial facilities

Hotels and restaurants

Healthcare infrastructure

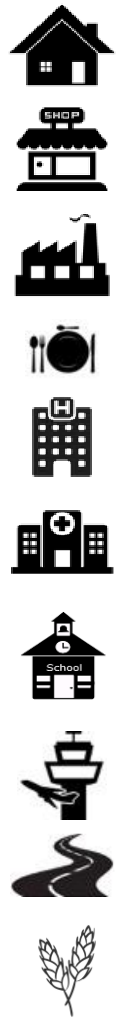
Education infrastructure

Ports

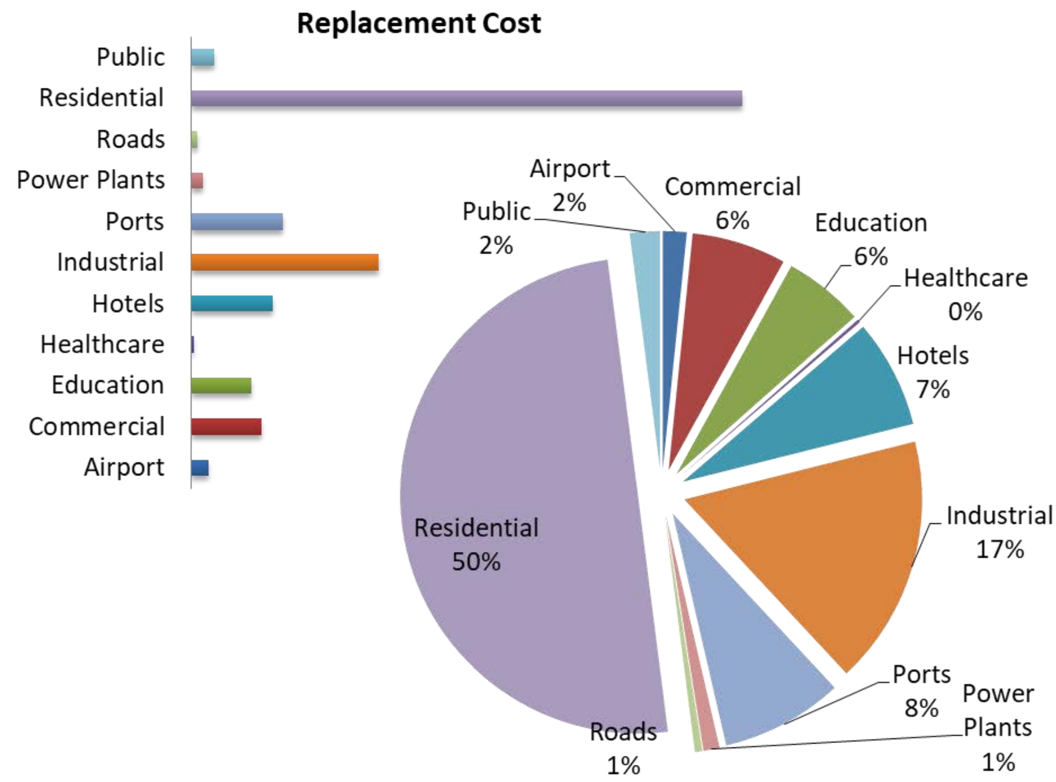
Airports

Transportation (roads) network

Crops



Example: St Kitts and Nevis



XSR – Vulnerability Module

A near-real time excess rainfall risk model for the Caribbean and Central America

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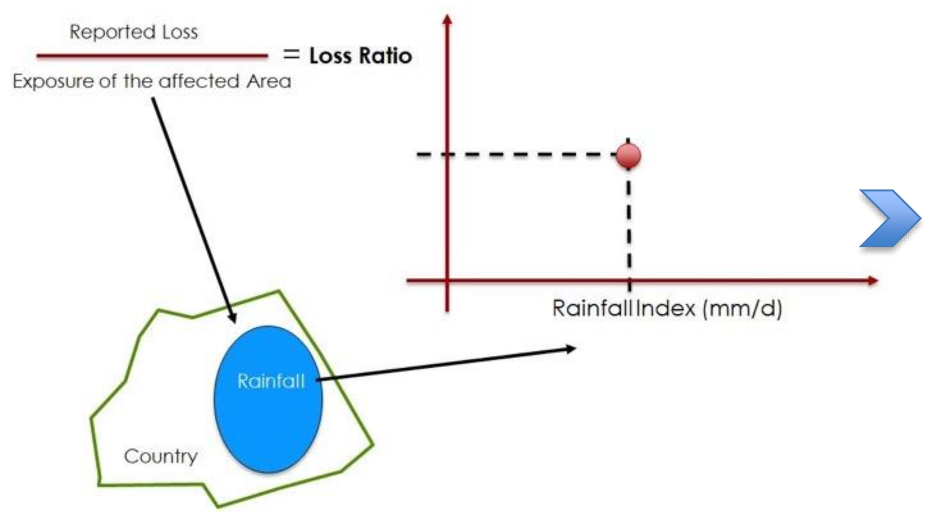
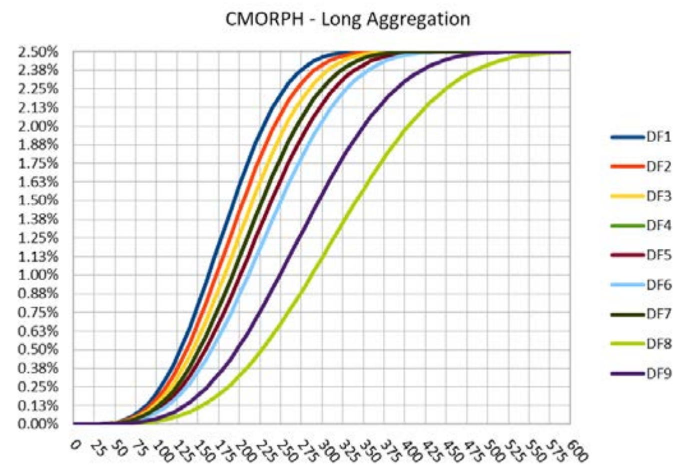
XSR Model - Vulnerability module

- The vulnerability module converts rainfall intensity to a loss ratio. This is done using the vulnerability functions
- Vulnerability functions are intensity-loss relationships which correlate rainfall intensity and observed losses

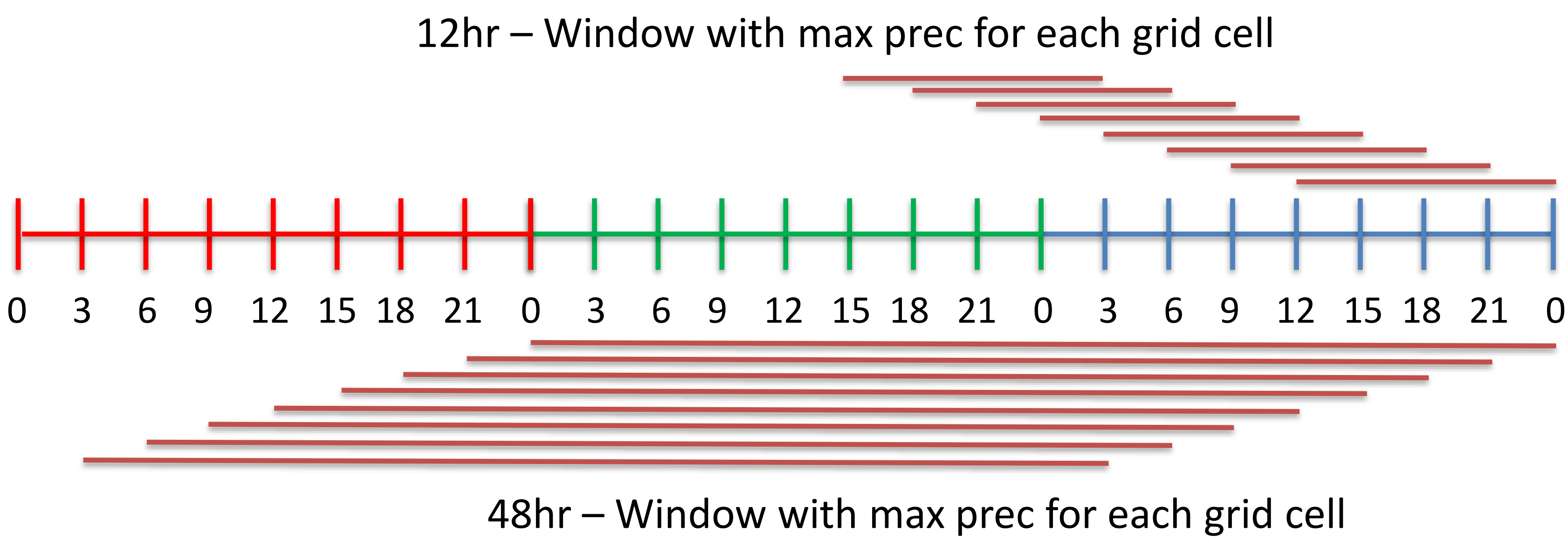




- In the XSR model the damage functions are built on a statistical basis, through a calibration process to reproduce the historical losses

XSR Model - Vulnerability module

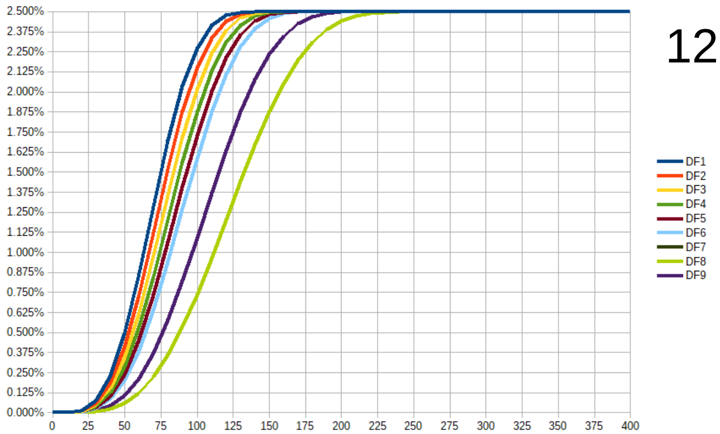
The precipitation is aggregated over the window with maximum precipitation



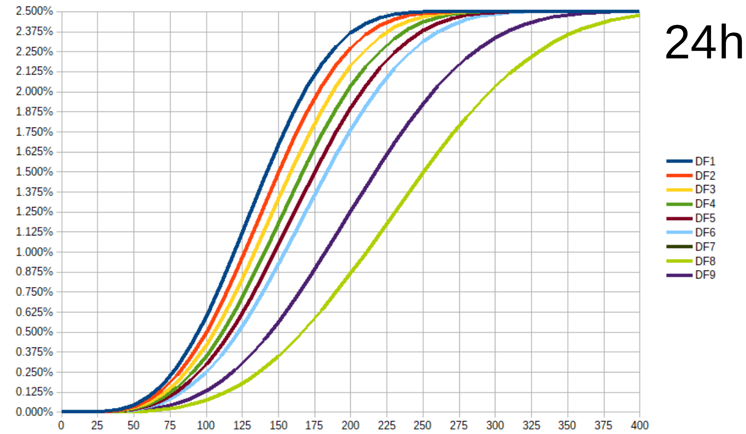
This ensures that the entire precipitation event is caught and it is not split between 2 consecutive days

XSR Model - Vulnerability module

- Damage functions
  - Damage not strictly correlated to rainfall depth, so the classic approach of fitting observed damage values cannot be followed
  - Theoretical damage functions:



12h



24h

  - Nine different damage functions corresponding to nine categories of asset

XSR – Loss Module

A near-real time excess rainfall risk model for the Caribbean and Central America

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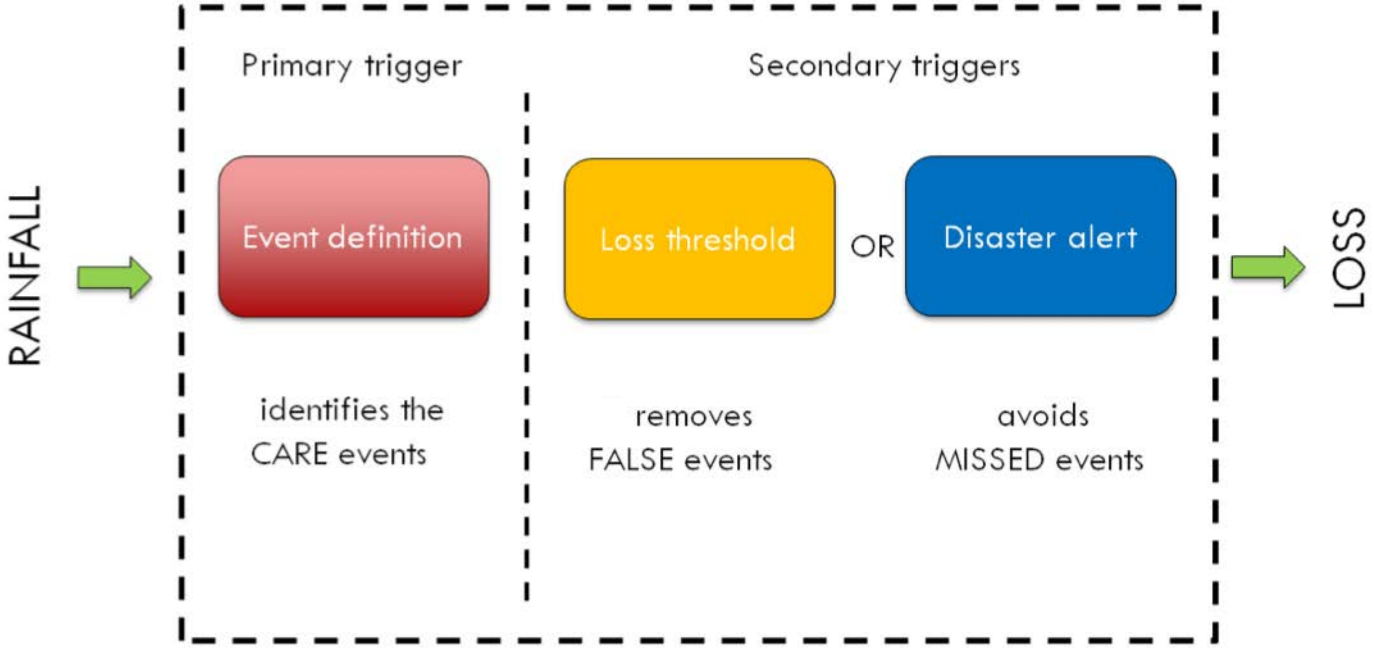
XSR Model - Loss module

Double trigger system: first trigger based on hazard, second trigger based on impacts



XSR Model - Loss module

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Covered Area Rainfall Event (CARE) definition

The main trigger only depends on estimated rainfall from satellite observations

An event that triggers the main trigger is identified as a CARE

Variables involved:

- Rainfall intensity over all the cells of a country
- Active cells, i.e., cells where the rainfall has been especially intense
- Tolerance period, i.e., maximum number of days during which the event is "paused"

XSR Model - Loss module

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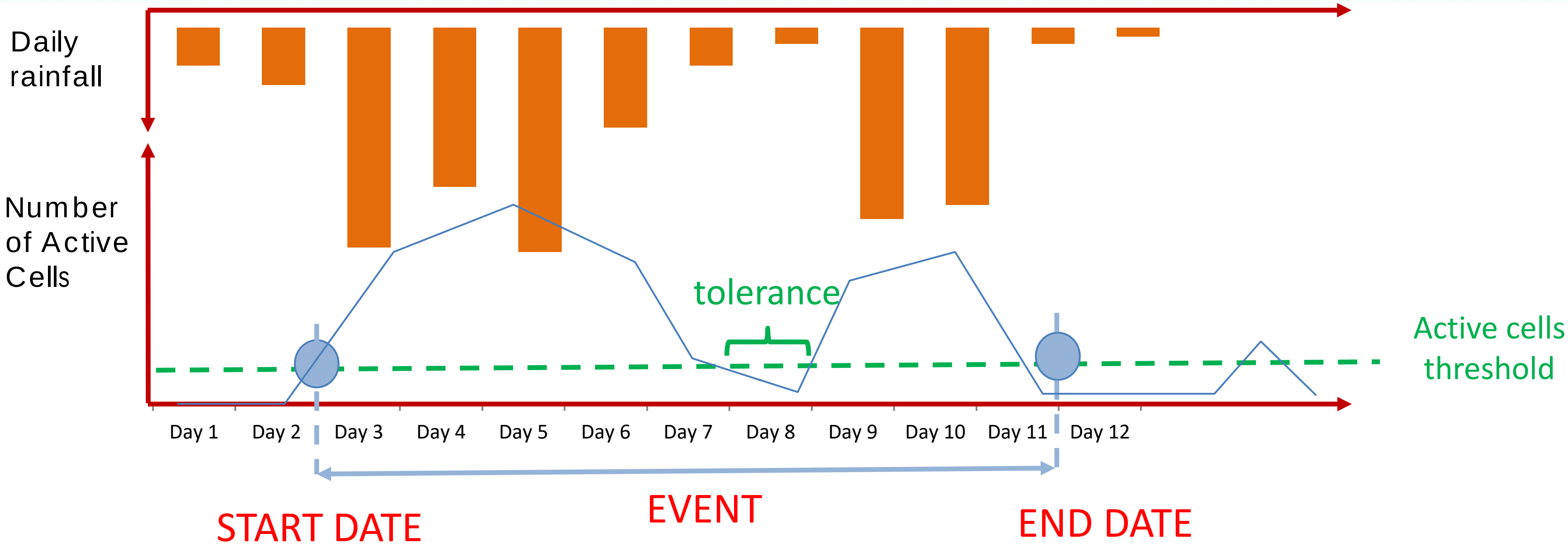


4 Steps for CARE Definition

- Calculate the maximum rainfall during the aggregation periods
- Calculate the number of active cells, those with rainfall above the threshold according to at least one of the aggregation periods
- Set the start date as the first day that the number of active exposure cells exceeds the threshold.
- The CARE ends when the above conditions are not met for at least a consecutive number of days called the tolerance period.

XSR Model - Loss module

The secondary trigger depends on the Rainfall Index Losses (RIL) estimated by the model

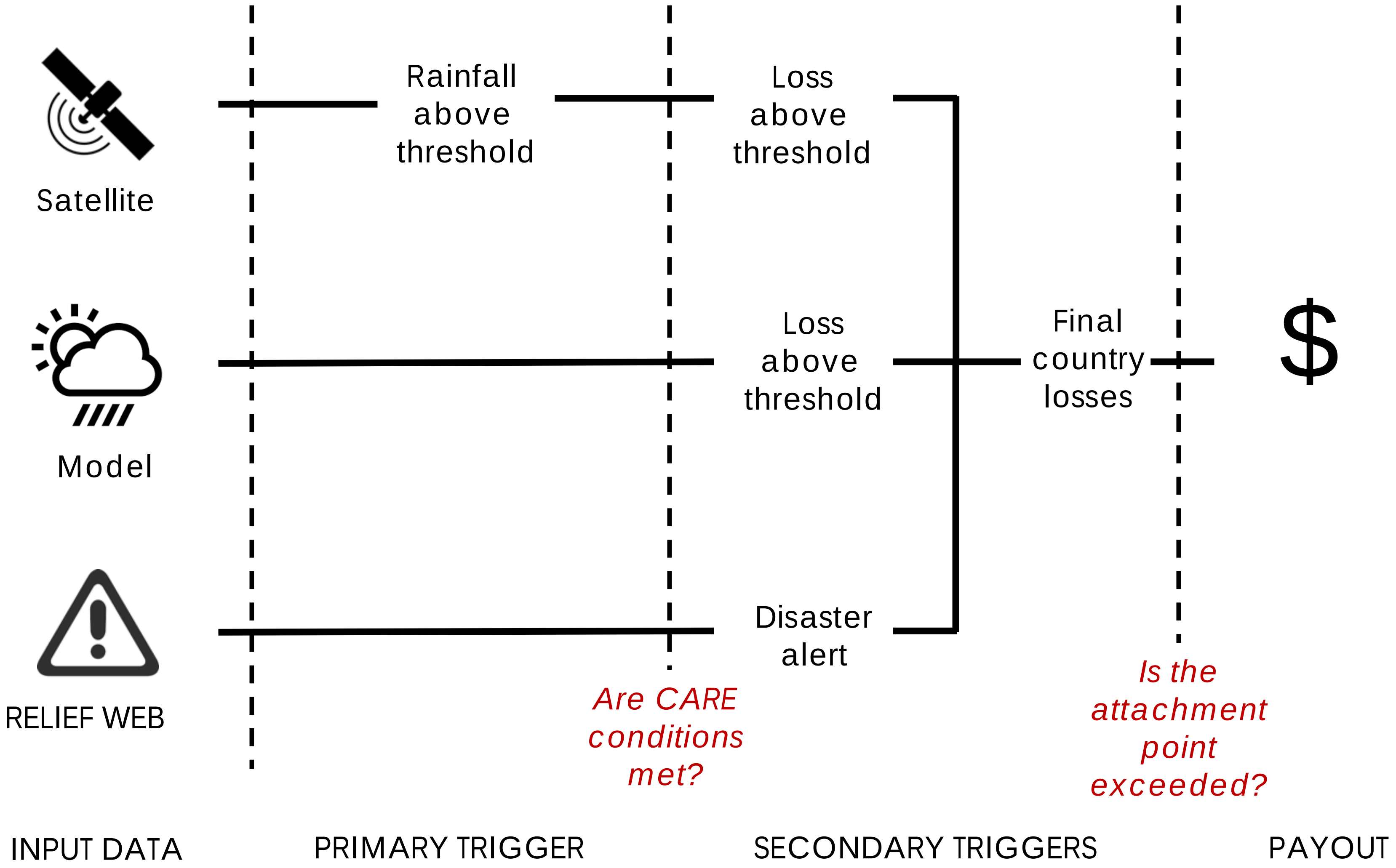
The secondary trigger can be activated in two cases:

- Loss threshold: satellite-based losses are above a loss threshold

OR

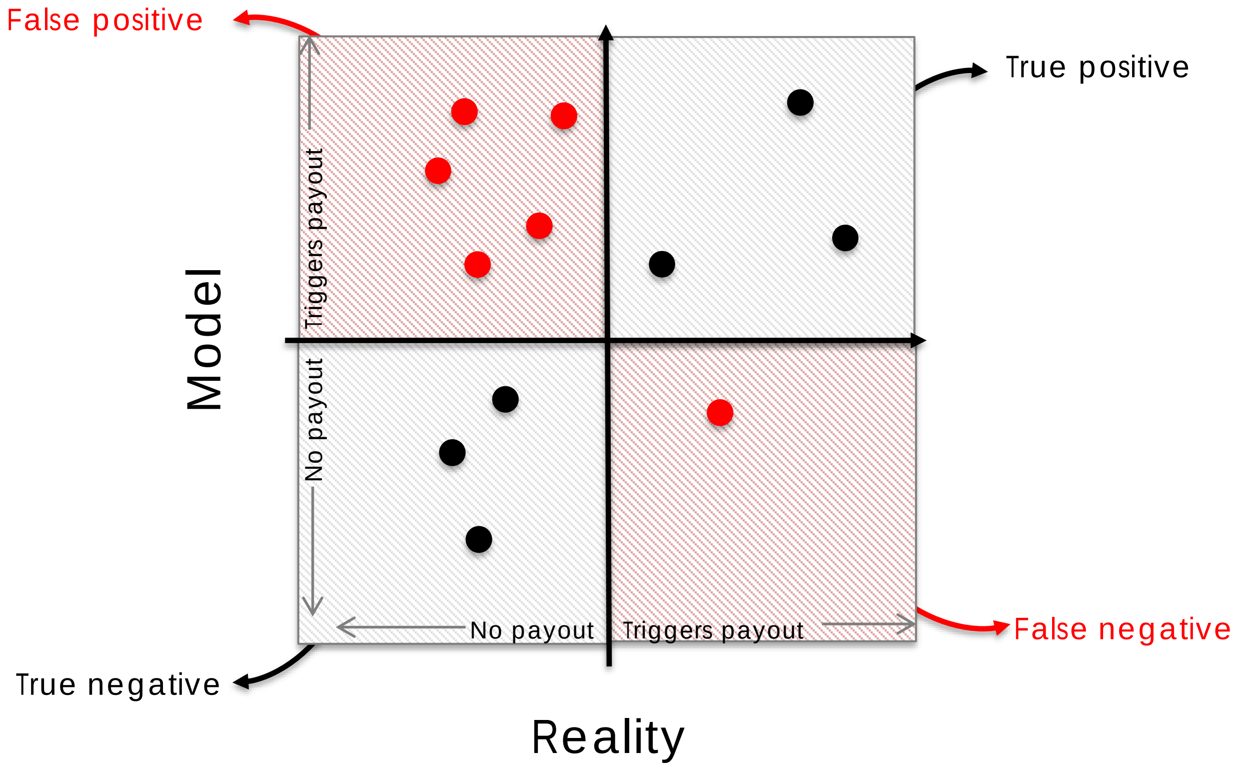
- A declaration of disaster alert for that event by ReliefWeb website by OCHA

XSR Model - Loss module



XSR Model - Loss module

- Primary trigger:
  - Satellite rainfall: precipitation analysis



XSR Model - Loss module

- Primary trigger:

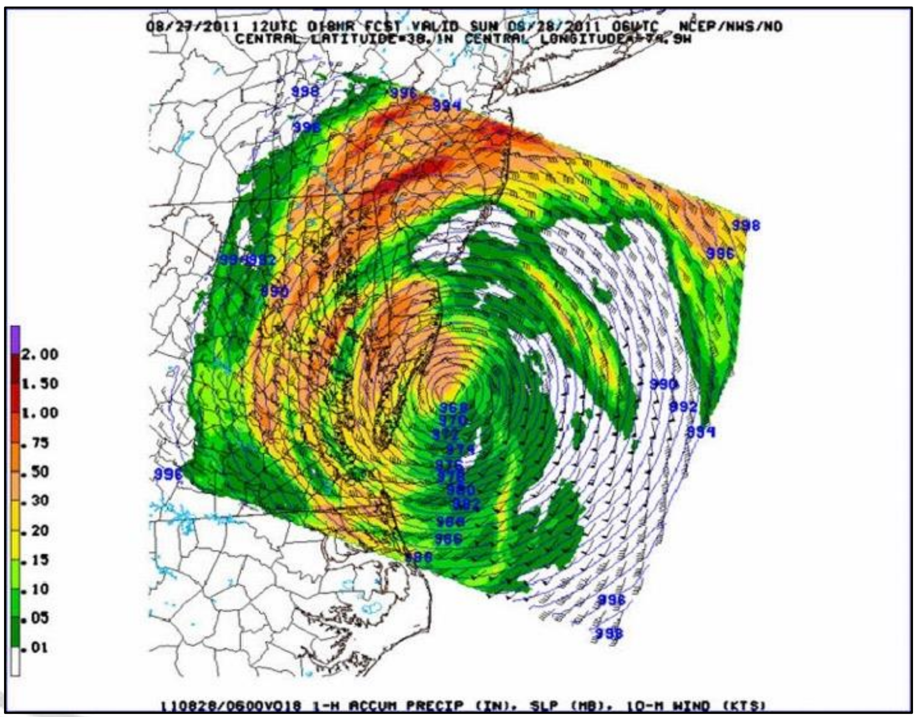
  - Satellite rainfall has a good spatial accuracy

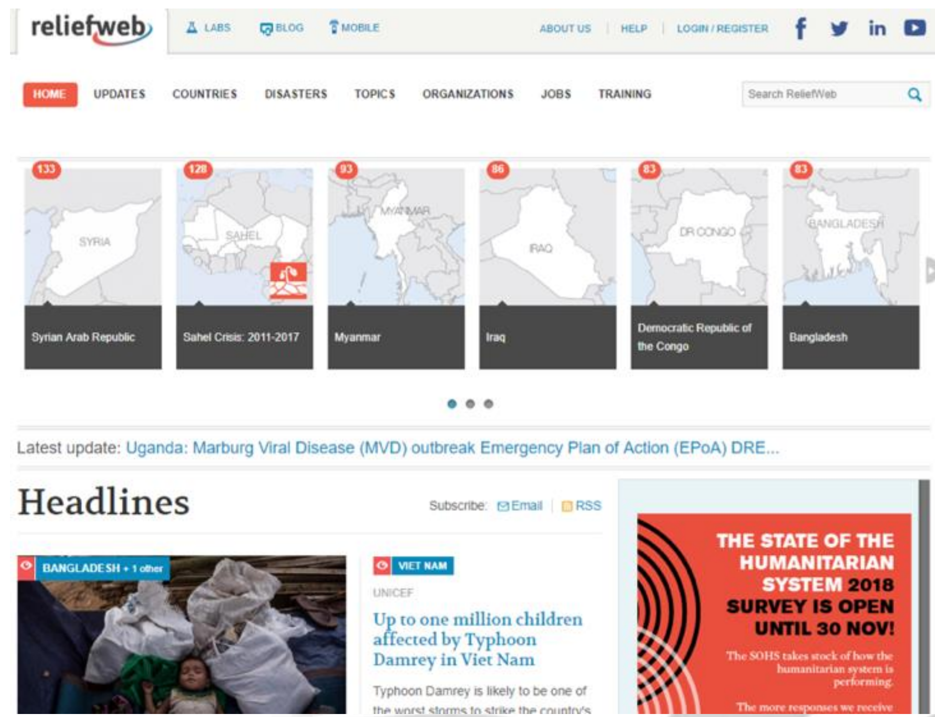
  - The primary trigger is easily activated in order to identify as many events as possible (minimise false negative events)

  - High risk of false events (false positive)!

XSR Model - Loss module

- Secondary trigger:
  - Loss-based trigger
  - Satellite and numerical weather model used to compute losses and discard events below a loss threshold
  - Disaster alert from reliefweb.int





XSR Model - Loss module

- Secondary trigger:
  - Loss-based trigger
    - Help identifying those events that the satellite datasets have underestimated
    - Correct some satellite datasets errors
    - Cannot be used alone, due to model uncertainties
  - Reduced basis risk!

XSR Model - Loss module

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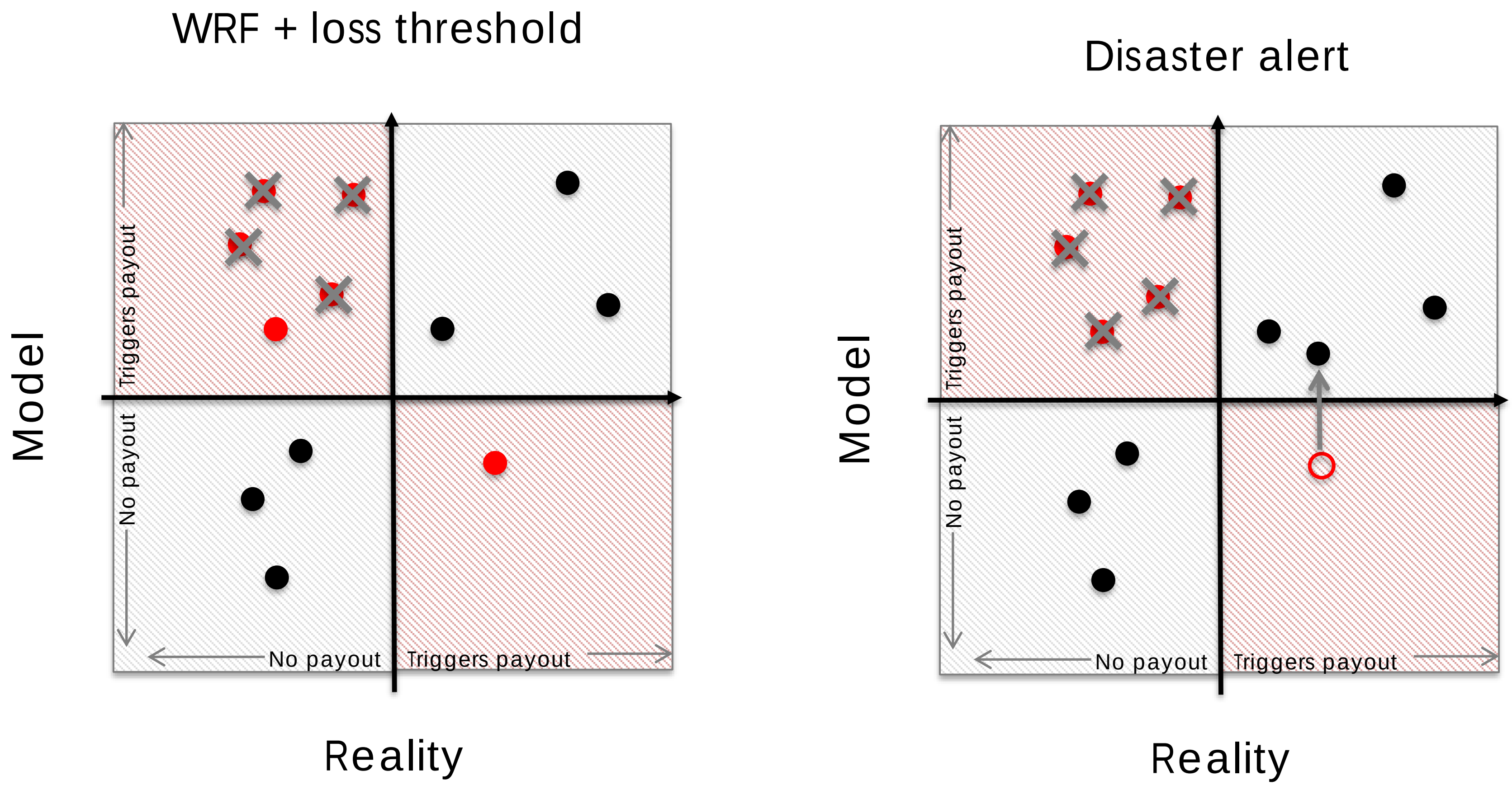
- Secondary trigger:
  - Disaster alert from reliefweb.int
    - Help identifying those events that have not been identified by satellite data and models, e.g. highly localised events
    - It avoids missed events
    - Not useful alone, since disaster alert is often triggered before the disaster occurs (e.g. hurricane forecast)
    - Helpful if used along other indicators
  - Reduced basis risk!

XSR Model - Loss module

- Secondary trigger:



XSR - Real-time operation

A near-real time excess rainfall risk model for the Caribbean and Central America

XSR Model – Real Time Operation

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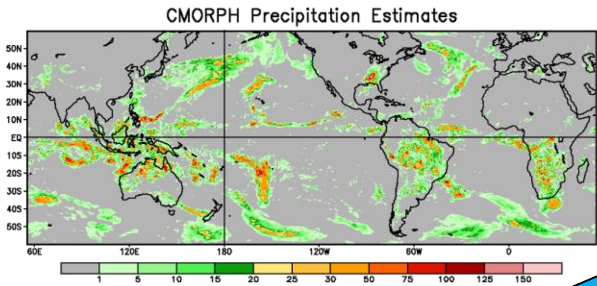
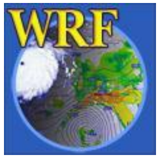
- Post-event (or quasi real-time) operational workflow

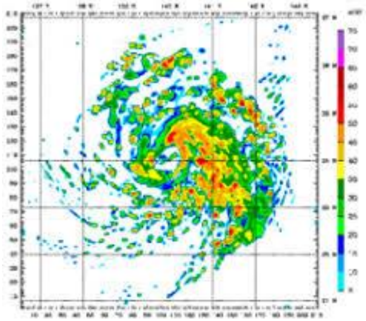
1 – NOAA and NSA provide global satellite data and low-resolution models



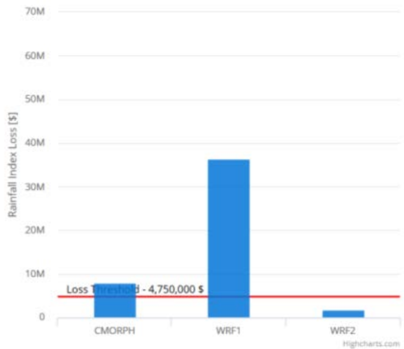
2 – The data are downloaded and cut over the geographical domain

3 – CCRIF's calculation agent runs the WRF model

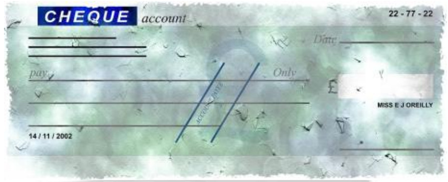




4 – XSR produces estimates of economic losses



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



XSR – Model updates 2023

A near-real time excess rainfall risk model for the Caribbean and Central America

XSR Model – Model updates 20223

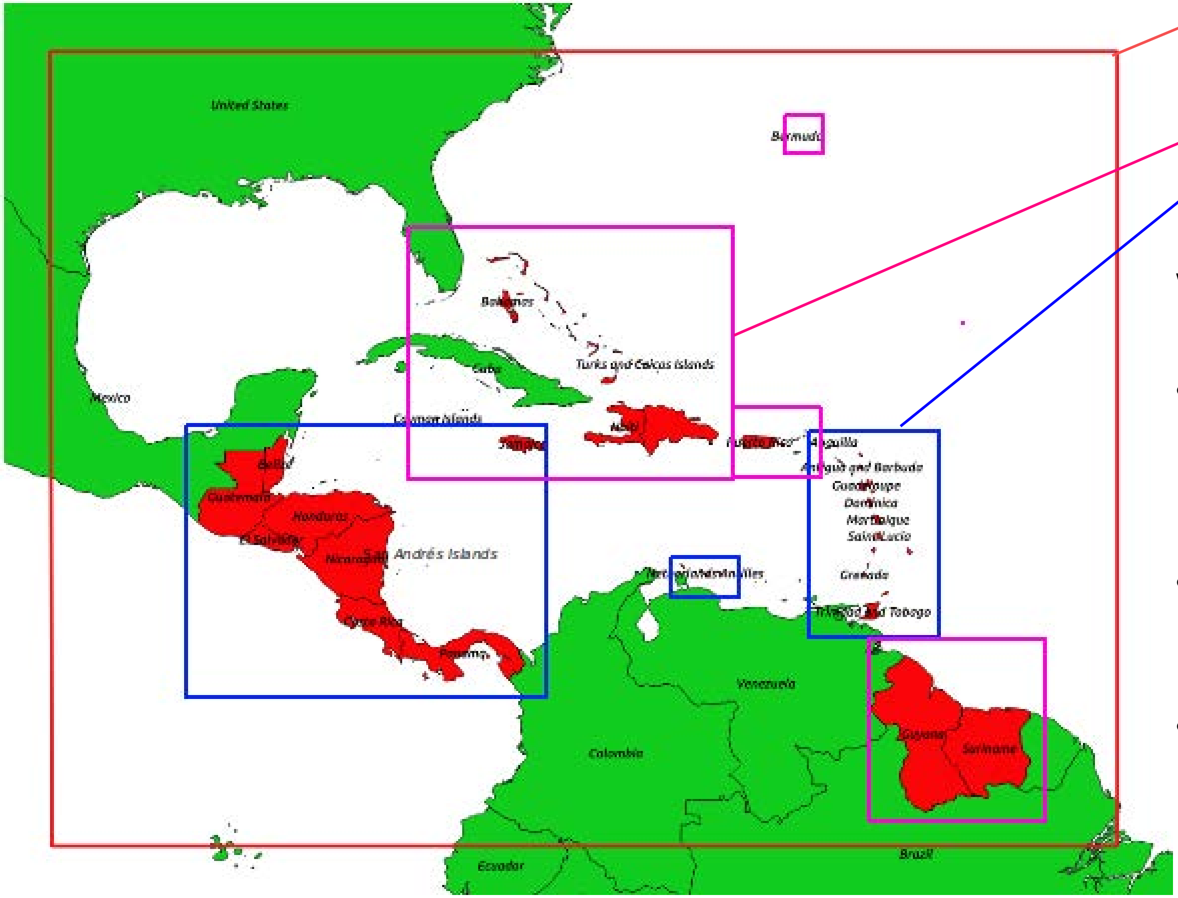
Updates 2023
WRF configuration update
Inclusion of IMERG
Review of the loss calculation approach
Adjustment of vulnerability curves
Additional trigger for localized events
Generation of an ensemble of loss curves
Additional trigger for wet seasons
Inclusion of latest events in the hazard assessment
Inclusion of soil crusting effect
Inclusion of cash crops

XSR Model 2023

- WRF model update
  - Previous WRF configurations:
    - WRF5 (8km resolution)
    - WRF7 (8km resolution, includes data assimilation)
  - New WRF configurations based on CIMH and INSIVUMEH:
    - WRF11 (based on CIMH's configuration, 4km resolution, nested on a coarser domain)
    - WRF15 (based on INSIVUMEH's configuration, 4km resolution, nested on a coarser domain , includes data assimilation)

XSR Model 2023

- WRF model update



Same domain as XSR2.5

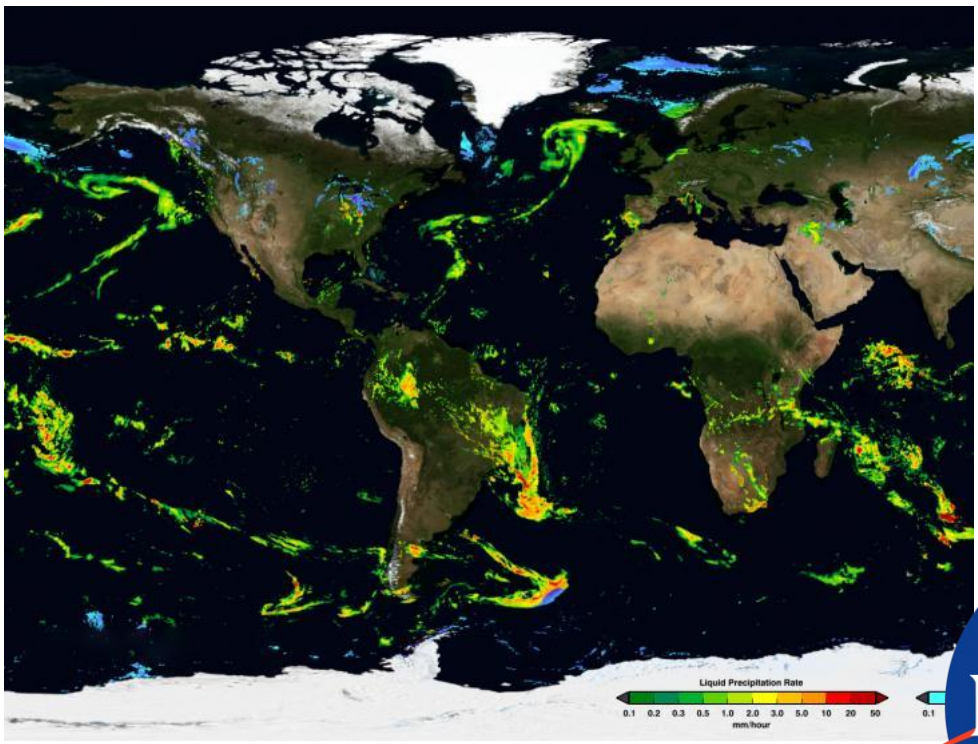
Nested domains, 4km resolution

Why:

- More accurate representation of topography, coastlines, land-use
- Avoid parametrization for convective precipitation
  ↓
- Enhancement of severe rainfall events mainly inland over small islands and mountains

XSR Model 2023

- Inclusion of IMERG
  - Improved satellite rainfall
  - Alternative product to CMORPH



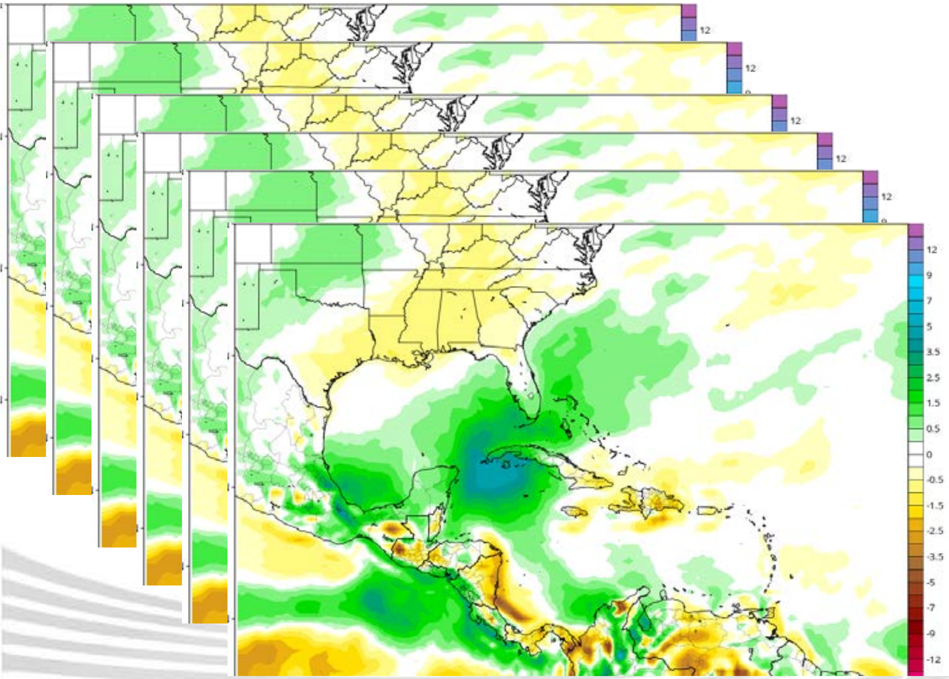
CMORPH underestimates precipitation average, maximum and 99° percentile

IMERG is more in agreement with observations

XSR Model 2023

1. New loss calculation approach
   1. Event definition: still based on CMORPH (works well, able to identify the occurrence of rainfall events)

      or Disaster Alert (DA) issued & one among IMERG, WRF11, WRF15 respects CARE activation conditions in a window of 7 days around the DA issuance date
   2. Loss calculation



6 Rainfall Models: CMORPH, WRF5 and WRF7
IMERG, WRF11 and WRF15

At least CMORPH or IMERG and other 2 Rainfall models with RIL > Loss Threshold	Disaster Alert

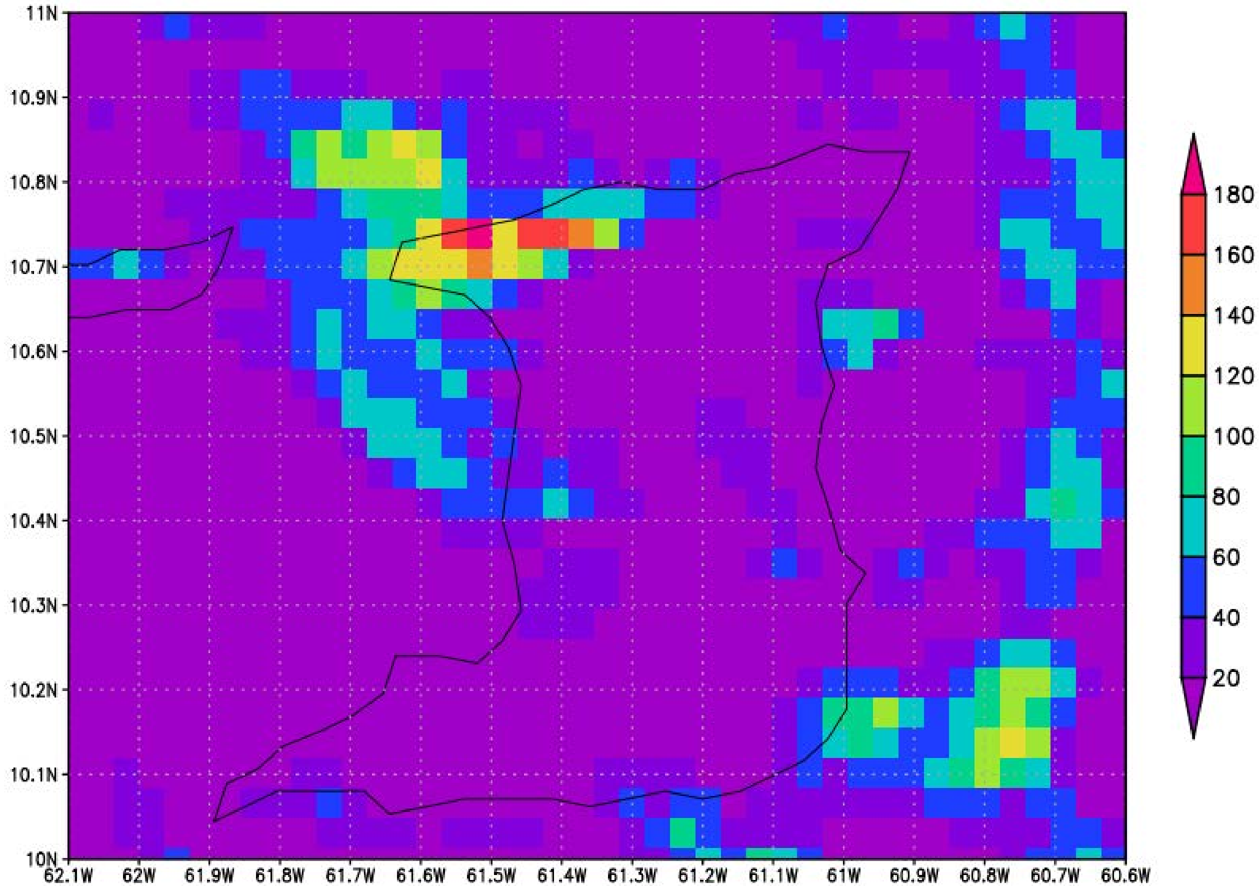
Event losses = average of the Rainfall Models above the Loss Threshold

XSR Model 2023

- Localised event trigger
  - Objective
    - Produce a payout for events that did not cause very large national-scale losses but affected a relatively small part of the country
  - Methodology
    1. Identify large precipitation events:
       - Local precipitation must exceed 70 mm/day (based on a minimum of 3 models)
       - Country-scale losses must be larger than 0
    2. Compute the ratio between local precipitation and country-scale precipitation: Precipitation index (Pindex)
    3. Produce a payout every time Pindex exceeds a certain threshold

XSR Model 2023

- Localised event trigger
  - Example: Diego Martin Flood 2012 in Trinidad



11/08/2012 to 13/08/2012 rainfall over Trinidad by WRF11

XSR Model 2023

- Wet season trigger
  - Objectives:
    - To detect rain events that happen after a long rainy spell, when the soil is already saturated
  - Methodology:
    1. Calculate the 1 month SPI (Standardized Precipitation Index) for each Country (subregion):

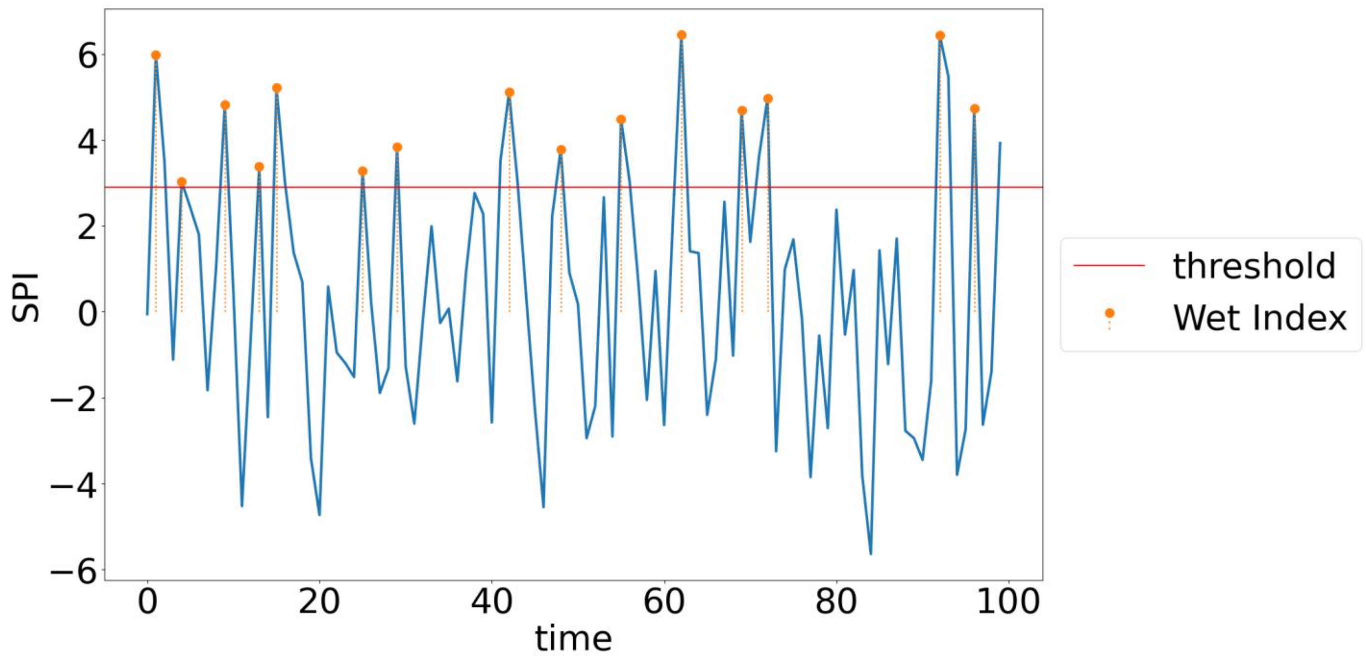
       The SPI measures if the precipitation in an area is above or below normal for a given time period (e.g., 1 month) and can be interpreted as the number of standard deviations that the current precipitation is from the long-term average.

       The higher the SPI, the higher the monthly precipitation was with respect to the long-term average

XSR Model 2023

– Methodology:

2. Define Wet Events as period of time where SPI is over a given threshold
3. Define a Wet Index (WI) as the maximum value of SPI during a wet event



XSR Model 2023

- Inclusion of soil crusting effect
  - Objective
    - To detect rain events that happen after a long drought, when exceptionally dry soil contributes to poor absorption ability (soil crusting)
  - Methodology
    - Calculate the 6 months SPI (Standardized Precipitation Index) for each Country (subregion): the lower the SPI, the lower the precipitation in the previous 6 months with respect to the long-term average
    - Set up a threshold for the 6 months SPI below which a loss event will receive an additional penalty (e.g., 20% increased RIL)

XSR - Conclusions

A near-real time excess rainfall risk model for the Caribbean and Central America

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XSR Model - Conclusions

- ✓ The XSR model is a sophisticated model designed to support parametric insurance against infrequent and catastrophic events
- ✓ It makes use of open data, produced by internationally recognized agencies
- ✓ It is based on an ensemble of precipitation datasets and a an innovative multiple trigger mechanism that allows reducing the basis risk
- ✓ It runs near real time and allows making payments very quickly
- ✓ It has been successfully operating for several years

XSR Model - Conclusions

The Caribbean Catastrophe Risk Insurance Facility

- ✓ The XSR model has become even more robust and reliable in its version 3.0 (2023) thanks to:
  - ✓ Improved WRF configurations kindly provided by the most experienced weather forecasting agencies in the area
  - ✓ Inclusion of new satellite rainfall dataset (IMERG)
  - ✓ New triggers for localised events and wet spell events
  - ✓ Many other features!

- ✓ XSR3.0 will start operating from the beginning of next policy year, June 1st 2023

CCRIF Regional Workshop, Miami, USA

16th February 2023

Thanks for your attention!

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