CCRIF SPC
The Caribbean Catastrophe Risk Insurance Facility

On behalf of
Caribbean XSR SP

Covered Area Rainfall Event
(7-9 September 2017)

Hurricane Irma
Excess Rainfall

Event Briefing
Turks and Caicos Islands

18 September 2017

Registered Office: CCRIF SPC c/o Sagicor Insurance Managers Ltd., 198 North Church Street
2nd Floor Sagicor House, P.O. Box 1087, Grand Cayman KY1-1102, Cayman Islands
Email: ccrif@ccrif.org | Website: www.ccrif.org | Twitter: @ccrif_pr | Facebook: CCRIF SPC

1 INTRODUCTION

Irma, now recognized as the most powerful Atlantic Ocean hurricane in recorded history, formed as a tropical storm on 30 August at 15UTC, west of the Cape Verde Islands. It was upgraded to hurricane status on 31 August at 15UTC. Irma intensified moving across the Atlantic Ocean and reached the Leeward Islands as a major hurricane (category 5) on 6 September at approximately 12UTC. Between 7 September at 15UTC and 8 September at 09UTC, the eye of the hurricane moved between Hispaniola (Haiti/Dominican Republic) and the Turks and Caicos Islands.The northern sector of Irma's core passed through the Turks and Caicos Islands with hurricane-force winds starting on 7 September at 21UTC and continuing until 09UTC on 8 September 2017.

This report describes the results of the Excess Rainfall model (XSR 2.0) on CCRIF member country the Turks and Caicos Islands. Other reports have been or will be issued regarding other CCRIF member countries that have Excess Rainfall policies.

The Turks and Caicos Islands was affected by locally intense rainfall mainly between 1515UTC on 7 September and 0915UTC on 8 September. The Rainfall Index Loss was calculated for this Covered Area Rainfall Event (CARE) that started on 7 September and ended on 9 September 2017, and it indicated government losses for the Turks and Caicos Islands above the attachment point of the country's Excess Rainfall policy. Final calculations show that a payout of US$1,232,768.60 is due.

As reported in the previous Event Briefing dated 10 September 2017 on wind and storm surge effects from Tropical Cyclone Irma on Haiti and the Turks and Caicos Islands. The final runs of CCRIF's loss model for wind and storm surge produced government losses for the Turks and Caicos Islands. Turks and Caicos Islands' Tropical Cyclone policy, which provides coverage for wind and storm surge, was triggered and a payout of US$13,631,864 was due under that policy.

2 EVENT DESCRIPTION

On 30 August 2017 at 15UTC, the US National Hurricane Center (NHC) reported that Tropical Storm Irma had developed west of the Cabo Verde Islands, with maximum sustained winds of 50 mph (85 km/h). During the following 24 hours, Irma moved toward the west at 13 mph (25 km/h) and it rapidly intensified due to the favourable thermodynamic environment: low wind shear, humid layers and the passage over warm water.

On 31 August at 15UTC, Irma was upgraded to a category 2 hurricane. At this time, Irma was located at 16.9N, 33.8W, featured maximum sustained winds of 100 mph (155 km/h) and the estimated minimum pressure was 979mb (Figure 1).

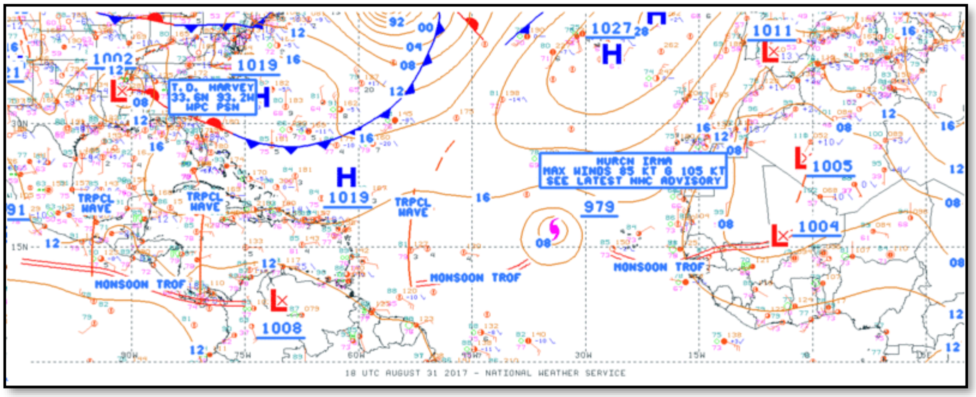


Figure 1 Surface analysis of the tropical Atlantic on 31 August at 18UTC.
Source: NOAA Ocean Prediction Center.

After 12 hours, Irma was further upgraded to a category 3 hurricane (thus becoming a major hurricane) since the observed maximum sustained winds were near 115 mph (185 km/h). During these hours, the hurricane moved in a west-northwest direction at 12 mph (19km/h), to the south of the subtropical high pressure system extending over the central Atlantic and centred over Azores (Figure 1). Even though Irma was still embedded in a favourable low wind shear environment, its passage over colder surface water and its close proximity to the dry air of the high pressure system prevented Irma from strengthening rapidly. During the next few days, Irma continued to move along the southern border of the high pressure system. This condition made the hurricane track initially steer west- southwest (from 2 September at 15UTC to 4 September at 3UTC), then west (from 4 September at 3UTC to 5 September at 15UTC) and finally towards west-northwest (from 5 September at 15UTC to 6 September at 12UTC) at a roughly constant forward velocity of about 13-15 mph (20-24 km/h) (Figure 2).

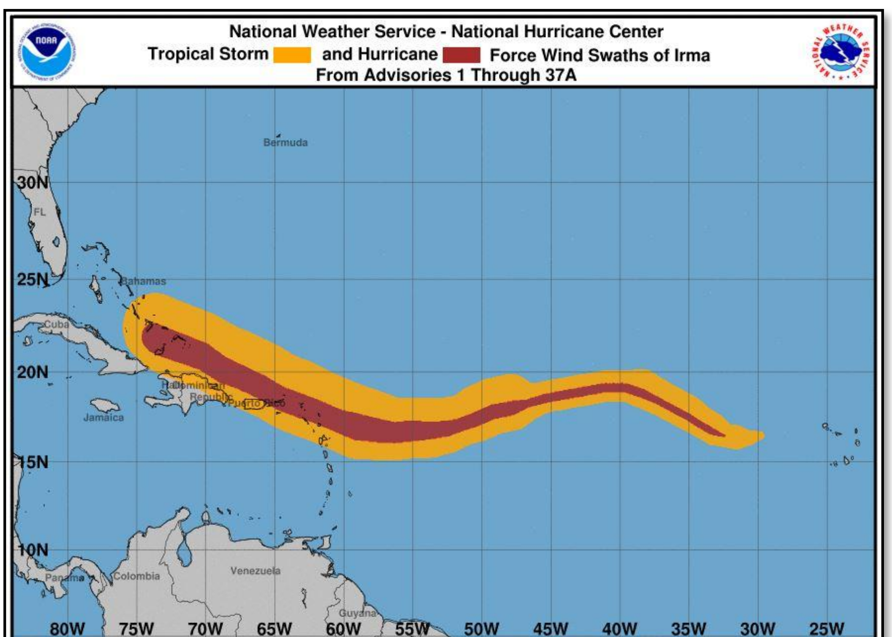


Figure 2 Irma's track and contouring of the wind speed intensity. Source: NHC

The hurricane-force winds remained constant until 4 September when further intensification took place. On 4 September at 21UTC, Irma became a category 4 hurricane, with maximum sustained winds of 140 mph (220 km/h) and minimum central pressure of 943 mb. At that time, the hurricane eye was located near 16.7N, 55.6W and the hurricane structure was well defined, showing a clear eye and a symmetrical cloud overcast ring around it, with very high top cloud (Figure 3).

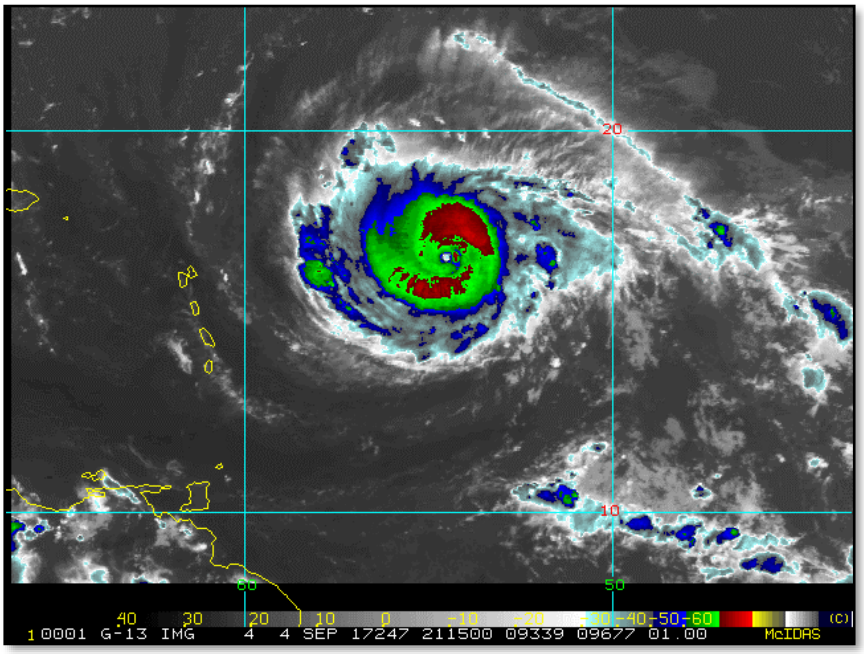


Figure 3 Enhanced infrared satellite image on 4 September at 2115UTC. Red and green indicate, respectively, very high and high top clouds. Source: NOAA

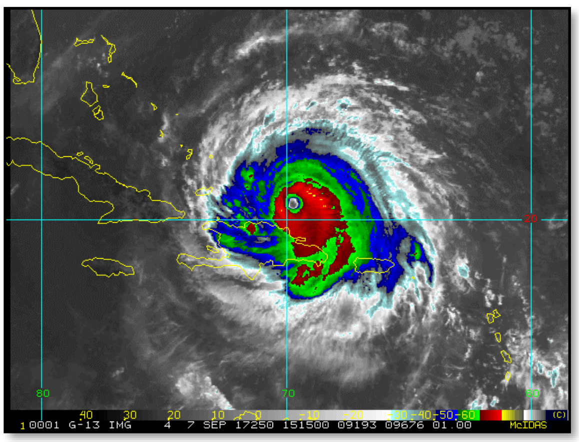
On 5 September at 1500UTC, NHC further upgraded it to a category 5 hurricane, with maximum sustained winds of 180 mph (285 km/h). The estimated minimum central pressure was 931 mb. Hurricane-force winds extended outward up to 60 miles (95 km) from the centre and tropical-storm-force winds extended outward up to 160 miles (260 km).

A few hours later, Irma reached the western edge of the subtropical high pressure system, thus allowing it to gain latitude and its track to turn towards the west-northwest, heading towards the northern Leeward Islands.

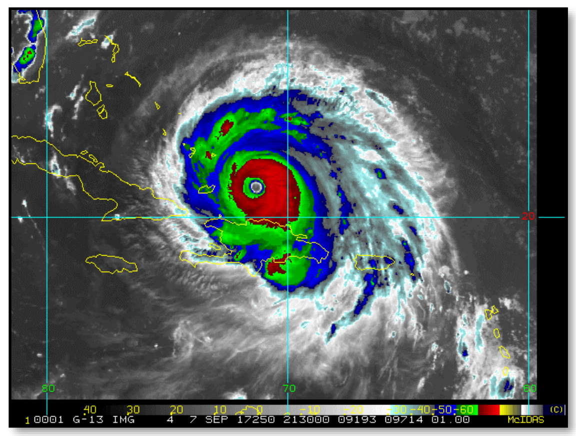
On 6 September between 6UTC and 12UTC Irma's core passed over Antigua and Barbuda, Anguilla and St. Kitts and Nevis as a category 5 hurricane. During the subsequent hours, the hurricane continued to move toward the west-northwest heading for the Turks and Caicos Islands with a forward velocity of 16 mph (26 km/h). The wind intensity was almost constant, while the minimum central pressure decreased to approximately 921 mb, and later remained constant. Hurricane-force winds extended outward up to 70 miles (110 km) from the centre and tropical-storm-force winds extended outward up to 185 miles (295 km).

Between 7 September 15UTC and 8 September 9UTC, the eye of the hurricane moved between the island of Hispaniola (Haiti/Dominican Republic) and the Turks and Caicos Islands (Figure 2 and Figure 4).

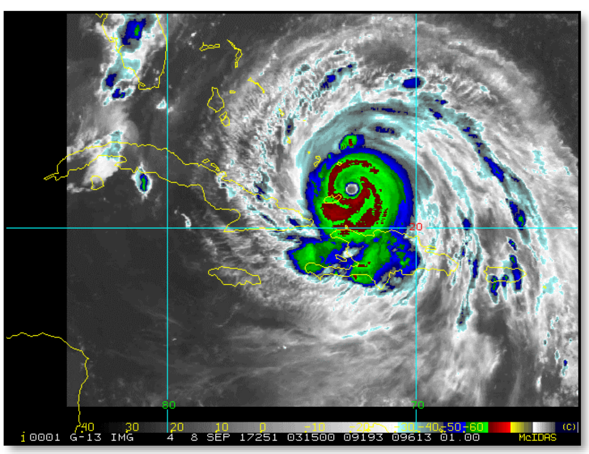
The northern sector of Irma's core passed through the Turks and Caicos Islands (Figure 4). This generated hurricane-force winds on these islands starting on 7 September at 21UTC and continuing until 8 September at 9UTC. The deep convection associated with the hurricane core (evidenced by the very high and high cloud canopy observed from satellites, as shown in Figure 4) led to heavy precipitation over the Turks and Caicos Islands. The estimated storm surge was about 15-20 feet (4-6 m). At that time, the southern sector of Irma's core passed over the northern coast of Haiti (Figure 4).



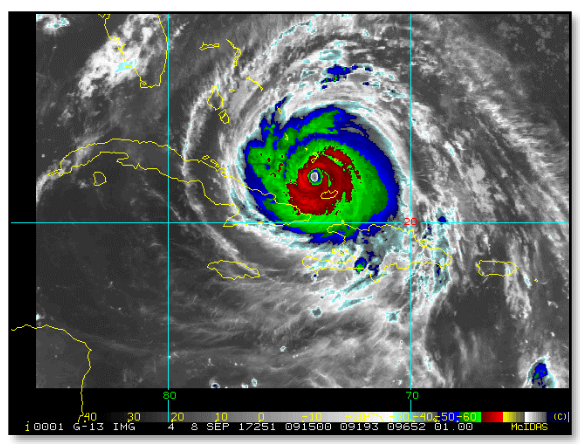
a) 7 September at 15:15 UTC



b) 7 September at 21:30 UTC



c) 8 September at 03:15 UTC



d) 8 September at 09:15 UTC

Figure 4 Enhanced infrared satellite image at different times. Red and green indicate, respectively, very high and high top clouds. Source: NOAA

3 IMPACTS

Nine days after Hurricane Irma passed through the Turks and Caicos Islands, the Department of Disaster Management and Emergencies (DDME) reported that nearly 90 per cent of homes were damaged, and many trees and utility poles had fallen, making roads impassable. The Director of the Caribbean Tourism Organization (CTO), Mr. Ramon Andrews, reported that no lives were lost or injuries in the country.

At the time of this report, the following information had been published in the local and regional news[1 2 3]:

- Hurricane Irma has caused widespread flooding.
- Mr. John Freeman, Governor of the Turks and Caicos Islands, declared the islands a disaster area with most of the buildings damaged, including major government buildings.
- All islands was damaged: South Caicos, Salt Cay and Grand Turk suffered significant damage, along with large portions of Providenciales, North and Middle Caicos.
- The Providenciales International Airport has been reopened, the airports in Grand Turk and South Caicos have emergency flights only.
- The roof of the hospital in Cockburn Town was damaged.

Figure 5 shows the flood damage caused by Hurricane Irma in the Turks and Caicos Islands.

Figure 5 Damage caused by Hurricane Irma in the Turks and Caicos Islands – September 2017.
Source: *Ministry of Defence*

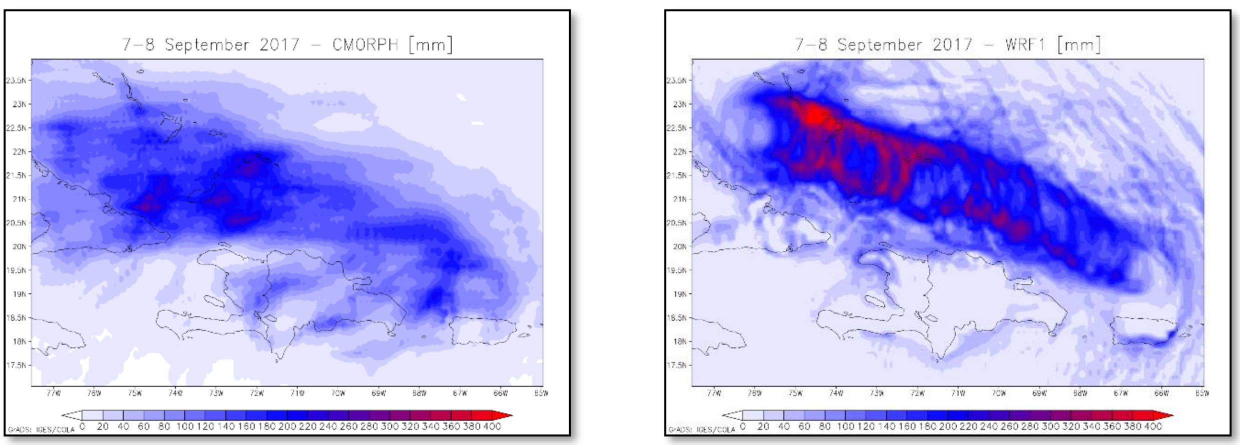
[1] The New York Times, available in: https://www.nytimes.com
[2] Travel Agent Central, available in: http://www.travelagentcentral.com
[3] Visit Turks and Caicos Islands, available in: https://www.visittci.com/

4 RAINFALL MODEL OUTPUTS

The trajectories of the accumulated precipitation reported by CMORPH[4] and the two WRF[5] configurations on 6 September agree with the trajectory inferred by the synoptic event description and from the radar reflectivity maps (Figure 4). The system core (the ring of heavy convective precipitation surrounding the eye) moved toward the west north-west, passing to the north of Puerto Rico. The peak of accumulated precipitation on 7 and 8 September was greater than 300 mm for both CMORPH and the two WRF configurations (Figure 6). However, the spatial pattern of accumulated precipitation differed in the following three configurations:

- CMORPH reported the highest accumulation (290 mm) on the waters between Haiti and the Turks and Caicos Islands.
- WRF1 simulated an extended and almost homogeneous area over which the daily accumulated precipitation was 440 mm, fully covering the waters between Puerto Rico and The Bahamas.
- WRF2 simulated the highest accumulation (250 mm) in a continuous line passing over the waters north of Hispaniola.

The difference between the two WRF configurations is explained by the fact that WRF1 represents the precipitation occurring in the hurricane core in a more symmetric way compared with WRF2. These divergent patterns evidenced by WRF1 and WRF2 result from the use of two different schemes of convection in the two model configurations.

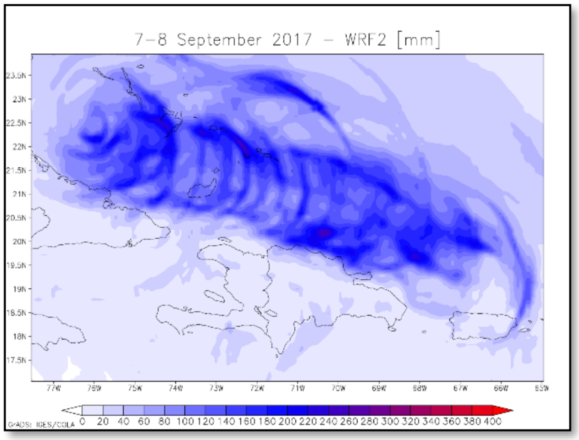


a) CMORPH b) WRF1

Figure 6 Rainfall accumulated precipitation at 8km resolution on 7-8 September 2017. Source: XSR Web.

[4] CMORPH Model: the satellite-based rainfall precipitation estimates provided by the NOAA Climate Prediction Center (CPC) using the so-called Morphing Technique http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html. Further details in the Definitions section of this report.

[5] WRF1 and WRF2 Models: the Weather Research and Forecasting Model [https://www.mmm.ucar.edu/weather-research-and-forecasting-model] weather model-based Configuration #1 and #2 data. These data is initialised by the NCEP FNL dataset. (NCEP FNL Operational Model Global Tropospheric Analyses [http://rda.ucar.edu/datasets/ds083.2/]). Further details in the Definitions section of this report.



c) WRF2

Figure 6 Rainfall accumulated precipitation at 8km resolution on 7-8 September 2017. Source: XSR Web.

The different spatial distribution of precipitation led to different daily accumulated precipitation over Turks and Caicos Islands. CMORPH estimated an accumulated precipitation ranging between 140 and 228 mm, while WRF1 simulated precipitation between 140 and 350 mm, and WRF2 simulated precipitation between 110 and 221 mm (Figure 7). All three datasets were in agreement in locating the most intense precipitation in the western islands on 8 September.

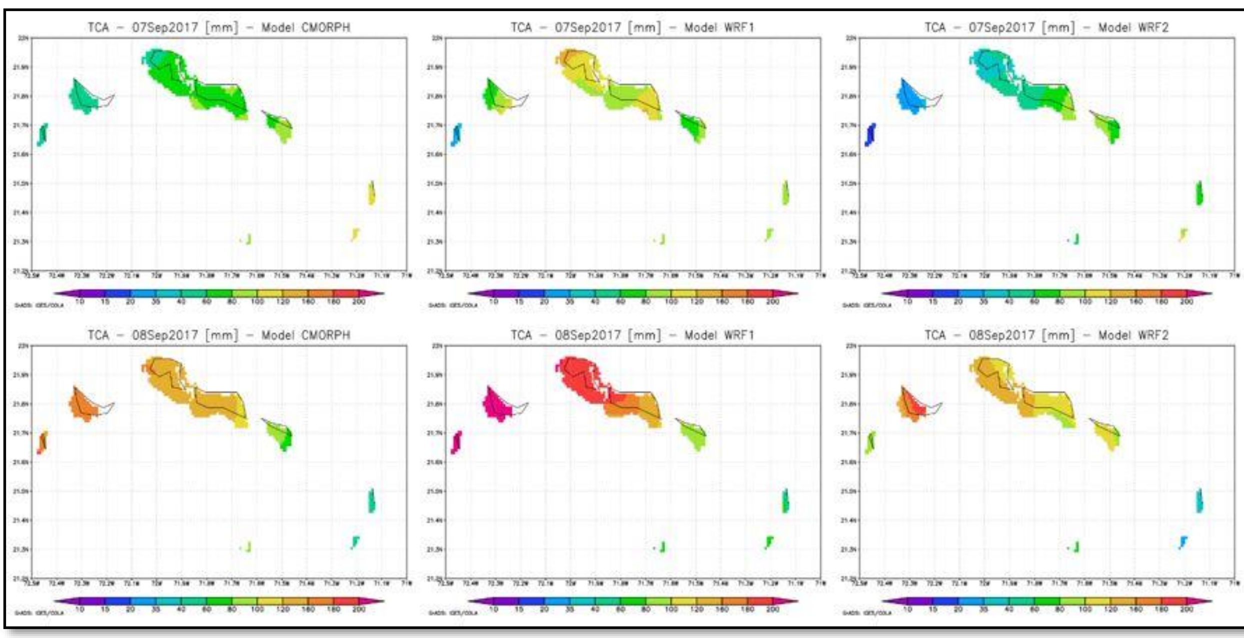
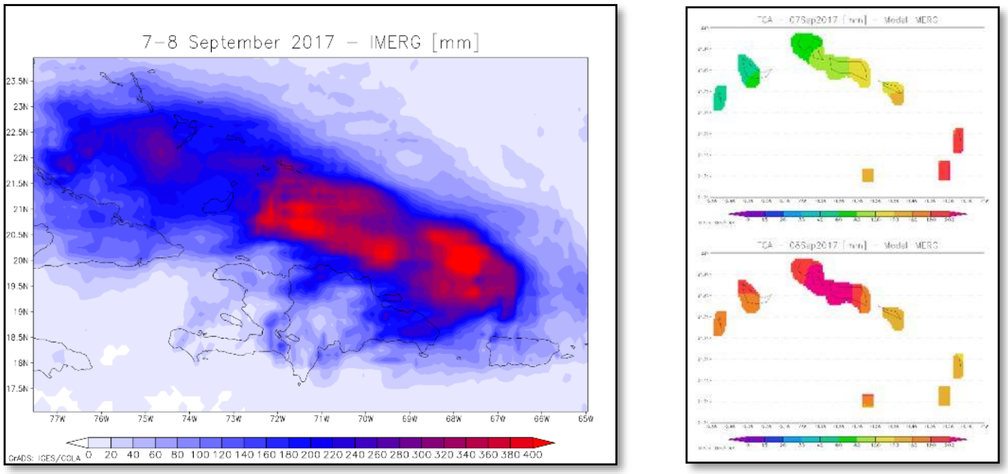


Figure 7 Accumulated precipitation (rainfall) at 1km resolution on 7 (top) and 8 (bottom) September 2017 CMORPH (left), WRF1 (middle) and WRF2 (right). Source: XSR Web.

No surface measurements of precipitation were available to us for the hours when the hurricane passed through the Turks and Caicos Islands. Satellite precipitation estimates were available through the IMERG (Integrated Multi-satellitE Retrievals for GPM) dataset (Figure 8), which estimated precipitation patterns in good agreement with those simulated by CMORPH, WRF1 and

WRF2. IMERG estimated precipitation values higher than those estimated by CMORPH, but in good agreement with the peaks simulated by WRF1, while WRF2 simulated lower values. IMERG located the peak of accumulated precipitation (about 440 mm) on the ocean to the northwest of Puerto Rico.

Over the Turks and Caicos Islands, IMERG estimated precipitation values, homogeneously distributed over the country, between 220 and 330 mm. These values were close to those estimated by WRF1, while they were greater than those estimated by CMORPH and WRF2.



a) b)

Figure 8 IMERG accumulated precipitation (rainfall) at 10km (a) and 1km (b) resolutions on 7-8 September, 2017. Source: XSR Web.

5 TRIGGER POTENTIAL

The Rainfall Index Loss calculated for this Covered Area Rainfall Event (CARE) that started on 7 September and ended on 9 September 2017 produced government losses which were above the attachment point of the Turks and Caicos Islands’ Excess Rainfall policy. Final calculations show that a payout of US$1,232,768.60 is due.

CCRIF expresses sympathy with the Government and people of Turks and Caicos Islands for the impacts on communities and infrastructure caused by this event.

For further information, please contact ERN-RED, the CCRIF SPC Risk Management Specialist.

Evaluación de Riesgos Naturales
Vito Alessio Robles No.179
Col. Hda. Gpe. Chimalistac.
Del. Álvaro Obregón. CP 01050, México D.F.
+52 (55) 5616-8161, 62, 64
cavelar@ccrif.org

DEFINITIONS

Active Exposure Cell Percentage Threshold	The percentage of the total number of XSR Exposure Grid Cells as defined in the Schedule, with in the covered Area of the Insured, which when exceeded triggers a Covered Area Rainfall Event.
Active Exposure Grid Cells	The XSR Exposure Grid Cells for which in the same single day the Average Aggregate Rainfall value computed using the CMORPH-based Rainfall Estimate equals or exceeds the Rainfall Event Threshold.
Average Aggregate Rainfall	The Average Aggregate Rainfall amount (where the number of days in the Rainfall Aggregation Period is defined in the Schedule) as measured in millimeters per day (mm/day) in any of the XSR Exposure Grid Cells in the Covered Area of the Insured. For a given number of days n, the n-day aggregation period is the average of rainfall on the day itself and on the previous n-1 days.
Calculation Agent	Entity charged with undertaking the primary calculation of the Rainfall Index Loss as described in the Calculation Agency Agreement.
CMORPH-based Maximum Average Aggregate Rainfall	The maximum value during the Covered Area Rainfall Event of the Average Aggregate Rainfall computed using the CMORPH-based Daily Rainfall Estimates in any given XSR Exposure Grid Cell over the Covered Area of the Insured.
CMORPH-based Covered Area Rainfall Parameters	The CMORPH Model information provided on a continuous basis by the XSR Model Data Reporting Agency used by the Calculation Agent to obtain the CMORPH-based Daily Rainfall Estimates using the XSR Rainfall Model. Parameters are drawn from XSR Exposure Grid Cells within the Covered Area of the Insured as identified in the Cell Identification and Rainfall Exposure Value Table in the Schedule, by their respective latitude and longitude. Measurement units and precision of data ingested by the XSR Rainfall Model are identical to those provided by the XSR Model Data Reporting Agency and are further elaborated in the Attachment entitled ‘Calculation of Rainfall Index Loss and Policy Payment’.
CMORPH Model	The satellite-based rainfall estimation model provided by NOAA CPC as described in the Rainfall Estimation Models section of the Policy.

Covered Area	The territory of the Insured as represented in the XSR Rainfall Model.
Covered Area Rainfall Event	Any period of days, with an interruption less than or equals to the Event Tolerance Period, during which the number of Active Exposure Grid Cells is greater than or equal to the product of (a) Active Exposure Cell Percentage Threshold multiplied by (b) the total number of XSR Exposure Grid Cells within the Covered Area.
Country Disaster Alert	An official disaster alert issued by ReliefWeb (http://reliefweb.int/) for the country in question for one of the following types of events: tropical cyclone, flood, flash flood and severe local storm. Any disaster alert issued later than seven (7) days after the completion of the Covered Area Rainfall Event event will not be considered.
Maximum Average Aggregate Rainfall	The highest value during a Covered Area Rainfall Event of the Average Aggregate Rainfall amount in any of the XSR Exposure Grid Cells in the Covered Area of the Insured computed.
Rainfall Event Threshold	Average Aggregate Rainfall level as defined in the Schedule which should be exceeded to trigger an Active Exposure Cell.
Rainfall Aggregation Period	The number of days over which the Average Aggregate Rainfall is computed for all XSR Exposure Grid Cells during a Covered Area Rainfall Event.
Rainfall Index Loss	For any Covered Area Rainfall Event affecting the Insured, the US Dollar loss calculated by the Calculation Agent using the XSR Rainfall Model, as described in the Attachment entitled 'Calculation of Rainfall Index Loss and Policy Payment'. The Rainfall Index Loss can only be calculated once the Covered Area Rainfall Event is completed.
WRF1 Model	The weather research and forecasting rainfall model by NOAA with Configuration #1 data initialized by the National Center for Environmental Prediction as described in the Rainfall Estimation Models and in the Input Data to the Rainfall Estimation Models sections of the Policy.
WRF2 Model	The weather research and forecasting rainfall model by NOAA with Configuration #2 data initialized by the National Center for Environmental Prediction as described in the Rainfall Estimation

	Models and in the Input Data to the Rainfall Estimation Models sections of this Attachment.
XSR Rainfall Model	The computer model used to calculate the Rainfall Index Loss, as described in the Attachment entitled ‘Calculation of Rainfall Index Loss and Policy Payment’.
XSR Exposure Grid Cells	The 30 arc-second by 30 arc-second grid of cells each of which is attributed with an XSR Grid Cell Exposure Value greater than zero, as provided in the Schedule.
XSR Grid Cell Exposure Value	The value, as shown in the Cell Identification and Rainfall Exposure Value Table in the Schedule, used to calculate the CMORPH-based Exposure Grid Cell Loss, the WRF1-based Exposure Grid Cell Loss, and the WRF2-based Exposure Grid Cell Loss.