CCRIF SPC
The Caribbean Catastrophe Risk Insurance Facility

On behalf of
Caribbean XSR SP

Covered Area Rainfall Event
(28-29 September 2018)

Tropical Storm Kirk
Excess Rainfall

Event Briefing

Barbados

6 October 2018

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1 INTRODUCTION

Kirk was the 12th named tropical cyclone in the 2018 Atlantic Hurricane Season. It formed as a tropical storm over the eastern tropical Atlantic Ocean on 22 September 2018 at 1500UTC. Along its movement toward the east north-east, it was downgraded to an open trough on 24 September at 1500UTC and regenerated as a tropical storm on 26 September at 0900UTC. Kirk presented a strong vertical sheared shape, with the maximum winds at the north and east of the centre. Heavy rainfall was experienced over the Windward and Leeward Islands, as well as tropical-storm-force winds of up to 50 mph (85 km/h) with higher gusts.

This report describes the results of the Excess Rainfall model (XSR 2.1) on CCRIF member country Barbados during rains associated with Tropical Storm Kirk.

Barbados was affected by heavy rainfall from 27 September at 2230UTC to 28September at 0215UTC. From this time and during the first part of 28 September, the precipitation persisted over the island with a moderate and in some areas locally heavy. The Rainfall Index Loss calculated for this Covered Area Rainfall Event (CARE) that started on 28 September and ended on 29 September 2018 indicated government losses for Barbados above the attachment point of the country's Excess Rainfall policy. Final calculations show that a payout of US$5,813,299 is due.

2 EVENT DESCRIPTION

On 22 September 2018 at 1500UTC, the US National Hurricane Center (NHC) reported that a small area of low pressure south of the Cabo Verde Islands (at 8.3N - 23.6W) became a tropical storm, with a well-defined centre and maximum wind intensity at 34-40 mph (55-64 km/h). It was named Kirk. Initially, the tropical storm moved toward the west-northwest at 13 mph (22 km/h), experiencing a slight strengthening due to the passage over warm sea waters in a low-shear environment (Kirk's track is displayed in Figure 1). After 48 hours, on 24 September at 1500UTC, Kirk dissipated due to the strong easterly winds that pushed the system toward west at a very high speed (24 mph, 39 km/h) and damped the cyclone convection. After another 48 hours, on 26 September at 0900UTC, the remnants of Kirk steered a little north of due west, moving along the south side of the strong Bermuda-Azores high pressure system. Thus, the forward velocity fell to approximately 18 mph (30 km/h). The low vertical shear of the environment and the warm sea surface favored a re-intensification of the system, which regenerated as a tropical storm. At this time, Kirk was located at 11.8N, 52.7W and it presented a maximum wind speed of 45 mph (72 km/h).

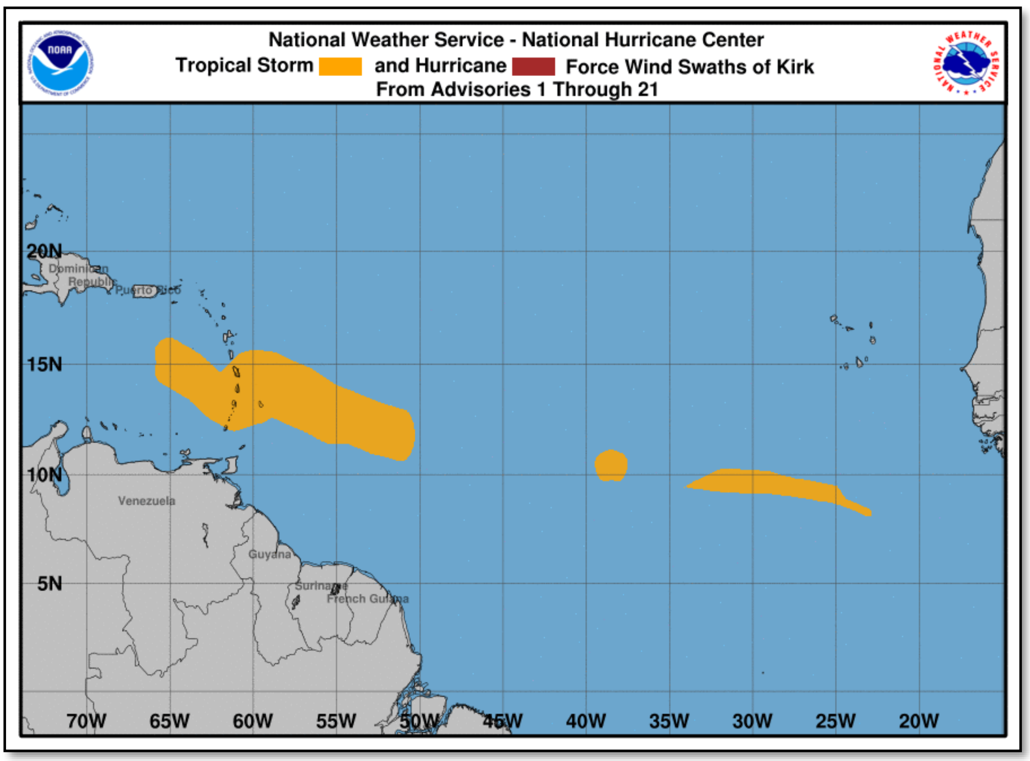


Figure 1 Track of the TC Kirk and wind history. Source: National Hurricane Center.

On 27 September at 0000UTC, Tropical Storm Kirk was at the eastern edge of the Caribbean Sea (12.7N, 56.1W, Figure 1 and Figure 2) and it started to experience the strong upper-level westerly or southwesterly winds flowing over the entire Caribbean area. These winds increased the vertical shear between the upper level and the low level (see the wind speed shear in Figure 3) and shifted the thunderstorm activity on the rainbands to the east of the low-level cyclone centre, as shown by the radar reflectivity maps in Figure 4.

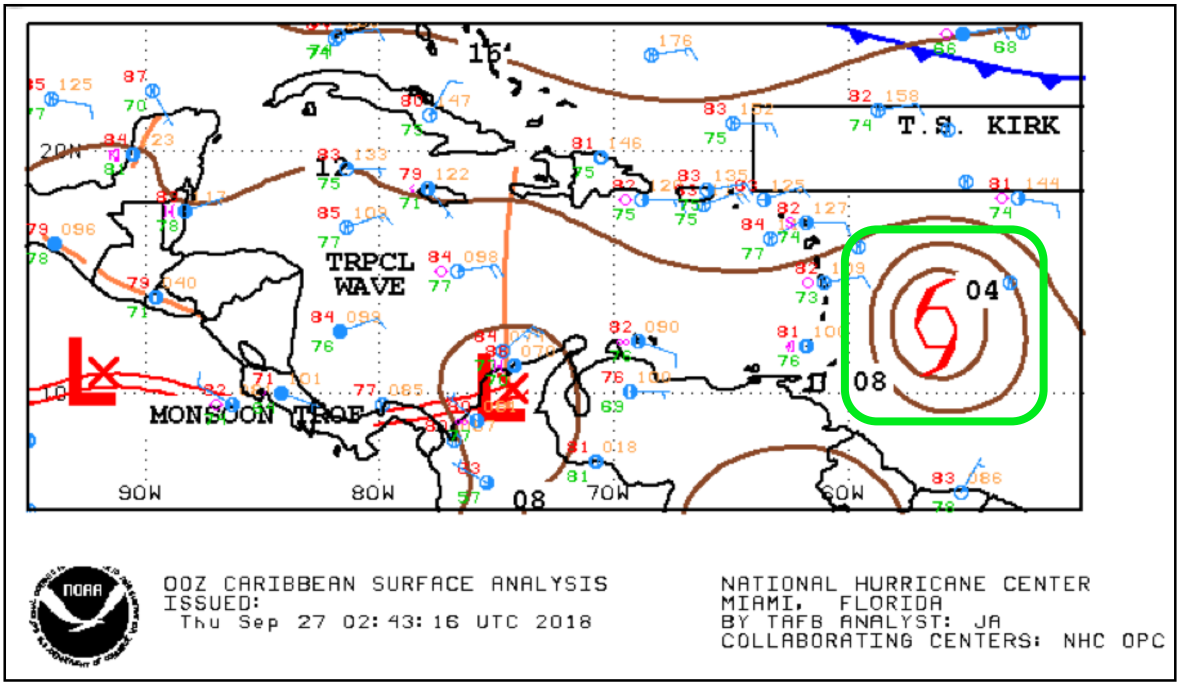


Figure 2 Surface analysis over the Caribbean area at 27 September at 0000UTC. The tropical storm Kirk is located to the east of the Lesser Antilles at 12.7 N, 56.1 W. Source: US National Hurricane Center (NHC).

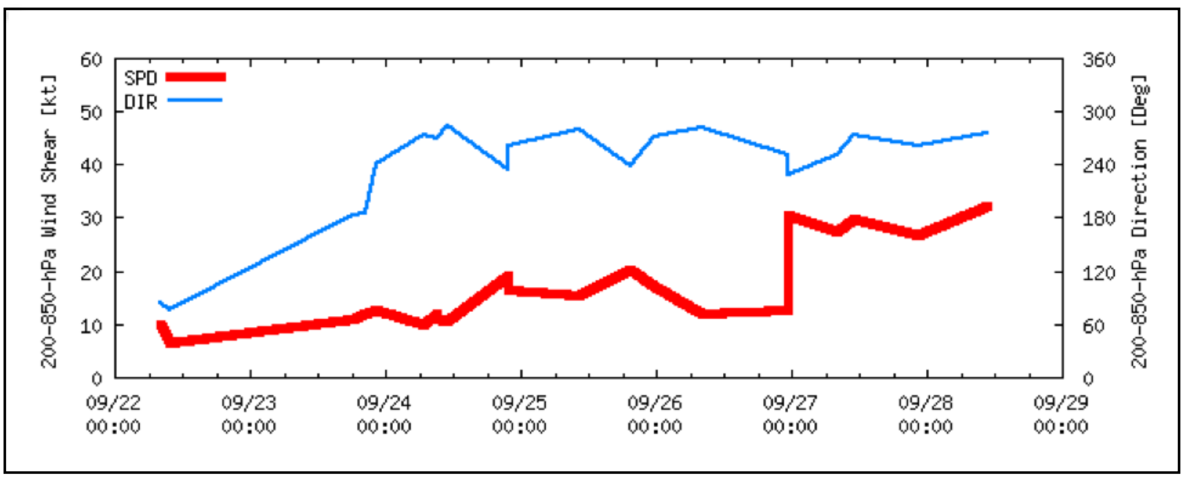
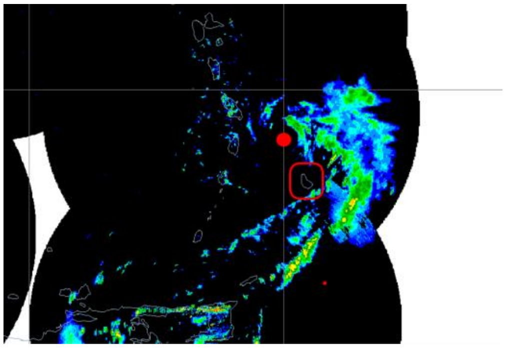
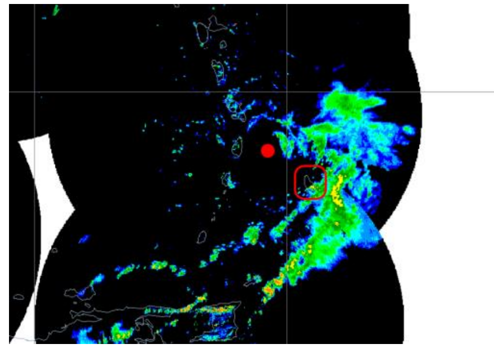


Figure 3 Vertical wind shear between 200 hPa (approximately 12 km of altitude) and 850 hPa (approximately 1.5 km of altitude) in speed (red) and direction (blue). The sudden increase in the speed shear on 27 September at 0000UTC caused the steady weakening of TS Kirk. Source: NOAA, National Environmental Satellite, Data and Information Service.

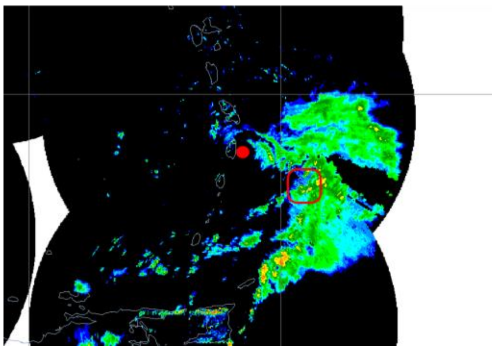
The nucleus of more intense precipitation persisted for several hours over Barbados and the surrounding waters. The reflectivity maps (a selection is shown in Figure 4) show that heavy rainfall started to affect Barbados on 27 September at 2230UTC and persisted over the island until 28 September at 0215UTC. From this time and during the first part of 28 September, the precipitation persisted over the island with a moderate and in some areas locally heavy intensity.



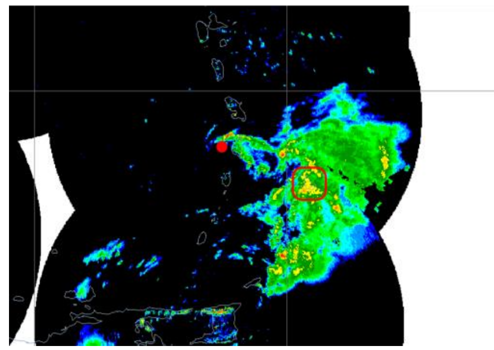
a) 27 September at 2100UTC



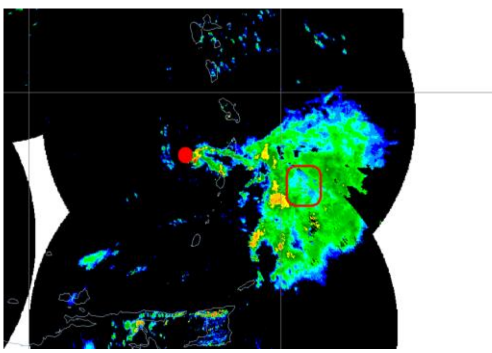
b) 27 September at 2230UTC



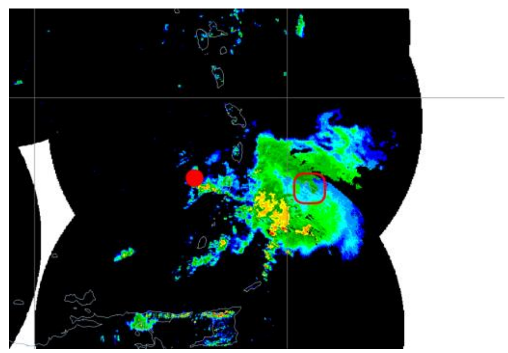
c) 28 September at 0000UTC



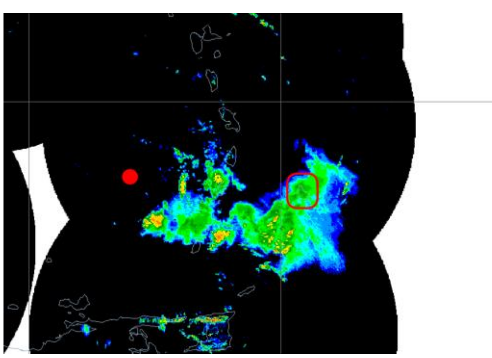
d) 28 September at 0130UTC



e) 28 September at 0300UTC



f) 28 September at 0600UTC



g) 28 September at 1200UTC

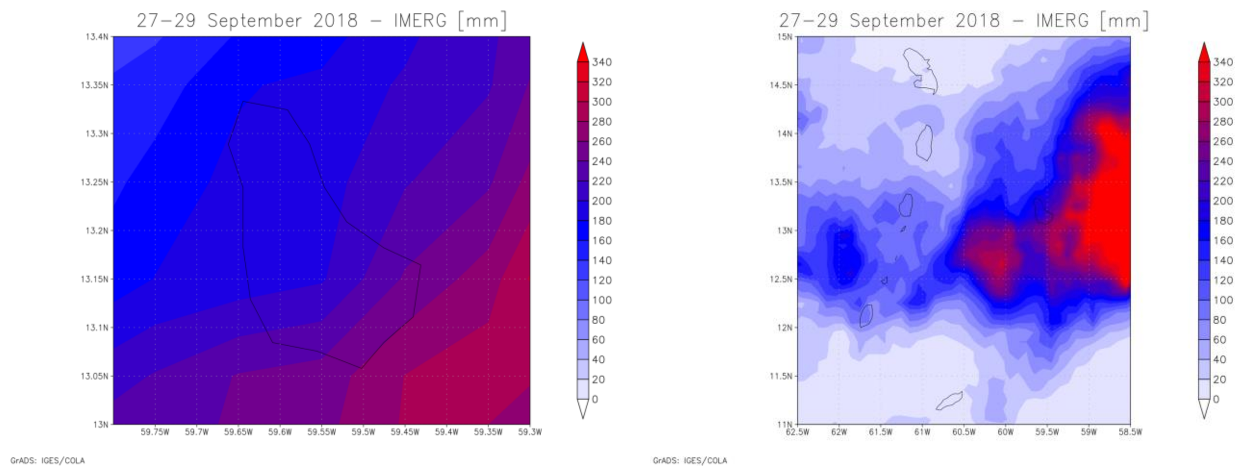
Figure 4 Reflectivity maps collected as a composite by the weather radar stations located over the Lesser Antilles during TS Kirk at different times. The approximate location of the TC centre is indicated by a red dot, while Barbados and the surrounding waters are within the red square.
(Source:*http://www.barbadosweather.org/Composite*).

Over Barbados, as published by NOAA (NNDC Climate data online, source: *https://data.noaa.gov/dataset/dataset/global-surface-summary-of-the-day-gsod*, the surface rain gauges reported the following accumulated measurements during TS Kirk:

Grantley Adams International Airport (13.07N, 59.48W)	253.5 mm

Satellite precipitation estimates were available also through the IMERG (Integrated Multi-satellitE Retrievals for GPM) dataset (Figure 5). During TS Kirk the maximum accumulated precipitation over Barbados (240 – 260 mm) was estimated along the southern coast.

The reflectivity maps (Figure 4) and IMERG (Figure 5) show that Saint Lucia, St. Vincent and the Grenadines and Grenada experienced less intense (moderate to locally intense) and less persistent precipitation on 28 September.



a) b)

Figure 5 IMERG accumulated precipitation (rainfall) at 10 km resolution over Barbados (a) and over the Lesser Antilles (b) on 27-29 September 2018. Source: XSR Web.

When the storm left the Lesser Antilles, the unfavourable environmental conditions (high upper-level wind shear, Figure 3) led to a rapid weakening of the tropical storm, which finally dissipated on 28 September at 1500UTC.

3 IMPACTS

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

- Floods occurred in low areas, making roads impassable and affecting the sewage system.
- Most of Bridgetown was flooded; in some Districts the electricity and water supply were interrupted.
- Several buses were damaged when crossing flooded areas and some flights were suspended.
- Prior to the arrival of Tropical Storm Kirk, Barbados' authorities took precautionary measures, including closing all educational institutions, businesses and government offices.
- A Tropical Storm Warning was activated and the Barbados Meteorological Services issued a High Surf Advisory and Small Craft Warning until October 1.

Figure 6 shows some of the flood damage caused by heavy rainfall in Barbados.

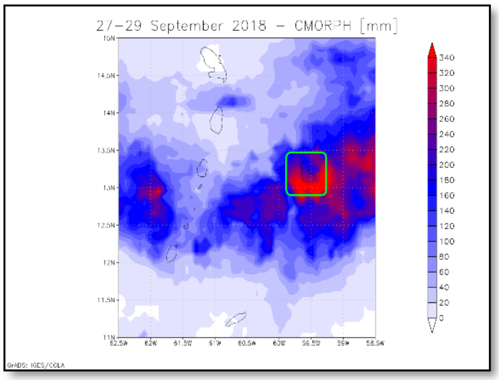
Figure 6 Damage caused by heavy rainfall in Barbados – September 2018.
Sources: *Magnetic Media* and *Loop*

[1] Loop, available in: http://www.loopnewsbarbados.com/
[2] Nation News, available in: http://www.nationnews.com/

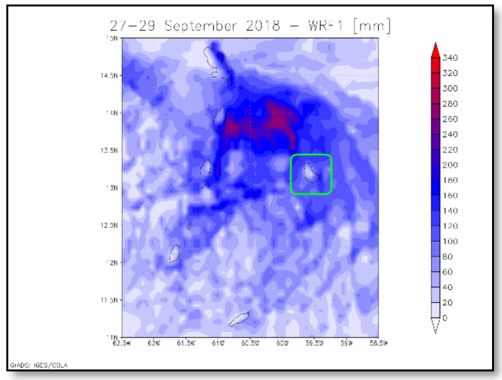
4 RAINFALL MODEL OUTPUTS

All three models used by the XSR 2.1 model, CMORPH[3], WRF1 and WRF2[4], simulated the passage of the tropical storm Kirk and the occurrence of the associated precipitation in the region during the period 27-29 September 2018. However, they differed in the spatial and temporal localization and intensity of the precipitation.

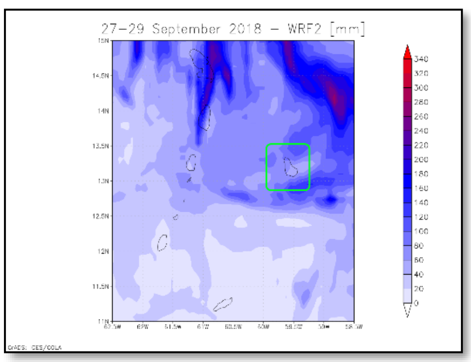
CMORPH simulated the highest precipitation occurring over Barbados and the surrounding waters (especially to the east and south of the island) and to the west of the Lesser Antilles, Figure 7). WRF1 simulated the highest precipitation passing more towards the north, over the waters between Barbados and Saint Lucia (Figure 7). WRF2 represented the track of the highest precipitation even further north, over Martinique, the waters to the east of Martinique and the Leeward Islands (Figure 7).



a) CMORPH



b) WRF1



c) WRF2

Figure 7 Accumulated precipitation at 8km resolution during 27-29 September 2018 simulated by the models CMORPH, WRF1 and WRF2. Source: XSR Web

[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 weather model-based Configuration #1 and #2 data https://www.mmm.ucar.edu/weather-research-and-forecasting-model. 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.

In particular, over Barbados (Figure 8):

- CMORPH simulated the greater part of the rainfall falling on 28 September (more than 200 mm) and the smaller portion on the previous day (between 20 and 60 mm on the southern sector of Barbados). The total accumulated precipitation during TS Kirk ranged between 180 and 320 mm, with the highest values in the southern sector of the island.
- WRF1 showed approximately the same rainfall falling on 27 and 28 September (values ranged between 40 and100 mm on 27 September and between 20 and 80 mm on 28 September, both on the southern sector of Barbados). The maximum accumulated rainfall estimated during TS Kirk was 120-140 mm in the south-eastern section of Barbados, while an accumulated rainfall of less than 80 mm was estimated over the greater part of the island.
- WRF2 simulated the precipitation occurring only on 27 September, with values ranging between 40 and 80 mm and the greatest rainfall occurring in the northern sector of Barbados.

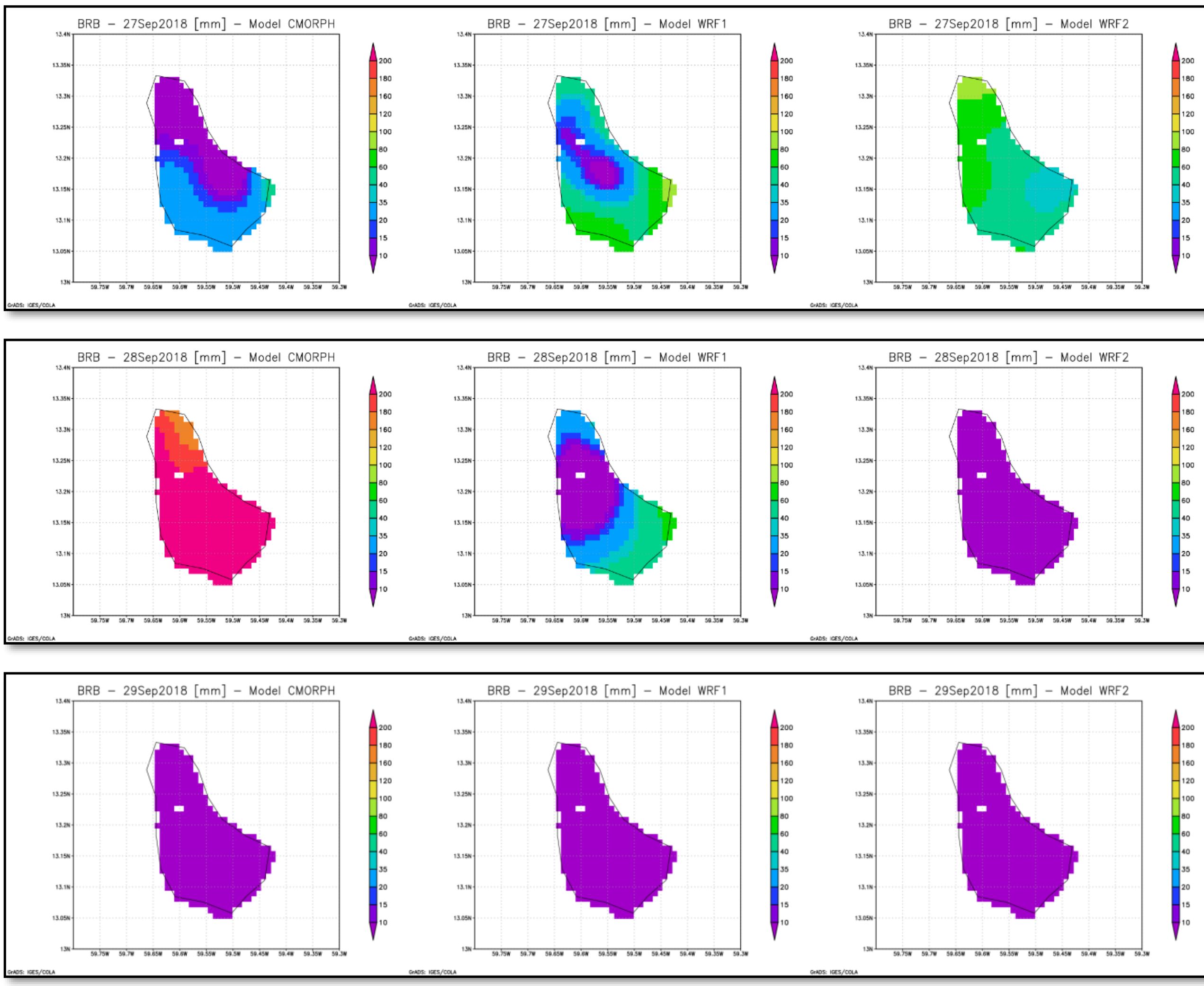


Figure 8 Accumulated precipitation (rainfall) at 1km resolution on 27 (top), 28 (middle) and 29 (bottom) September 2018 by CMORPH (left), WRF1 (centre) and WRF2 (right). Source: XSR Web.

The largest Rainfall Index Loss (RIL) was produced by CMORPH (RIL_{CMORPH} = US$61,168,135.01), because it simulated the trajectory of the maximum rainfall passing closer to Barbados and high accumulated values over the island. WRF1 also produced an RIL larger than the Country Loss Threshold (RIL_{WRF1} = US$7,414,036.25), but lower than that from CMORPH, since the simulated accumulated rainfall was smaller. The RIL from WRF2 (RIL_{WRF2} = US$2,120,070.50) was lower than the Country Loss Threshold (US $6,600,000), since the maximum precipitation was simulated to affect principally the waters to the north of the island.

According to the calculation procedure outlined in the policy the final RIL for this event is equal to the average of the RILs of CMORPH and WRF1, which are above the Country Loss Threshold. The final RIL is US$34,291,085.63. Since the final RIL is above the attachment point, this event is identified as a triggering event, with associated payout equal to US$5,813,299.39.

5 TRIGGER POTENTIAL

The Rainfall Index Loss was calculated for this Covered Area Rainfall Event (CARE) that started on 28 September and ended on 29 September 2018, producing government losses which were above the attachment point of Barbados' Excess Rainfall policy. Final calculations show that a payout of US$5,813,299.39 is due.

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 Relief Web (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 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.