CCRIF SPC
The Caribbean Catastrophe Risk Insurance Facility

On behalf of
Caribbean XSR SP

Covered Area Rainfall Event (6-7 September 2017)

Hurricane Irma Excess Rainfall

Event Briefing
Anguilla

16 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. Heavy rainfall was experienced over the Leeward Islands, as well as hurricane-force winds (185 mph or 295 km/h) with higher gusts.

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

Anguilla was affected by locally intense rainfall mainly between 0630UTC and 1400UTC on 6 September. The Rainfall Index Loss was calculated for this Covered Area Rainfall Event (CARE) that startedg on 6 September and ended on 7 September 2017, and it indicated government losses for Anguilla above the attachment point of the country's Excess Rainfall policy. Final calculations show that a payout of US$158,823 is due.

As reported in the previous Event Briefing on dated 8 September 2017 wind and storm surge effects from Tropical Cyclone Irma in the Leeward Islands, heavy rains and strong winds were experienced in Anguilla. Anguilla's Tropical Cyclone policy which provides coverage for wind and storm surge was triggered and a payout of US$6,529,100 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.

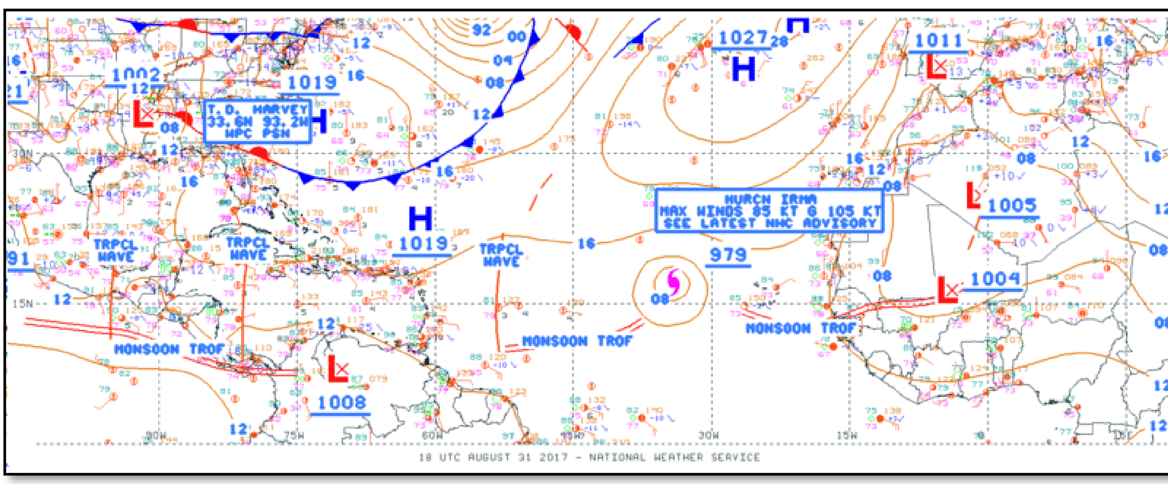


Figure 1 Surface analysis of the tropical Atlantic on 31 August at 18UTC.
Source: NOAA Ocean Prediction Center.

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).

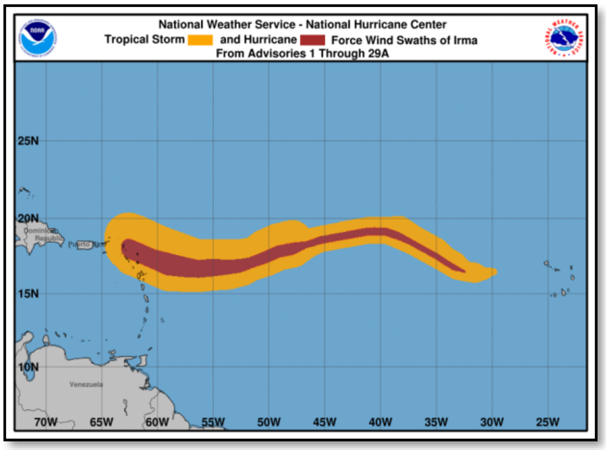


Figure 2 Irma's track and contouring of the wind speed intensity. Source: NHC

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). At this time, the hurricane moved in a west-northwest direction at 12 mph (19 km/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 stopped Irma's rapid strengthening. 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 the 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).

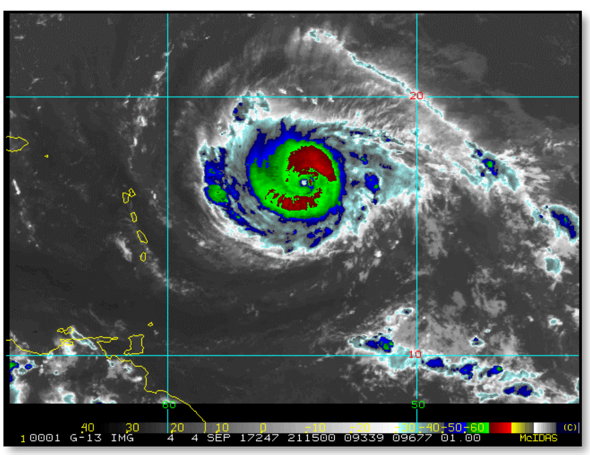


Figure 3 Enhanced infrared satellite image on 4 September at 2115UTC. Red and green indicate, respectively, very high and high top clouds. Source: NOAA

The hurricane-force winds remained constant until 4 September when a 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).

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.

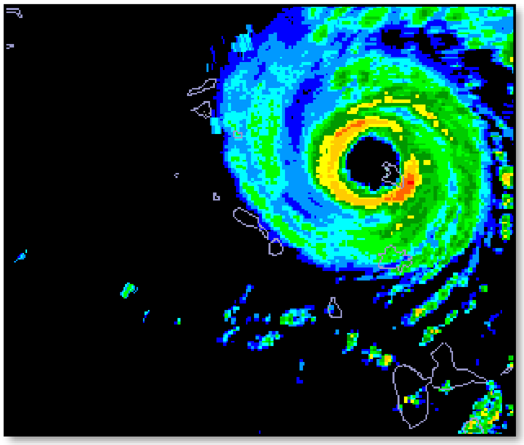
The core passage over the northern Leeward Islands occurred on 6 September at about 06-12UTC. At this time, the maximum sustained winds were approximately 185 mph (295 km/h) with higher gusts and the estimated minimum central pressure was 914 mb.

On 6 September at 0630UTC, the heavy rain associated with the core of the hurricane reached Anguilla (Figure 4a). The northern sector of Irma’s eyewall passed directly over Anguilla, yielding high rates of precipitation between 0945UTC and 1215UTC (Figure 4b, Figure 4c and Figure 4d). The core of Irma left Anguilla at 14UTC (Figure 4e). Isolated rain showers associated with the outward rain bands of Irma intermittently affected the island from that time until 6 September at 22UTC.

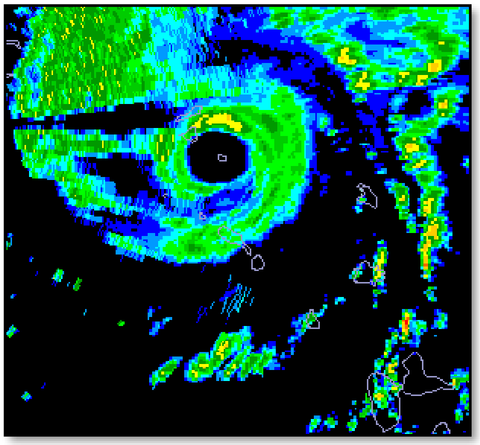
Antigua and Barbuda and St. Kitts and Nevis were among the Leeward Islands also affected by the heavy precipitation associated with the core of the hurricane.

During the following hours, the hurricane continued to move towards the west-northwest with a forward velocity of 16 mph (26 km/h) and constant wind intensity and minimum pressure. The British Virgin Islands, Puerto Rico, Dominican Republic, Haiti, the Turks and Caicos Islands and The Bahamas were also affected.

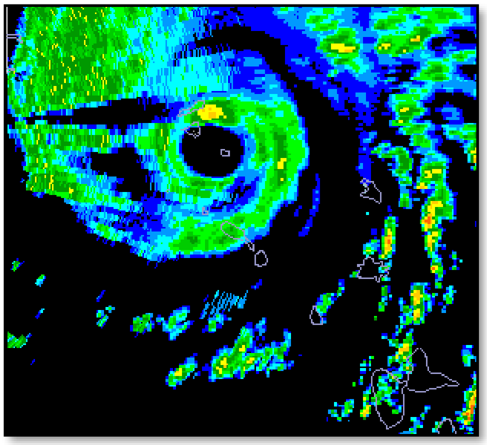
Additional Event Briefing Reports were prepared for the other CCRIF countries that were affected.



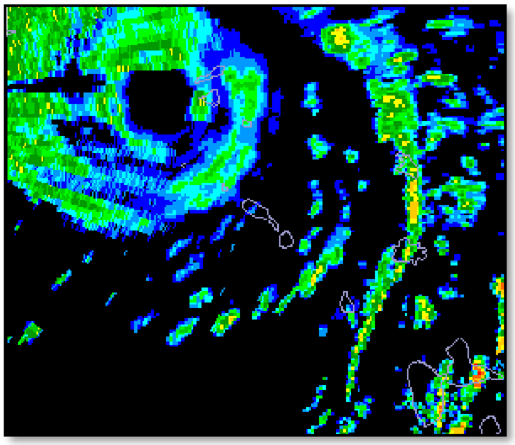
a) 6 September at 06:30 UTC



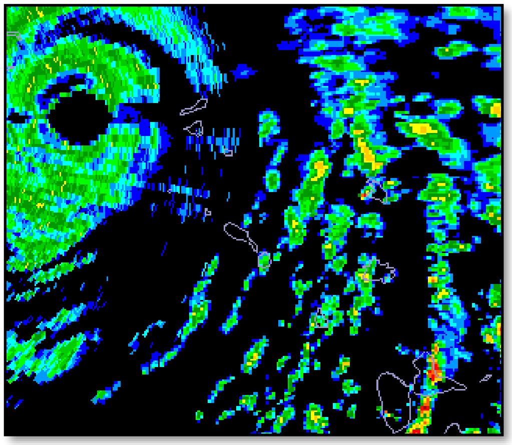
b) 6 September at 09:30 UTC



c) 6 September at 10:00 UTC



d) 6 September at 12:00 UTC



e) 6 September at 14:00 UTC

Figure 4 Reflectivity maps from the radar composite collected at different times.
(Source: www.barbadosweather.org)

3 IMPACTS

Nine days after Hurricane Irma, according to Mr. John McKendrick, Anguilla's Attorney General, the island suffered "huge devastation" from Hurricane Irma. Executive Director of the Caribbean Disaster and Emergency Management Agency (CDEMA), Mr. Ronald Jackson, reported that one person died due to the hurricane. Police stations, hospitals, school facilities, emergency shelters, as well as the fire station were damaged.

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

- 90% of houses and 90% of roads were damaged.
- Fallen trees blocked many roads.
- Phone service was interrupted.
- Ports and the airport were closed.

Prior to the arrival of hurricane Irma, precautionary measures were taken, including:

- Schools and government offices were closed.
- Three shelters were opened.

4 RAINFALL MODEL OUTPUTS

The trajectories of the accumulated precipitation reported by CMORPH[3] and the two WRF[4] configurations on 6 September agreed with the trajectory inferred by the synoptic event description and from the radar reflectivity maps (Figure 4). Indeed, the system core (the ring of heavy convective precipitation surrounding the eye) moved toward the west north-west, passing over the northern Leeward Islands. The peak of accumulated daily precipitation was greater than 200 mm on 6 September for both CMORPH and the two WRF configurations (Figure 5). However, the spatial pattern of accumulated precipitation differed in the following three configurations:

- CMORPH reported the highest accumulation (230 mm) on the waters between Barbuda and Anguilla
- WRF1 simulated an extended and almost homogeneous area over which the daily accumulated precipitation was 340 mm, fully covering the waters between the British Virgin Islands and Antigua and Barbuda
- WRF2 simulated the highest accumulation (328 mm) in a continuous line passing over the waters north of the northern Leeward Islands.

[1] Anguilla-Beaches.Com, available in: *http://www.anguilla-beaches.com/*

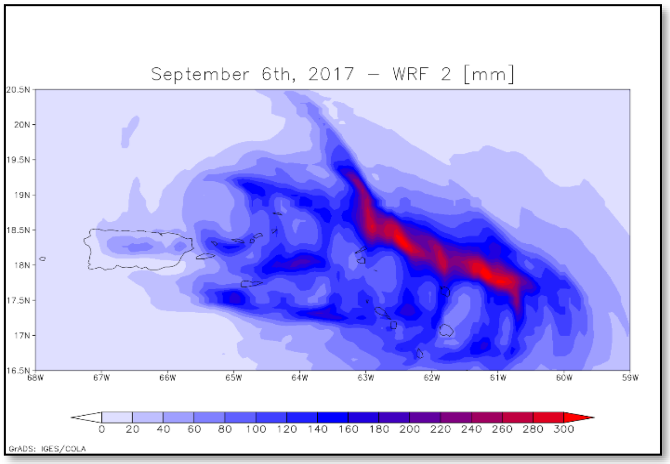
[2] The New York Times, available in: *https://www.nytimes.com*

[3] 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.

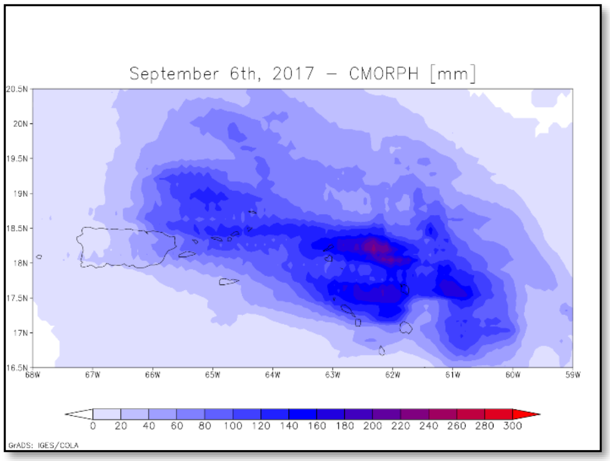
[4] WRF1 and WRF2 Models: the Weather Research and Forecasting Model [*https://www.mmm.ucar.edu/weather-research-and-forecasting-model*] weather model-based Configuration #1 and #2 data. These data is initialised by the NCEP FNL dataset. (NCEP FNL Operational Model Global Tropospheric Analyses [*http://rda.ucar.edu/datasets/ds083.2/*]).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

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. WRF2 shows the highest rainfall in the northern sector of Irma's core and in this sense, better captures the asymmetric pattern of precipitation evidenced by the reflectivity radar maps (Figure 4), for which the highest rainfall rates often occurred in the northern sector of the core.

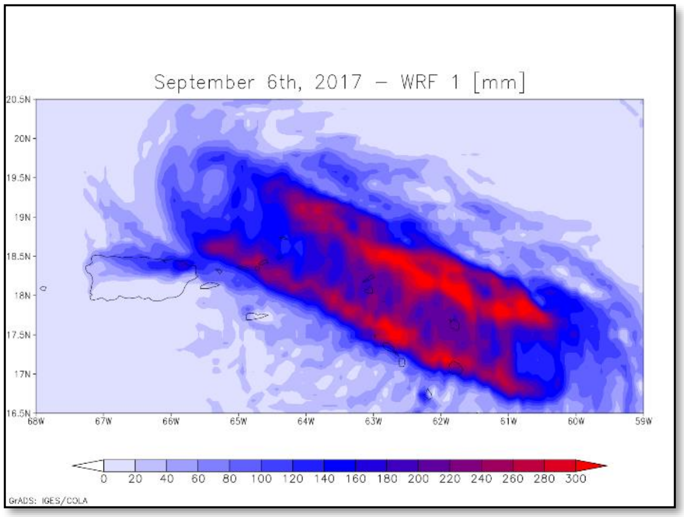
These divergent patterns evidenced by WRF1 and WRF2 are caused by the use of two different schemes of convection in the two model configurations.



a) CMORPH



b) WRF1



c) WRF2

Figure 5 Rainfall accumulated precipitation at 8km resolution on 6 September 2017. Source: XSR Web.

The different spatial distribution of the precipitation led to different daily accumulated precipitation over Anguilla. CMORPH estimated an accumulated precipitation ranging between 135 and 165 mm, while WRF1 simulated a range between 190 and225 mm, and WRF2 between 80 and 180 mm (Figure 6).

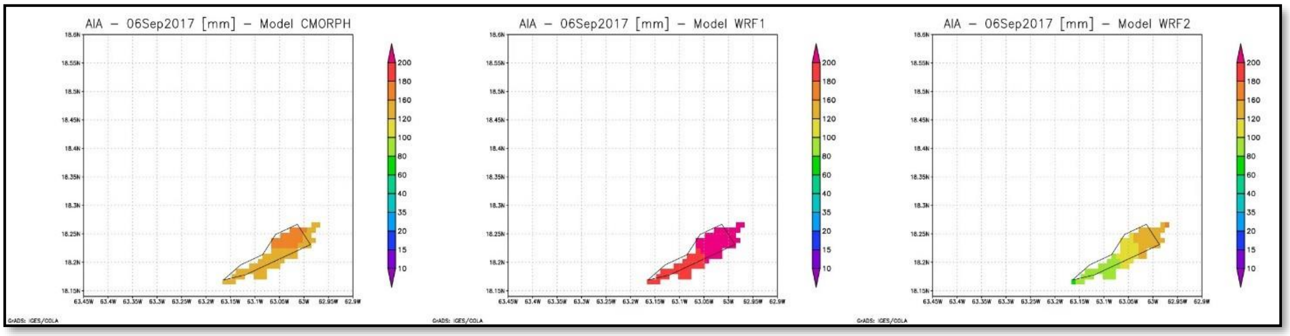
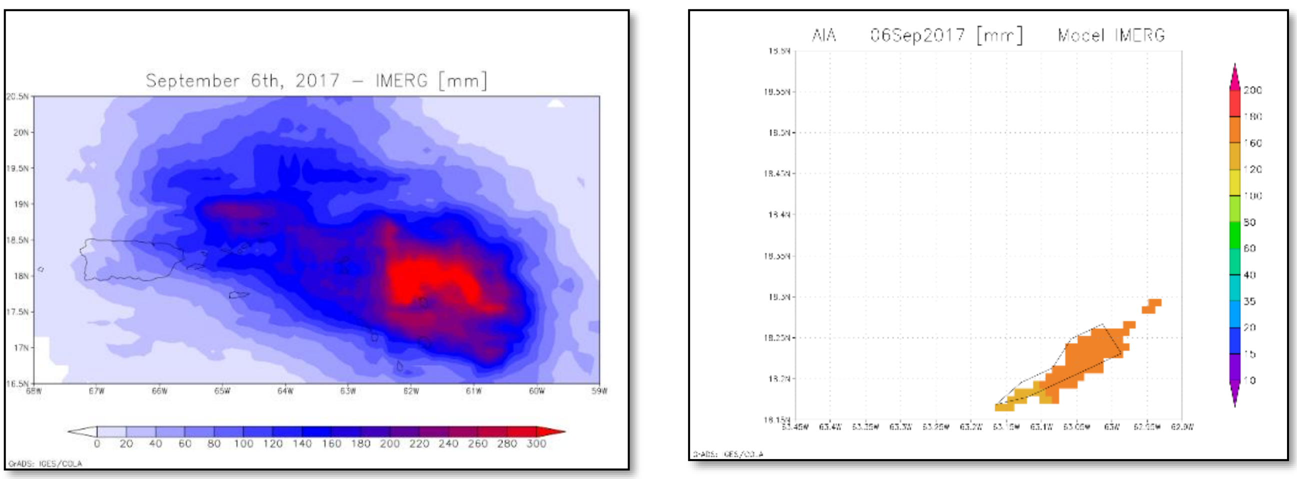


Figure 6 Accumulated precipitation (rainfall) at 1km resolution on 6 September 2017 CMORPH (left), WRF1 (middle) and WRF2 (right). Source: XSR Web

No surface measurements of precipitation were available to us for the hours of the hurricane passing over the island of Anguilla. NHC forecasted an accumulated precipitation of 8 to 12 inches (200-300 mm), with isolated areas of 20 inches (500 mm) over the Northern Leeward Islands associated with Irma's passage. In this respect, the precipitation accumulation simulated by WRF1 is closer to the NHC estimate.



a) b)

Figure 7 IMERG accumulated precipitation (rainfall) at 10km (a) and 1km (b) resolutions on 6 September 2017. Source: XSR Web.

Additional satellite precipitation estimates are available through the IMERG (Integrated Multi-satellitE Retrievals for GPM) dataset (Figure 7), which estimated precipitation patterns and values in good agreement with those simulated by CMORPH, WRF1 and WRF2. The peak of accumulated daily precipitation is about 380 mm, located on the ocean to the northwest of Barbuda.

Over Anguilla, IMERG estimated precipitation values between 150 and 175 mm, which are very close to those estimated by CMORPH, slightly lower than those estimated by WRF1 and higher than those simulated by WRF2.

5 TRIGGER POTENTIAL

The Rainfall Index Loss was calculated for this Covered Area Rainfall Event (CARE) that started on 6 September and ended on 7 September 2017, producing government losses which were above the attachment point of Anguilla's Excess Rainfall policy. Final calculations show that a payout of US$158,823 is due.

CCRIF expresses condolences to the Government and people of Anguilla for the loss of life and severe 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.