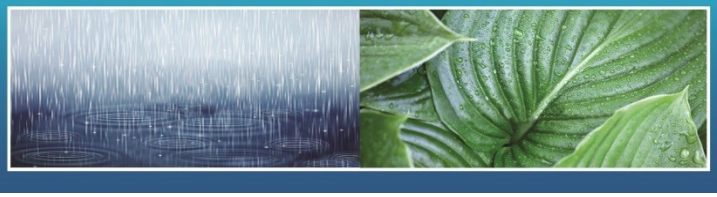
CCRIF SPC
The Caribbean Catastrophe Risk Insurance Facility

On behalf of
Caribbean XSR SP



Covered Area Rainfall Event (18-19 September 2017)

Hurricane Maria Excess Rainfall

Event Briefing

Barbados

28 September 2017

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1 INTRODUCTION

Maria, the 15th named tropical cyclone of the 2017 Atlantic Hurricane Season, formed as a tropical storm on 16 September at 2100UTC, east-southeast of the Lesser Antilles. It was upgraded to hurricane status on 17 September at 2100UTC. Maria intensified moving across the Atlantic Ocean and reached the Leeward Islands near Dominica as a major hurricane (category 5) on Monday 18 September at approximately 2345UTC. Heavy rainfall was experienced over the Windward Islands, as well as hurricane-force winds of up to 85 mph (140 km/h) with higher gusts.

This report describes the results of the Excess Rainfall model (XSR 2.0) on CCRIF member country Barbados during rains associated with Hurricane Maria. Other reports have been issued regarding other CCRIF member countries that have Excess Rainfall policies and were affected by Maria.

Barbados was affected by locally intense rainfall mainly between 2200UTC on 17 September and 2100UTC on 18 September. The Rainfall Index Loss was calculated for this Covered Area Rainfall Event (CARE) that started on 18 September and ended on 19 September 2017, and it indicated government losses for Barbados above the attachment point of the country's Excess Rainfall policy. Final calculations show that a payout of US$1,917,506 is due.

2 EVENT DESCRIPTION

On 16 September 2017 at 2100UTC, the US National Hurricane Center (NHC) reported that a tropical storm named Maria had developed over the far eastern Atlantic, with maximum sustained winds of 50 mph (85 km/h).

In the next 24 hours, Maria moved toward the west-northwest at almost 15 mph (24 km/h) and it rapidly intensified due to the favourable thermodynamic environment: low-shear, humid layers and the passage over warm sea. At that time Maria was upgraded to a category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale and was located at 13.8N, 57.5W. It featured maximum sustained winds of 75 mph (120 km/h), and the estimated minimum pressure was 982 mb (Figure 1).

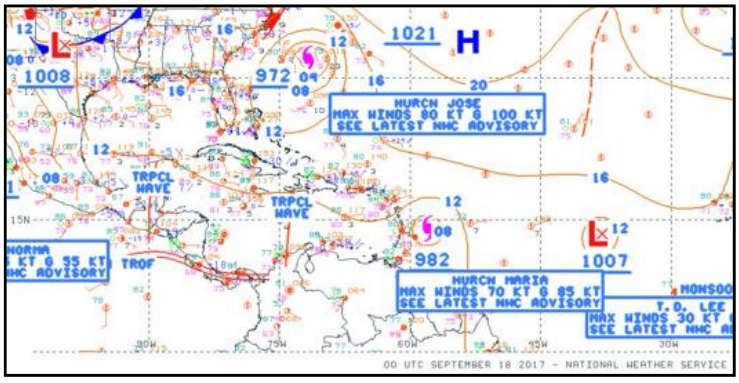
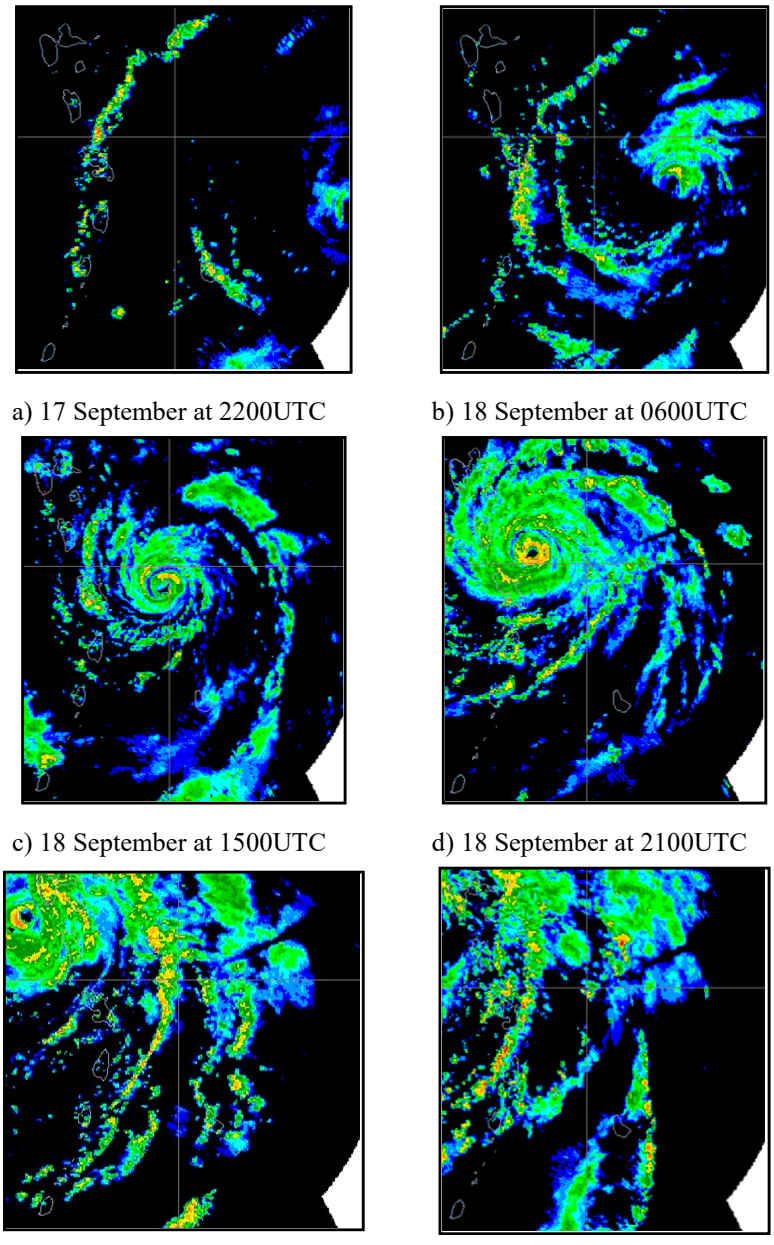


Figure 1 Surface analysis of the tropical Atlantic on 18 September at 0000UTC.
Source: NOAA Ocean Prediction Center.

Heavy and intermittent precipitation associated with the hurricane rain bands started to affect Barbados on 17 September at 2200UTC (Figure 2). The precipitation over the island became heavy and continuous on 18 September from 0600UTC to 1500UTC, when the core of Maria was at its minimum distance from Barbados (Figure 2). In the subsequent hours, the hurricane moved away from Barbados heading for Dominica. Heavy and intermittent precipitation associated with the southern sector of the hurricane rain bands continued to affect Barbados from 18 September at 1500UTC until 19 September at 1200UTC.



a) 17 September at 2200UTC b) 18 September at 0600UTC

c) 18 September at 1500UTC d) 18 September at 2100UTC

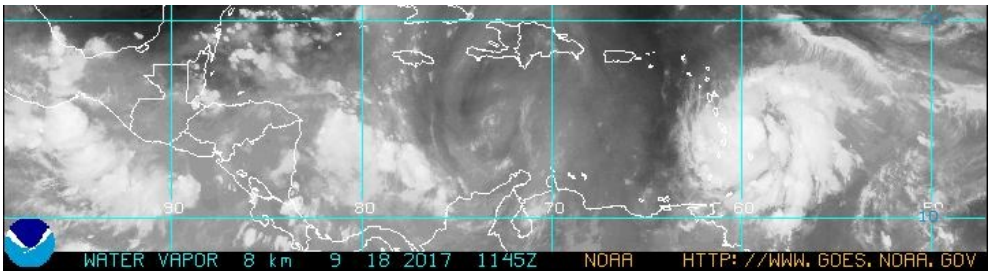
e) 19 September at 0600UTC f) 19 September at 1200UTC

Figure 2 Reflectivity maps of the radar composite over the Caribbean region at different times.
Source: http://www.barbadosweather.org

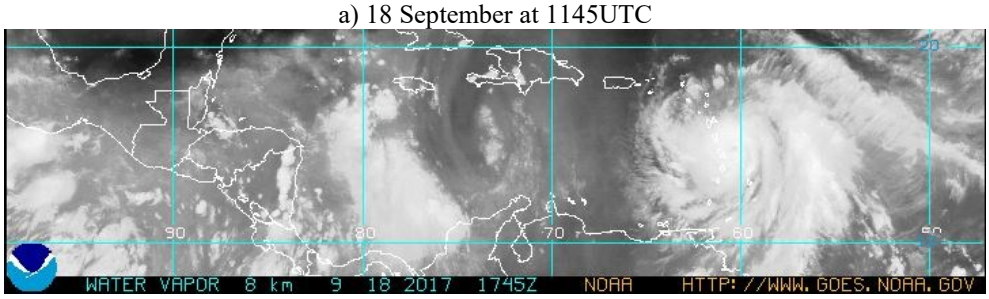
Within this period, Maria strengthened further and was upgraded on 18 September at approximately 2100UTC to a category 4 hurricane with maximum sustained winds of 130 mph (215 km/h). At that time, the eye of the hurricane was located near 15.1N, 60.7W and the hurricane structure was well defined, showing a clear eye and a symmetrical cloud with an overcast ring around it, with very high top cloud. (Figure 3)

At 2345UTC, Maria, which had already become a category 5 hurricane, was located between Dominica and Martinique with maximum sustained winds of almost 160 mph (260 km/h) with higher gusts. The system was moving towards the west-northwest at almost 9 mph (15 km/h) and the minimum central pressure reported by National Hurricane Center was 925 mb (Figure 3).

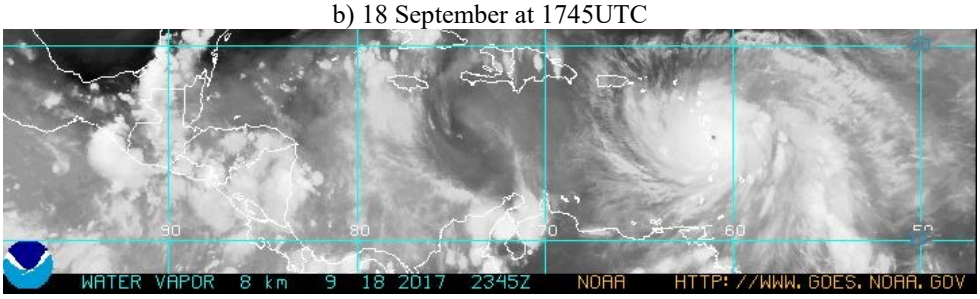
After three hours, at 0300 UTC, the centre of Maria passed over Dominica, affecting Saint Lucia and Martinique with tropical-storm-force winds, and Guadeloupe with hurricane-force winds. Air Force Reserve Hurricane Hunter aircraft reported that the maximum sustained winds were almost 44 mph (70 km/h).



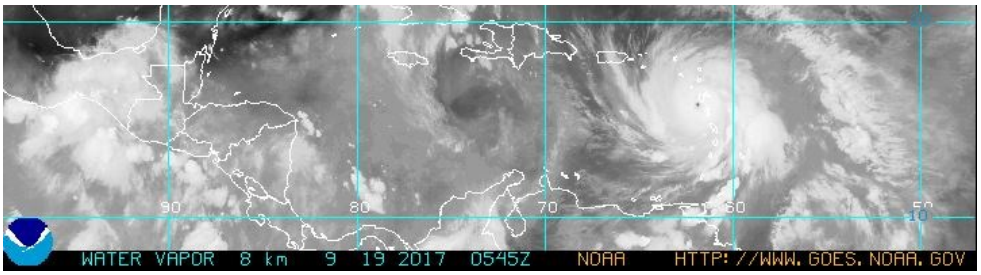
a) 18 September at 1145UTC



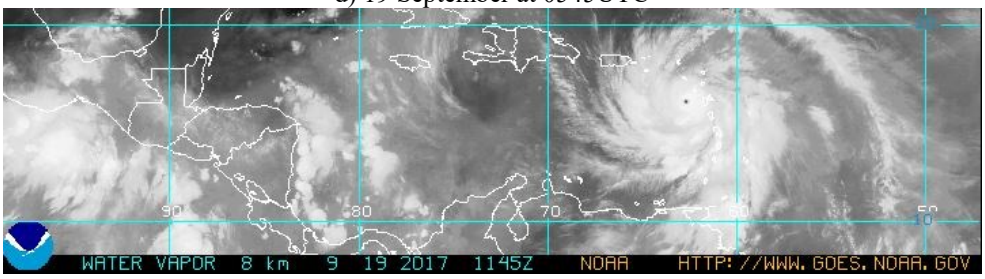
b) 18 September at 1745UTC



c) 18 September at 2345UTC



d) 19 September at 0545UTC



e) 19 September at 1145UTC

Figure 3 Maria's evolution over Windward and Leeward Islands. Source: https://www.goes.noaa.gov/

At 1500 UTC on 19 September, Maria moved toward the west-northwest at almost 10 mph (17 km/h) with constant wind intensity and minimum pressure. On its trajectory, Maria subsequently affected the British Virgin Islands, Puerto Rico, Dominican Republic, Haiti, the Turks and Caicos Islands and the south-eastern sector of the Bahamas islands (Figure 4).

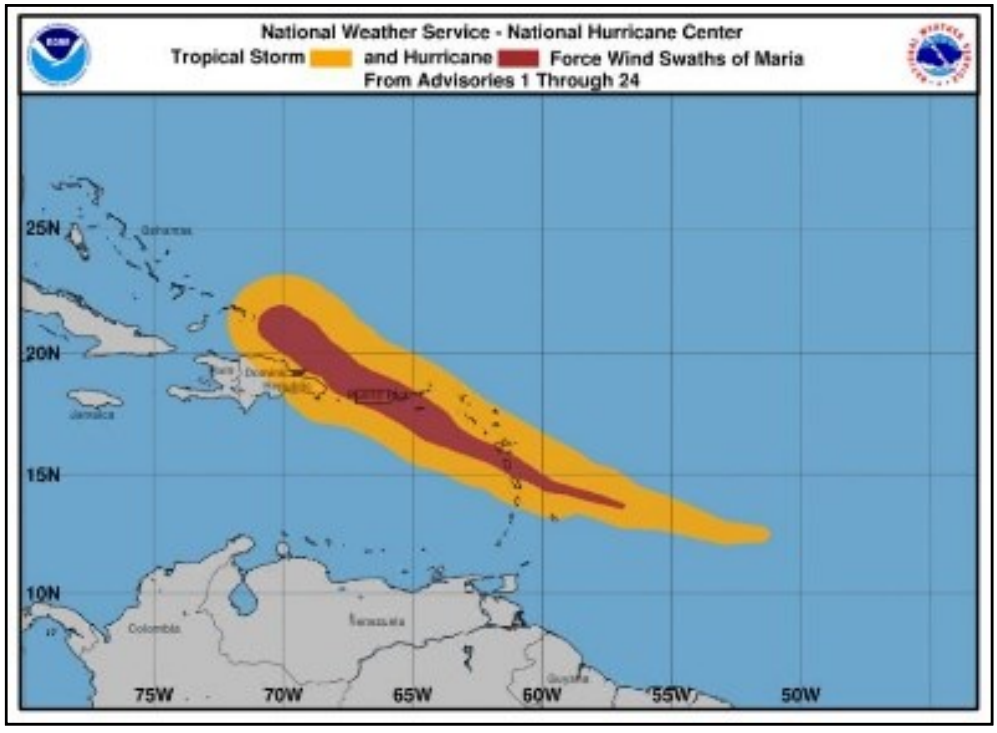


Figure 4 Maria's track and contouring of the wind speed intensity. Source: NHC

An additional Event Briefing Report will be issued for the CCRIF countries affected.

3 IMPACTS

According to reports and assessments provided by the Caribbean Disaster Emergency Management Agency (CDEMA), Barbados' authorities took precautionary measures prior to the arrival of Hurricane Maria. A Tropical Storm Watch and Flood Warnings were issued and primary and secondary schools and training centres were closed.

At the time of this report, local news [1] had reported flooding and blockage of springs due to falling trees

Figure 5 shows flooding caused by Hurricane Maria in Barbados.

Figure 5 Damage caused by Hurricane Maria in Barbados – September 2017.
Source: *Loop News Barbados*

4 RAINFALL MODEL OUTPUTS

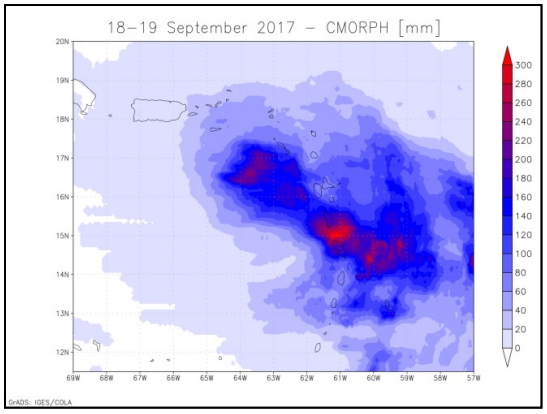
The trajectories of the accumulated precipitation reported by CMORPH[2] and the two WRF[3] configurations between 18 and 19 September agree with the trajectory inferred by the synoptic event description and from the radar reflectivity maps (Figure 2). The system core (the ring of heavy convective precipitation surrounding the eye) moved toward the west north-west, passing to the north of Barbados. The peak of accumulated precipitation on 18 and 19 September was

[1] Caribbean Broadcasting Corporation, available in; *http://www.cbc.bb/*
[2] 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.
[3] 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.

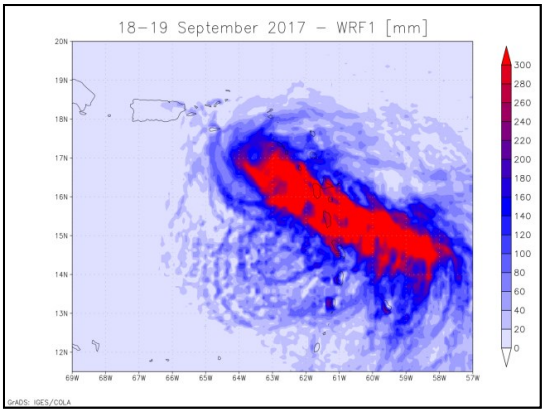
about or greater than 300 mm for both CMORPH and the two WRF configurations (Figure 6). However, the spatial pattern of accumulated precipitation differed in the following three configurations:

- CMORPH reported the highest accumulation (234 mm) on the waters between the islands of Martinique and Dominica.
- WRF1 simulated an extended and almost homogeneous area over which the accumulated precipitation was 512 mm, fully covering the waters from the northeast of Barbados to the southwest of Saint Kitts and Nevis.
- WRF2 simulated the highest accumulation (433 mm) in a continuous line passing over the waters from the northeast of Barbados to the southwest of Saint Kitts and Nevis.

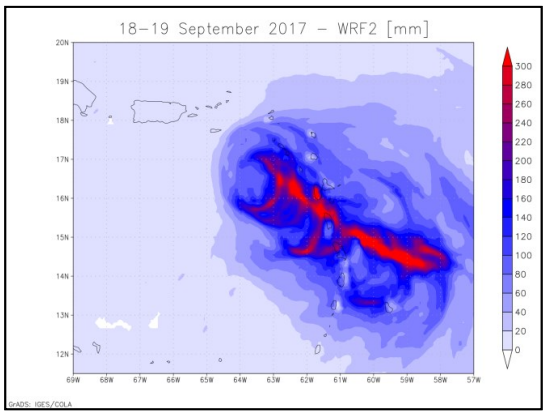
The difference between the two WRF configurations is explained by the fact that WRF1 represents the precipitation occurring in the hurricane core in a more symmetric way compared with WRF2. These divergent patterns evidenced by WRF1 and WRF2 result from the use of two different schemes of convection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



a) CMORPH



b) WRF1



c) WRF2

Figure 6 Rainfall accumulated precipitation at 8km resolution during 18-19 September 2017. Source: XSR Web.

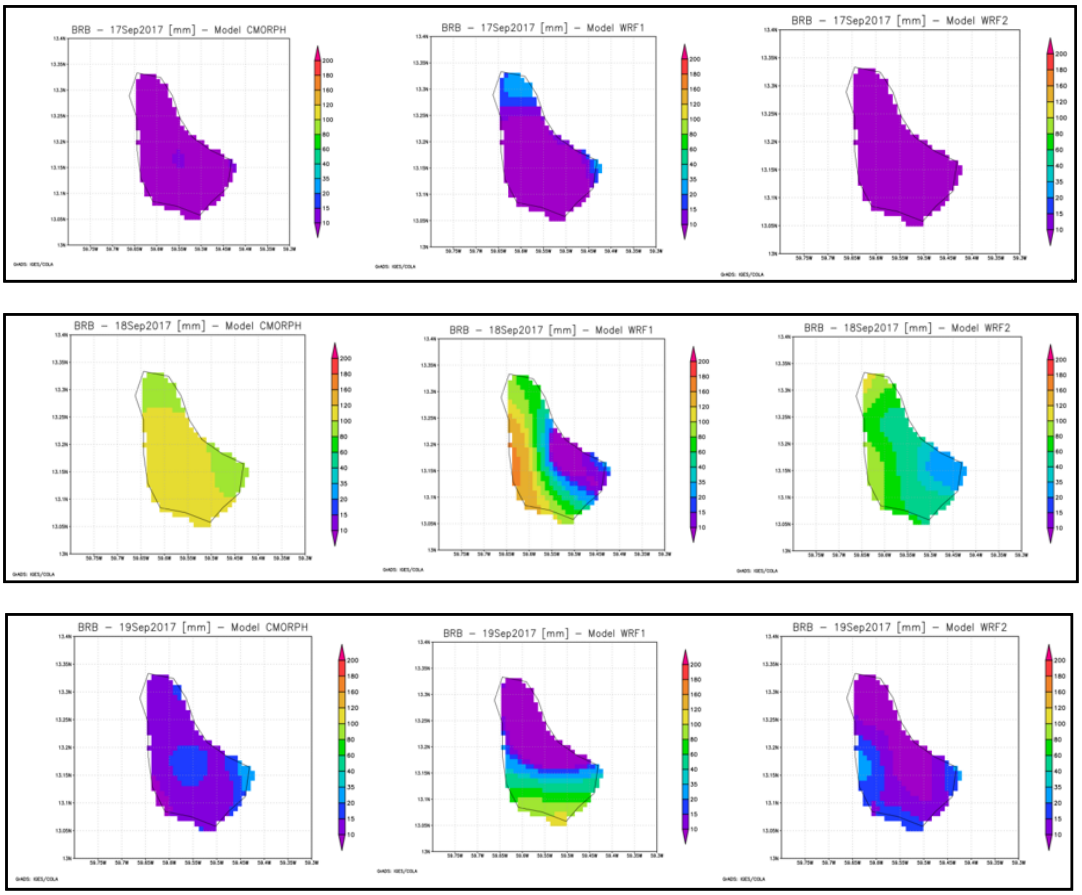
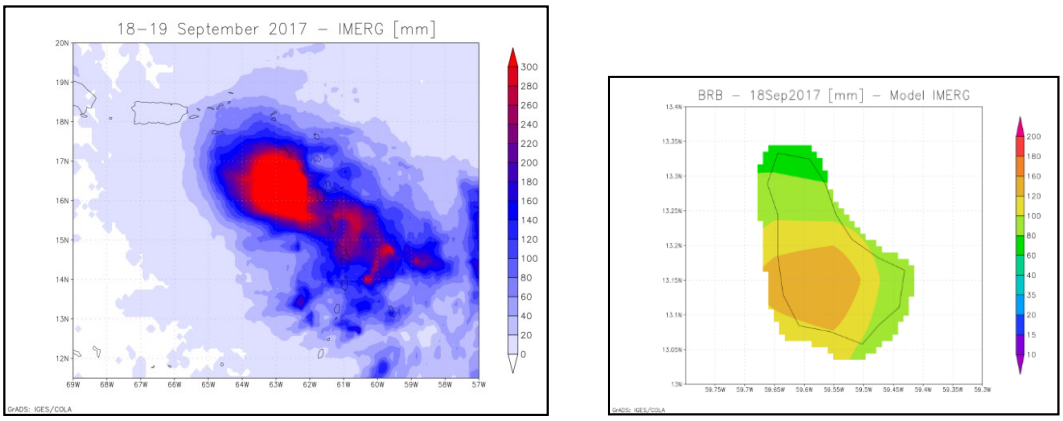


Figure 7 Accumulated precipitation (rainfall) at 1km resolution on 17(top), 18 (middle) and 19 (bottom) September 2017 CMORPH (left), WRF1 (middle) and WRF2 (right). Source: XSR Web.

As described in section 2, the precipitation associated with Maria occurred over Barbados on 17, 18 and19 September. On 17 September, CMORPH and the two WRF configurations presented low daily accumulated rainfall values. On 18 September, CMORPH located the precipitation peak in the southwest sector of the island. The WRF1 and WRF2 configurations were generally in agreement, locating the precipitation peaks in the west and northwest regions respectively. On 19 September, CMORPH and the two WRF configurations presented low daily accumulated rainfall values with the maximum located in the southern sector of the island (Figure 7).

Few measurements of precipitation were available to us for the hours when the hurricane passed over Barbados. A rain gauge located in the southern sector of the island reported the following daily accumulated values: 24 mm (17 September), 61 mm (18 September), 55 mm (19 September). On 17 September, both CMORPH and the two WRF configurations presented higher values than this observation. On 18 September, WRF 1 and WRF2 were in fair agreement with the surface record, while CMORPH overestimated it. On 19 September, WRF1 was in fair agreement with the surface record, while CMORPH and WRF2 underestimated it.

Satellite precipitation estimates are 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.



a) b)

Figure 8 IMERG accumulated precipitation (rainfall) at 10km (a) and 1km (b) resolutions on 18-19 September 2017 (left) and on 18 September (right). Source: XSR Web.

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 544 mm) on the waters to the south of St. Kitts and Nevis. Over Barbados, on the day of the largest rainfall accumulation (18 September), IMERG estimated the largest accumulated precipitation on the southwestern sector of the island, in agreement with CMORPH and the two WRF configurations. The observed values were up to 120-160 mm, which were close to those estimated by WRF1, while they were greater than those estimated by CMORPH and simulated by WRF2.

5 TRIGGER POTENTIAL

The Rainfall Index Loss was calculated for this Covered Area Rainfall Event (CARE) that started on 18 September and ended on 19 September 2017, producing government losses which were above the attachment point of Barbados' Excess Rainfall policy. Final calculations show that a payout of US$1,917,506 is due.

CCRIF expresses empathy with the Government and people of Barbados for the impacts caused by this event.

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

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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.