Tropical Cyclone Beryl

01/07/2024 to 02/07/2024

Excess Rainfall
Wind and Storm Surge

Final Event Briefing

NAWASA Grenada

10 July 2024

1 SUMMARY

Tropical Cyclone Beryl is the second named cyclone and the first hurricane of the 2024 Atlantic Hurricane Season. On 30 June at 1530UTC, Beryl became a Category 4 hurricane while approaching the Windward Islands. During the next day, 1 July, it crossed the waters between Barbados and Tobago. Later on the same day, Hurricane Beryl made landfall on the island of Carriacou (Grenada), with its centre passing about 30 mi (50 km) NNE of the island of Grenada. Grenada experienced tropical-storm-force winds on 1 July from 0900UTC until 1800UTC, increasing to hurricane-force winds between 1400UTC and 1600UTC. Moderate to locally intense precipitation continuously affected the country between 1200UTC and 1800UTC. TC Beryl then moved away from the Windward Islands, towards the central Caribbean Sea.

The runs of the CCRIF CWUIC model have produced losses for the National Water and Sewerage Authority (NAWASA) in Grenada. The losses for NAWASA are above the Attachment Point of its CWUIC policy and therefore a payout under this policy is due.

This event briefing is designed to review the modelled losses due to wind, storm surge and excess rainfall calculated by CCRIF's CWUIC model for affected CCRIF member water utilities, to be analyzed with respect to members' CWUIC policies. NAWASA was the only CCRIF member water utility for which the CCRIF loss model for wind, storm surge and excess rainfall produced losses due to Tropical Cyclone Beryl at the time of writing this report.

2 EVENT DESCRIPTION

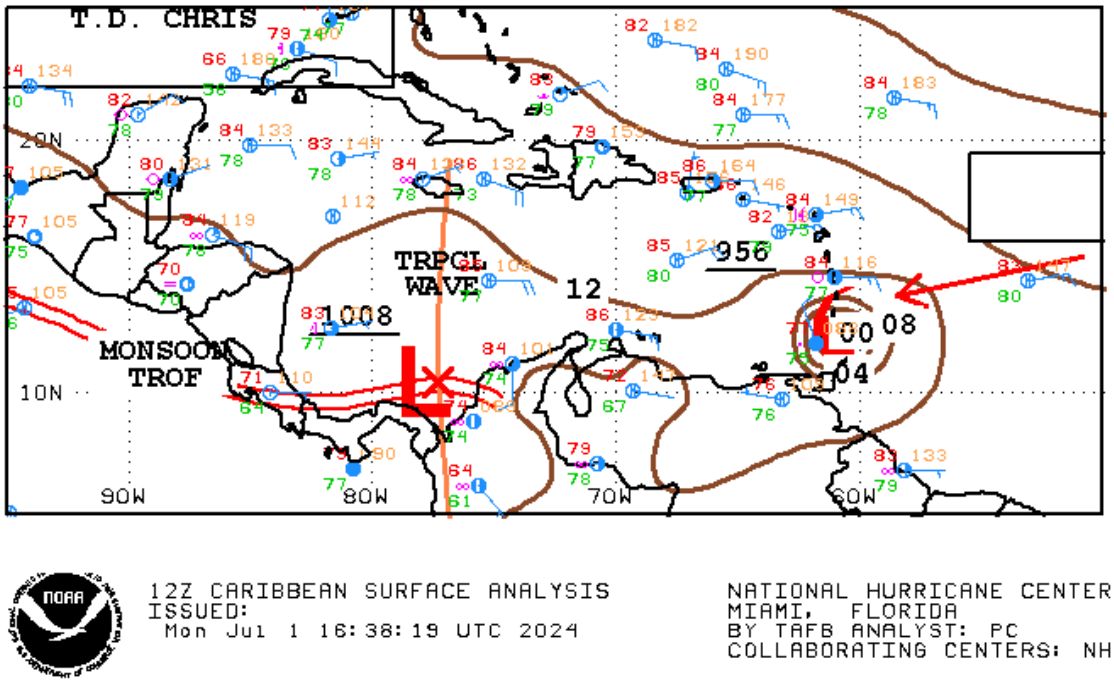
On 29 June at 0300UTC, the US National Hurricane Center (NHC) reported that a tropical storm formed in the central tropical Atlantic Ocean, and it was named Beryl. The system proceeded westward with estimated forward velocity of 18 mph (30 km/h), along the southern periphery of a strong subtropical ridge. In the next 30 hours, the tropical storm rapidly intensified due to the low wind shear, the high moisture content and the warm surface temperature over the tropical Atlantic. Thus, on 29 June at 2100UTC it became a hurricane and on 30 June at 1530UTC, it evolved into a Category 4 hurricane, as reported by NHC. At this time, the centre of Beryl was sited near latitude 10.8° North, longitude 54.9° West, about 350 mi (565 km) ESE of Barbados, and it proceeded towards the Windward Islands with almost unvaried forward velocity and direction. The maximum sustained winds were estimated at 130 mph (215 km/h) and the minimum central pressure at 962 mb.

During the final hours of 30 June and the first hours of 1 July, despite the environmental conditions that were still supportive for the intensification of the hurricane, an eyewall replacement cycle hindered the further strengthening of the system. Indeed, a new outer eye formed outside the small inner core, weakening the latter and gradually becoming dominant. For this reason, when Beryl started to affect the Windward Islands with tropical-storm conditions, during the first hours of 1 July, it had weakened to a Category 3 hurricane, with maximum sustained winds estimated at 120 mph (195 km/h). During these

hours, Beryl passed over the waters between Barbados and Tobago, spreading tropical-storm conditions over these islands, and headed towards Grenada (Figure 1). At 0900UTC, the western outer rainband of the hurricane passed rapidly over Grenada, bringing locally intense rainfall over the country (Figure 3a). Moreover, at the same time, tropical-storm-force winds started to affect Grenada (Figure 4a).

Three hours later, at 1200UTC, Hurricane Beryl strengthened again, due to the completion of the eye replacement cycle and it became a Category 4 hurricane again. The satellite imagery showed a solid ring of deep convection surrounding the warming, well-defined eye of the hurricane (Figure 2). At this time, the precipitation associated with the hurricane's core started to affect Grenada (Figure 3b).

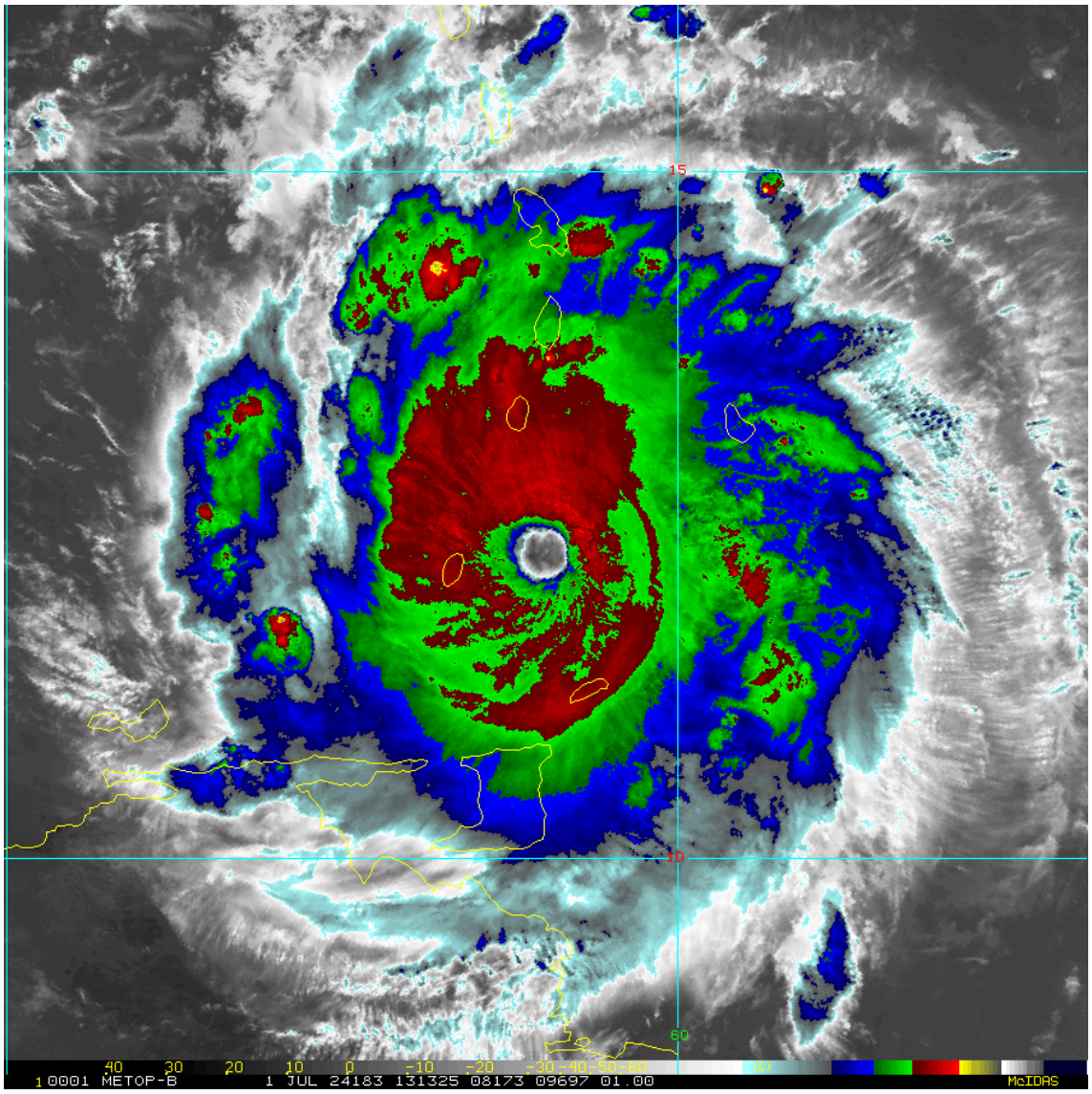
Hurricane-force winds started to affect Carriacou (Grenada) at 1400UTC, when the hurricane centre was about 25 mi (40 km) SE of the island. One hour later, at 1500UTC, Beryl made landfall on Carriacou, with maximum sustained winds estimated at 150 mph (240 km/h), Figure 1c. At this time the main island of Grenada also began to experience hurricane-force winds. Until 1600UTC, life-threatening winds were experienced on Carriacou and Grenada, due to the eyewall passing over or very close to these islands. During the same time, the precipitation became progressively more intense. At 1500UTC, the heavy rainfall associated with the eyewall was affecting the northern coast of Grenada (Figure 3c). During the next three to six hours, Grenada experienced constantly moderate to locally intense precipitation as the eastern quadrant of the hurricane, the portion characterized by the heaviest rainfall, passed over the country (Figure 3d), while hurricane-force winds decreased to tropical-storm force winds.At 2100UTC, Beryl moved away from the southern Windward Islands, and the associated rainfall and winds ceased over Grenada. The hurricane continued to proceed west-northwestwards at almost 20 mph (31km/h), towards the central Caribbean Sea.



01 July at 1200UTC

Figure 1 Surface analysis over the Caribbean area on 1 July 2024 at 1200UTC. Source: US National Hurricane Center[1]

1 National Oceanic and Atmospheric Administration - FTP, National Hurricane Center, review date: 1 July 2024, available at: *https://www.nhc.noaa.gov/tafb/CAR_12Z.gif*



01 July at 1313UTC

Figure 2 Satellite imagery on 1 July, 2024 at 1313UTC from the thermal infrared channel enhanced with colour. Blue/green colours represent high altitude clouds (top cloud temperature between -50°C and -70°C), while the red/yellow colours represent very high-altitude clouds (top cloud lower than -70°C). High altitude clouds indicate strong convection associated with intense precipitation. Source: NOAA, National Environmental Satellite, Data and Information Service2.

2 RAMSDIS Online Archive, NOAA Satellite and Information Service, available at: https://rammb-data.cira.colostate.edu/tc_realtime/storm.asp?storm_identifier=al022024

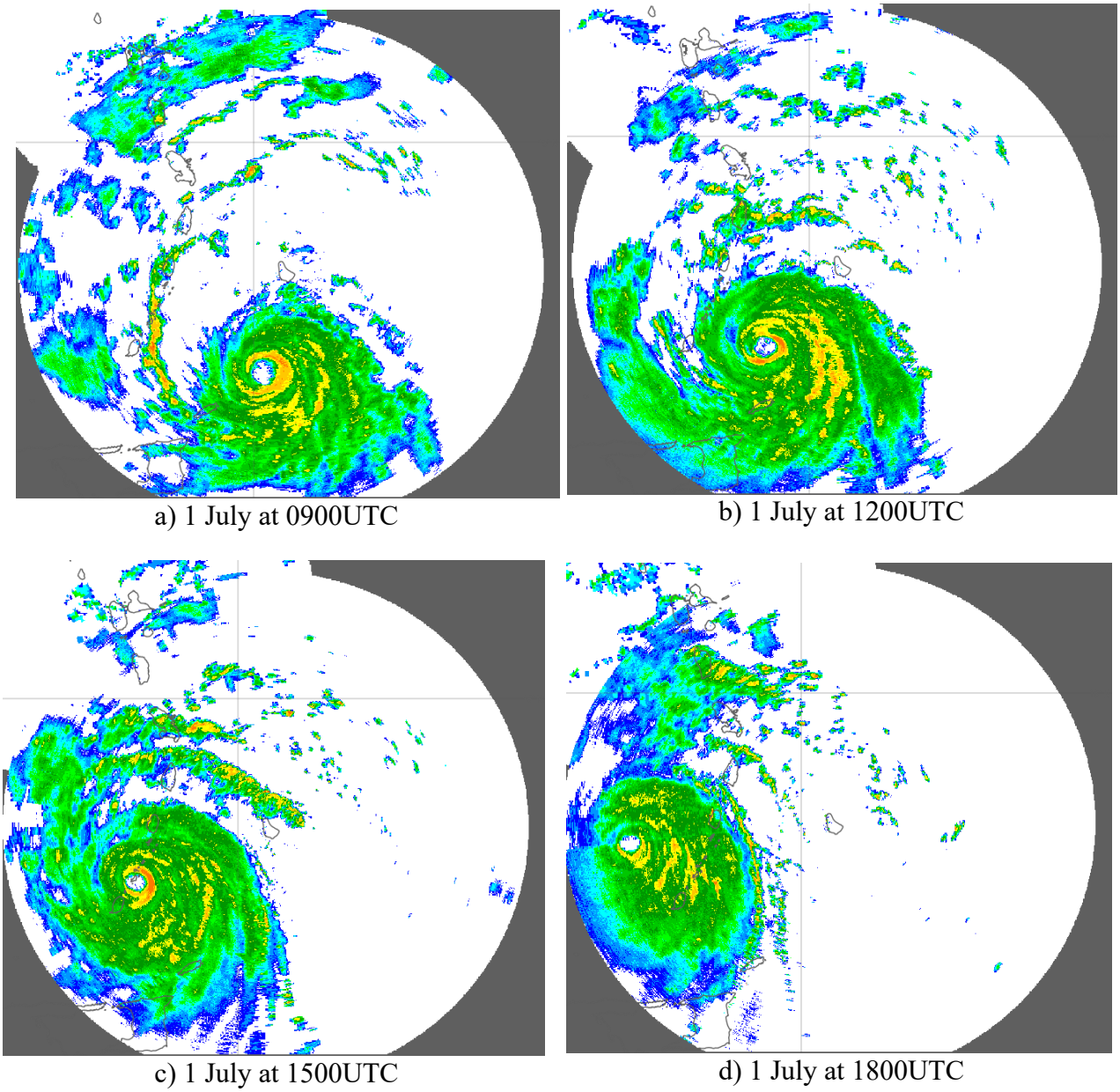
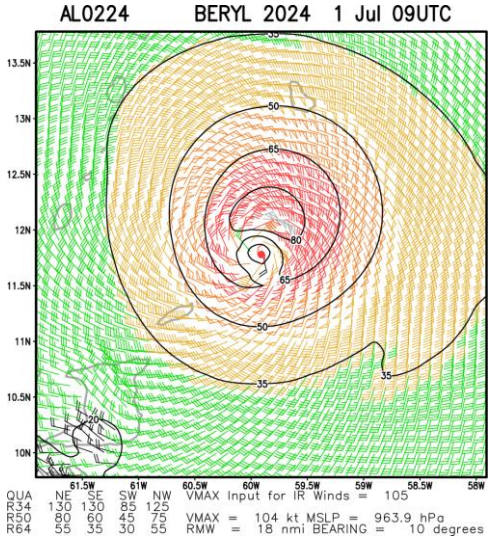
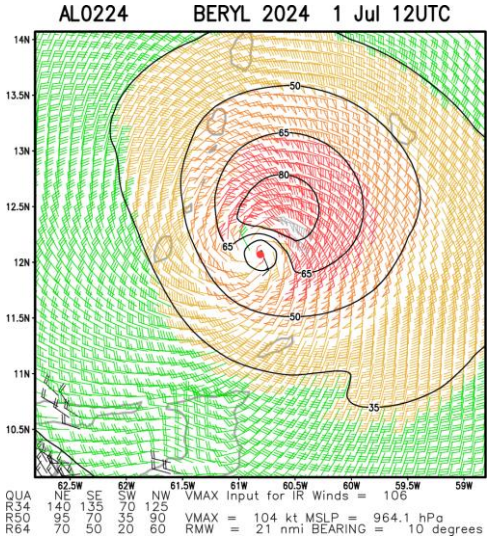


Figure 3. Radar imagery on 1 July, 2024, at different times as indicated in the labels from the radar composite over the Caribbean and Central America region. Blue/green colours represent low to moderate rainfall, while the yellow/red colours represent intense and very intense precipitation. Source: Barbados Radar Composite[3].

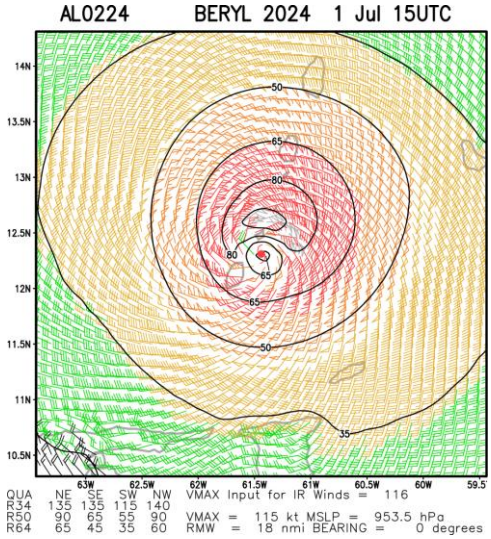
3 Barbados Radar Composite, available on 1July at: *https://www.barbadosweather.org/BMS_Radar_Composite_Resp.php#*



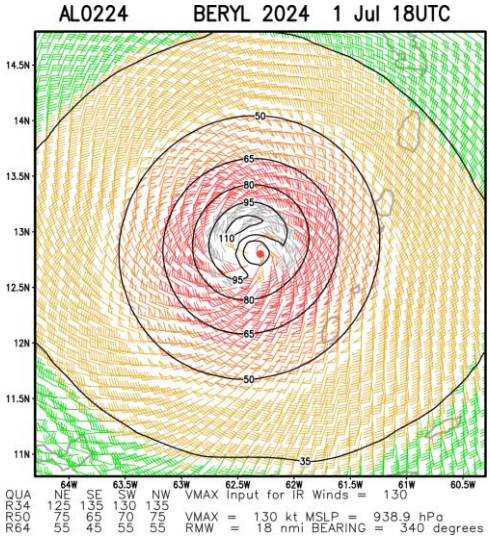
a) 1 July at 0900UTC



b) 1 July at 1200UTC



c) 1 July at 1500UTC



d) 1 July at 180UTC

Figure 4 Multi-platform satellite based tropical cyclone surface wind analysis estimated on 1 July, 2024 at different times as indicated by the labels. Contouring indicates wind intensity at 20 kn (23 mph, 37 km/h), at 35 kn (40 mph, 65 km/h), 50 kn (57mph, 93 km/h), 65 kn (75 mph, 120 km/h), 80 kn (92 mph, 148 km/h), 95 kn (109 mph, 176 km/h), 110 kn (127mph, 204 km/h), Source: NOAA, National Environmental Satellite, Data and Information Service[4]

4 RAMSDIS Online Archive, NOAA Satellite and Information Service, available at: https://rammb-data.cira.colostate.edu/tc_realtime/storm.asp?storm_identifier=al022024

3 CCRIF SPC MODEL OUTPUTS

The CWUIC model is made up of two components: the tropical cyclone (TC) component, accounting for the losses produced by wind and storm surge, and the excess rainfall (XSR) component, accounting for the losses associated with the excess rainfall. Each of the two model components estimates a loss value specifically related the hazard for which it is designed. When both a TC event and a Covered Area Rainfall Event (CARE) happen at the same time, the outputs of the two model components are added together. In the following description, the model output for each component is described separately.

TC Component

The wind footprint shown in the following figure is one of the components of the SPHERA CWUIC model used for the estimation of Tropical Cyclone (TC) losses for water utilities. This wind footprint for TC Beryl shows that the region with highest wind speeds was in Grenada.

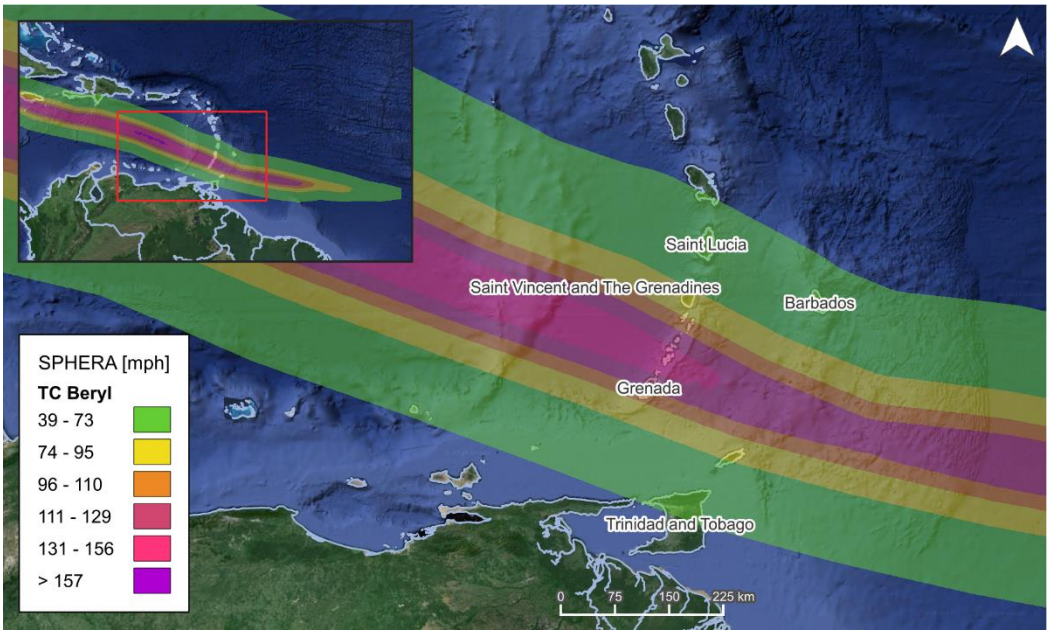


Figure 5 Map showing the wind field associated with Tropical Cyclone Beryl around Grenada
Source: NHC & CCRIF/SPHERA

XSR Component

All data sources used by the XSR 3.0 model, CMORPH, IMERG, WRF5, WRF7, WRF11 and WRF15[5], detected the occurrence of precipitation over Grenada and the surrounding waters during

5 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 are provided in the

the period 29 June to 02 July 2024. Each data source reported a specific distribution and accumulation of rainfall, as discussed below and shown in Figure 4. A CARE for Grenada was activated on 01 July and lasted until 02 July. The CARE was activated due to the use of the 12-hour and the 48-hour aggregation intervals for precipitation[6] and thus the period considered by the XSR 3.0 model for the loss estimate based on the accumulated precipitation in Grenada was 29 June to 02 July.

CMORPH reported total accumulated values of precipitation in the range between 100 mm and 125 mm over most of Grenada. Lower values, between 75 mm and 100 mm, were reported over a limited area in the parish of Saint John.

IMERG reported total accumulated values of precipitation between 125 mm and 150 mm over most of Grenada. Lower values, between 100 mm and 125 mm, were reported over the northern portion of the island of Grenada and the smaller islands to the north, including Carriacou.

WRF5 showed total accumulated precipitation values higher than 125 mm over most of Grenada, with the maximum values, between 175 mm and 225 mm, in the parishes of Saint Andrew and Saint David. Lower values, between 75 mm and 125 mm, were reported over the southern edge of Grenada.

WRF7 reported total accumulated precipitation values higher than 100 mm over the majority of Grenada, with the maximum values, between 125 mm and 150 mm, in the parishes of Saint Andrew, Saint George, and Saint David and over Carriacou. Lower values, between 75 mm and 100 mm, were reported over the northern edge of the island of Grenada.

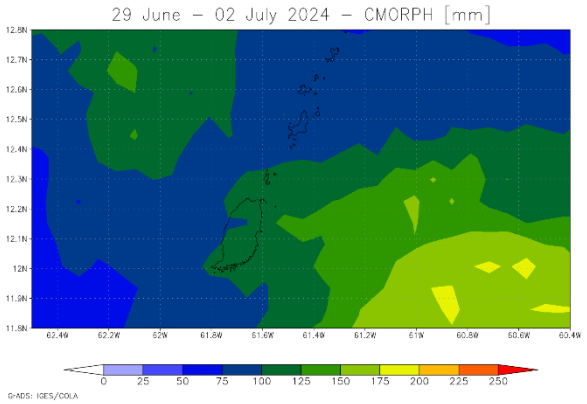
WRF11 showed total accumulated values of precipitation lower than the previous models over the territory of Grenada, with values under 50 mm on the south side of the island of Grenada and between 50 mm and 100 mm over the northern portion and over Carriacou. Higher values, between 125 and 150 mm, were reported over Ronde Island and the surrounding waters.

WRF15 reported accumulated values of precipitation higher than 75 mm over the centre of Grenada, with maximum values between 125 mm and 150 mm. Lower values, between 50 mm and 100 mm, were reported for the rest of the country.

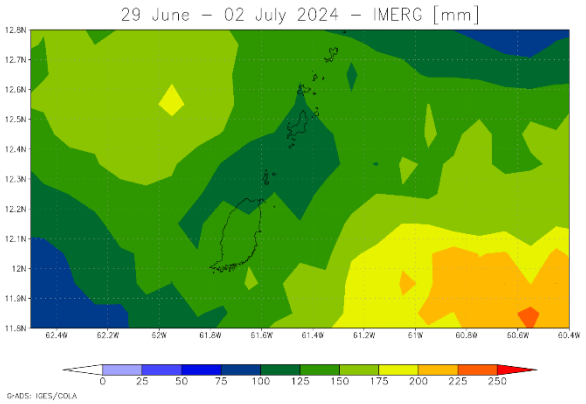
Definitions section of this report IMERG Model: The satellite-based rainfall estimation model developed by NASA, expressed in mm, derived by aggregating the IMERG 30-minute Rainfall Data at 10km spatial resolution and available at *https://jsimpsonhttps.pps.eosdis.nasa.gov/imerg/late*. Further details in the Definitions section of this reportWRF5,

WRF7, WRF11 and WRF15 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 are initialized by the NCEP FNL dataset. (NCEP FNL Operational Model Global Tropospheric Analyses [*http://rda.ucar.edu/datasets/ds083.2/*]). Further details are provided in the Definitions section of this report.

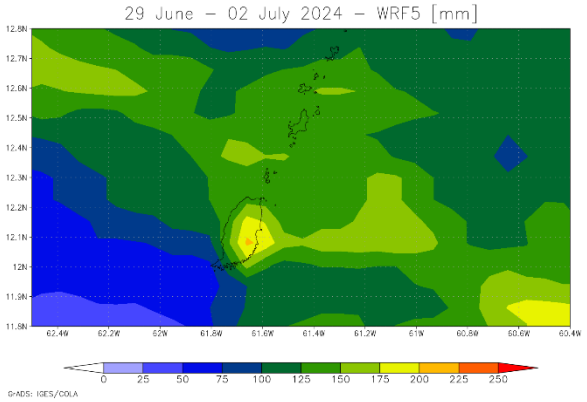
6 The two aggregation periods correspond to the Rainfall Aggregation Period #1 and Rainfall Aggregation Period #2, as indicated in the Schedule. Further details in the Definitions section of this report.



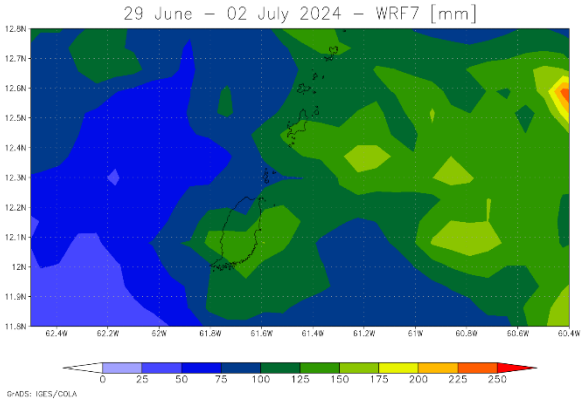
10 CMORPH



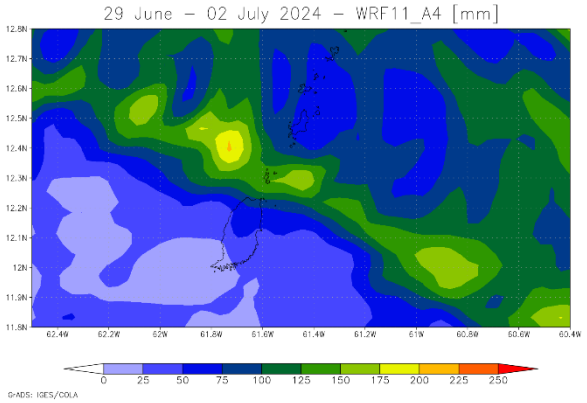
6 IMERG



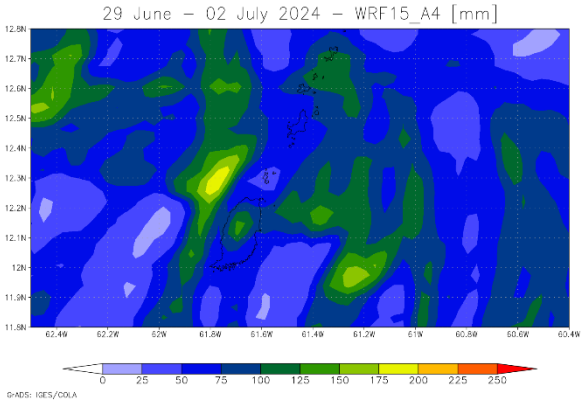
c) WRF5



d) WRF7



e) WRF11



f) WRF15

Figure 4 Total accumulated precipitation during the period 29 June and 02 July, 2024 estimated by CMORPH (a), IMERG (b), WRF5 (c), WRF7 (d), WRF11 (e), WRF15 (f). Source: CCRIF SPC

Daily rainfall maps by CMORPH, IMERG, WRF5, WRF7, WRF11 and WRF15 over the exposure map of XSR 3.0 are not included here and they can be downloaded at the following links for 12-hour aggregation and 48-hour aggregation respectively:

https://wemap.ccrif.org/OUTPUT/CCRIF/XSR/Events/GRD/CARE_1_2024/daily_prec_short.mp4
https://wemap.ccrif.org/OUTPUT/CCRIF/XSR/Events/GRD/CARE_1_2024/daily_prec_long.mp4

The final RIL (RIL_{FINAL}) was calculated as the average of the six RILs from CMORPH, IMERG, WRF5, WRF7, WRF11 and WRF15.

4 REPORTED IMPACTS

NAWASA reported that a damage assessment of the water systems would be carried out to determine the impact on infrastructure following Hurricane Beryl. The water systems were shut down as a precautionary measure.

Hurricane Beryl interrupted essential water supplies All 27 water systems were significantly impacted by Beryl but within 72 hours NAWASA was able to restore supply of 23 systems.

After Beryl, the roads were impassable and left damaged pipelines and blocked dams. Juan Lambert, the District Supervisor reported the challenge in enabling the proper water distribution for the Mirabeau, Mt. Horne, Spring Gardens, and Mamma Cannes Water Systems.

5 CCRIF LOSS MODEL

The final run of the CCRIF´s CWUIC tropical cyclone and excess rainfall loss model for NAWASA produced losses above the attachment point of its CWUIC policy and therefore a payout of US$2,201,833 is due.

For additional information, please contact CCRIF SPC at: pr@ccrif.org

DEFINITIONS

Active Exposure Cell Percentage Threshold	The percentage of the total number of XSR Exposure Grid Cells within the Covered Area of the Insured, that must be exceeded totrigger a Covered Area Rainfall Event.
Active Exposure Grid Cells	The XSR Exposure Grid Cells for which in the same single day the Aggregate Rainfall #1 value computed using the CMORPH-based Rainfall Estimate equals or exceeds the Rainfall Event Threshold #1 or the Aggregate Rainfall #2 value computed usingthe CMORPH-based Rainfall Estimate equals or exceeds theRainfall Event Threshold #2.
Aggregate Rainfall #1	The rainfall amount accumulated over the Rainfall Aggregation Period #1 (as defined in the Schedule) measured in millimeters (mm) in any of the XSR Exposure Grid Cells in the Covered Areaof the Insured. For a given day and a Rainfall Aggregation Period#1 of n hours, the Aggregate Rainfall #1 is the maximum amountof rainfall accumulated over any of the n-hour windows that intersect the day itself considering a time interval of 3 hours.
Aggregate Rainfall #2	The rainfall amount accumulated over the Rainfall Aggregation Period #2 (as defined in the Schedule) measured in millimeters (mm) in any of the XSR Exposure Grid Cells in the Covered Areaof the Insured. For a given day and a Rainfall Aggregation Period#2 of n hours, the Aggregate Rainfall #2 is the maximum amountof rainfall accumulated over any of the n-hour windows that intersect the day itself considering a time interval of 3 hours.
Calculation Agent	Entity charged with undertaking the primary calculation of theRainfall Index Loss.
CMORPH-based Maximum AggregateRainfall #1	The maximum value during the Covered Area Rainfall Event of the Aggregate Rainfall #1 computed using the CMORPH-based Rainfall Estimates in any given XSR Exposure Grid Cell over theCovered Area of the Insured.
CMORPH-based Maximum AggregateRainfall #2	The maximum value during the Covered Area Rainfall Event of the Aggregate Rainfall #2 computed using the CMORPH-based Rainfall Estimates in any given XSR Exposure Grid Cell over theCovered Area of the Insured.
CMORPH-based CoveredArea Rainfall Parameters	The CMORPH Model information provided on a continuous basisby the XSR Model Data Reporting Agency used by the

	Calculation Agent to obtain the CMORPH-based Rainfall Estimates using the XSR Rainfall Model. Parameters are drawn from XSR Exposure Grid Cells within the Covered Area of the Insured, 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 ReportingAgency 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 thePolicy.
Covered Area	The territory of the Insured as represented in the XSR RainfallModel.
Covered Area RainfallEvent	Any period of days, with an interruption less than or equals to theEvent 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 andsevere local storm. Any disaster alert issued later than seven (7) days after the completion of the Covered Area Rainfall Event (CARE) event will not be considered. The Disaster Alert description issued by ReliefWeb and/or its attached documentation must include specific reference to the CARE dateswith a tolerance period of 2 calendar days.
Maximum AggregateRainfall #1	The highest value during a Covered Area Rainfall Event of the Aggregate Rainfall #1 amount in any of the XSR Exposure Grid Cells in the Covered Area of the Insured computed.
Maximum AggregateRainfall #2	The highest value during a Covered Area Rainfall Event of the Aggregate Rainfall #2 amount in any of the XSR Exposure Grid Cells in the Covered Area of the Insured computed.
Rainfall Event Threshold #1	Aggregate Rainfall #1 level as defined in the Schedule whichshould be exceeded to trigger an Active Exposure Cell.

Rainfall Event Threshold #2	Aggregate Rainfall #2 level as defined in the Schedule whichshould be exceeded to trigger an Active Exposure Cell.
Rainfall AggregationPeriod #1	The number of hours over which the Aggregate Rainfall #1 is computed for all XSR Exposure Grid Cells during a Covered AreaRainfall Event.
Rainfall AggregationPeriod #2	The number of hours over which the Aggregate Rainfall #2 is computed for all XSR Exposure Grid Cells during a Covered AreaRainfall Event.
Rainfall Index Loss	For any Covered Area Rainfall Event affecting the Insured, the USDollar 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 AreaRainfall Event is completed.
WRF5 Model	The weather research and forecasting rainfall model by NOAA with Configuration #5 data initialized with and assimilating the data provided 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.
WRF7 Model	The weather research and forecasting rainfall model by NOAA with Configuration #7 data initialized with and assimilating the data provided 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, asdescribed 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 isattributed with an XSR Grid Cell Exposure Value greater than zero.
XSR Grid Cell ExposureValue	The value, used to calculate the CMORPH-based Exposure Grid Cell Loss, the WRF5-based Exposure Grid Cell Loss, and the WRF7-based Exposure Grid Cell Loss.

11 The ADC would be activated if the modelled loss value is between 10% of the Minimum Payment and 50% of a country's policy Attachment Point and a Disaster Alert is issued by ReliefWeb within 7 days after the event.