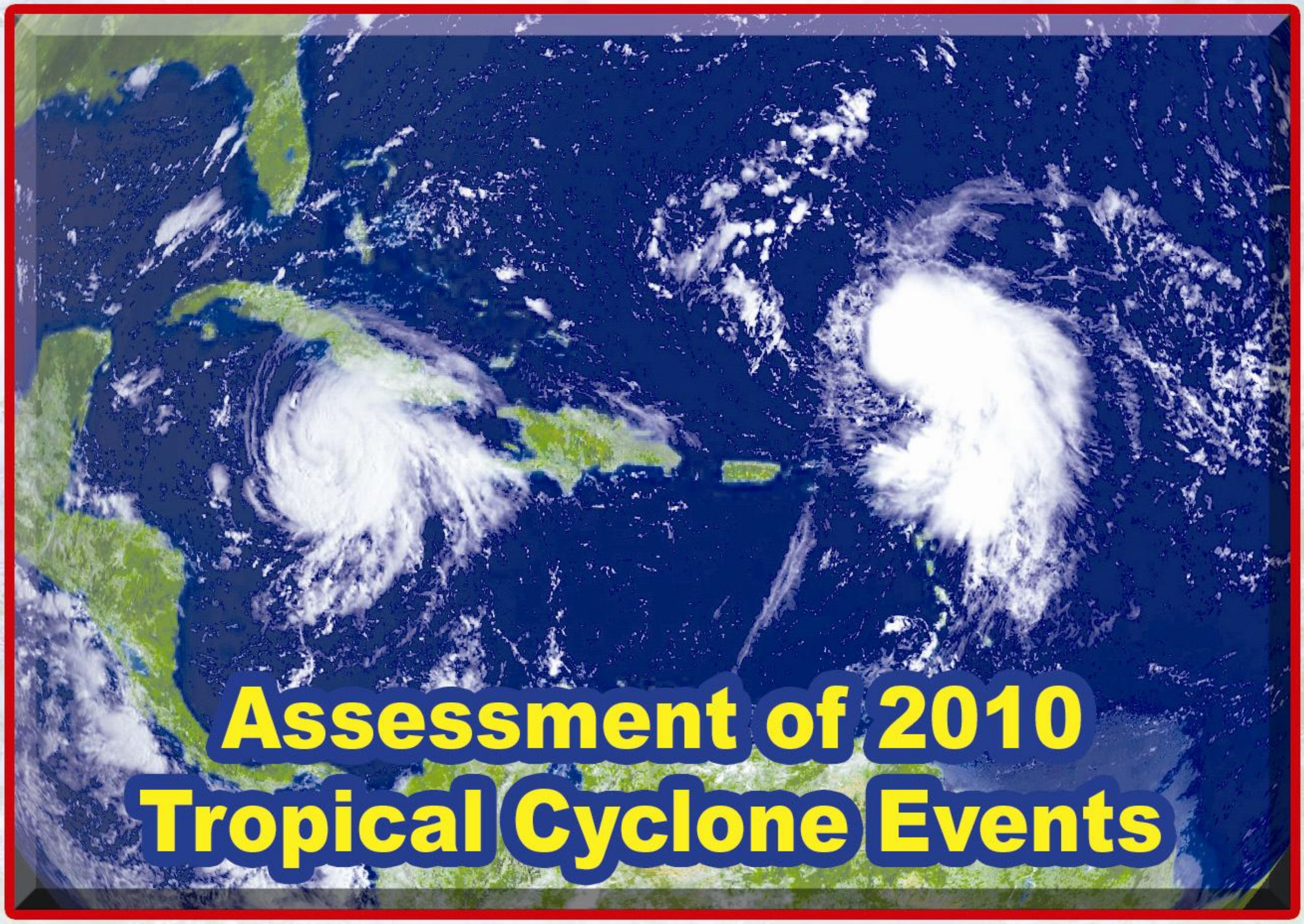
CCRIF

The Caribbean Catastrophe Risk Insurance Facility

# Verifying CCRIF's Tropical Cyclone Hazard and Loss Modelling

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# Verifying CCRIF's Tropical Cyclone Hazard and Loss Modelling

## *Assessment of 2010 Tropical Cyclone Events*

The Caribbean Catastrophe Risk Insurance Facility (CCRIF) is the first multi-country risk pool in the world, and is also the first insurance instrument to successfully develop parametric policies backed by both traditional and capital markets. It is a regional catastrophe fund for Caribbean governments designed to limit the financial impact of devastating hurricanes and earthquakes by quickly providing financial liquidity when a policy is triggered. CCRIF was developed through funding from the Japanese Government, and was capitalised through contributions to a multi-donor Trust Fund by the Government of Canada, the European Union, the World Bank, the governments of the UK and France, the Caribbean Development Bank and the governments of Ireland and Bermuda, as well as through membership fees paid by participating governments. Sixteen governments are currently members of the fund: Anguilla, Antigua & Barbuda, Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago and Turks & Caicos Islands.

CCRIF website: www.ccrif.org

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# 1 INTRODUCTION

This report provides an analysis of the behaviour of the Caribbean Catastrophe Risk Insurance Facility's (CCRIF's) Second-generation Hazard and Loss Estimation Model (2G Model) after the 2010 Tropical Atlantic Hurricane Season.

The CCRIF Facility Loss Model (FLM) is a stand-alone tool designed by Kinetic Analysis Corporation to act as a driver of the underlying 2G hazard/loss model. It enables the Facility to:

- estimate loss probabilities for individual territories and a portfolio of territories with specific contract terms;
- price contracts for specific territories; and
- estimate site-specific hazard levels and losses for specific events – either historical or active events – during the contract period.

Using the hazard modelling results, the loss module calculates event exposure losses by applying site-specific hazard forces to each individual element in the exposure database. The model calculates losses for each individual 'asset' in the exposure database using damage functions specific to the asset class and the specific hazard levels at the asset site (a 1-km grid square). Territory level losses are the aggregate of losses to all individual exposure elements in the territory.

An anticipated benefit of the new model is that it will result in a reduction in the basis risk inherent in the loss indexing approach used in the first-generation EQECAT model. The purpose of this review is to investigate whether the model has accomplished this goal by explicitly addressing the following questions:

- How closely are the CCRIF model wind footprints matched to the National Hurricane Center's (NHC's) H*WIND and other modelled footprints?
- How does ground meteorological data fit with the CCRIF footprint for wind?
- Do the final losses generated by the model correspond with government and independent estimates?
- How does the breakdown of impact costs affect what can be considered government losses?

In anticipation of the excess rainfall product which CCRIF will be making available to clients from the 2011/12 policy year, a review of ground- and satellite-based rainfall data has also been conducted. A number of questions will be addressed in this regard:

- What does the real rain gauge data look like and how does this compare with data from the Tropical Rainfall Measurement Mission (TRMM) satellites?

- To what extent does the rainfall model capture this information?
- How has excess rainfall contributed to overall country losses?

A section of the report will also be devoted to a review of the application of the CCRIF funds in countries where a policy was triggered by an event.

### *1.1 Framework for Analysis*

For ease of analysis and review, the performance of the CCRIF model will be analysed for those events regarded as reportable events and those which triggered a payout in a given country. The review will therefore involve an examination of the performance of the model for Tropical Cyclones Earl, Richard and Tomas and Tropical Depression 16.

## 2 TROPICAL CYCLONE EARL

***Tropical Cyclone Earl triggered Anguilla's policy with CCRIF. This resulted in a payout of US$4,282,733 to the Government. The CCRIF 2G model performed very well in replicating the impact of Tropical Storm Earl on Anguilla. This was particularly evident in the modelling of wind and storm surge impacts, which were the primary drivers of losses experienced in the island.***

Earl was the second major hurricane of the 2010 Tropical Atlantic Hurricane season. The system achieved the minimal requirements of a defined event under the CCRIF Policy by having winds of greater than 39mph somewhere in three member states: Antigua & Barbuda, St Kitts & Nevis and Anguilla. Figures 1 and 2 show the National Oceanic and Atmospheric Administration (NOAA) satellite image and St Maarten radar image of Tropical Cyclone Earl as it passed over the north eastern Leeward Islands.

**Figure 1** NOAA satellite image of Tropical Cyclone Earl.

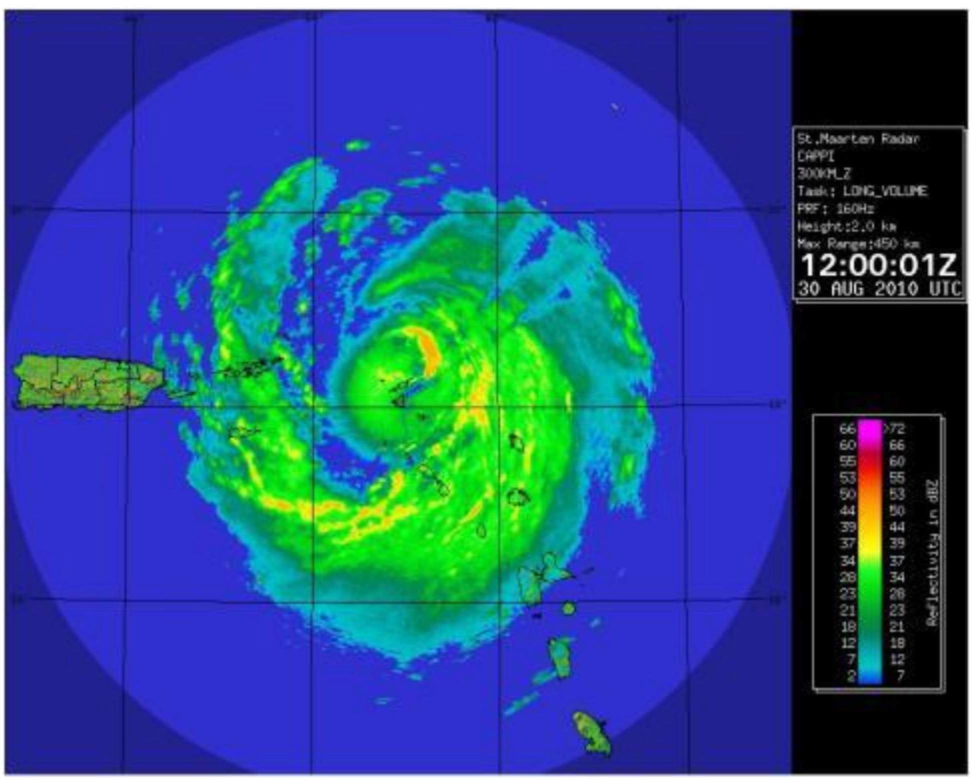



**Figure 2** St Maarten radar image of Tropical Cyclone Earl.

One of the outputs from the CCRIF 2G model is a wind footprint. As can be seen in Figure 3 below, the islands of Antigua, St Kitts and Nevis all had modelled sustained winds of weak tropical storm force (less than 50 mph), while Barbuda encountered Category 1 hurricane winds (74-95 mph) and Anguilla, Category 2 winds (96-110 mph).

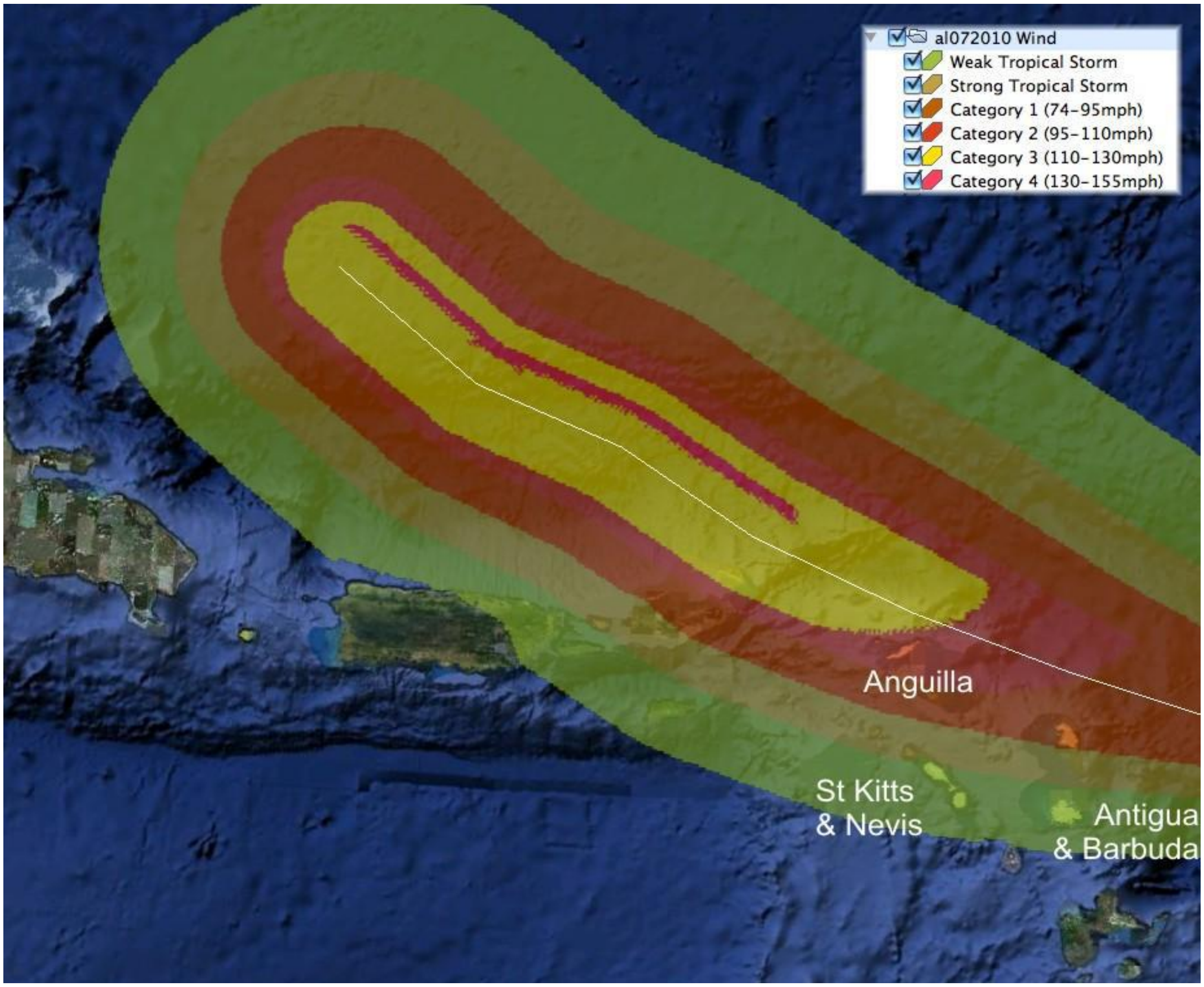



**Figure 3** CCRIF 2G model wind footprint for TC Earl.

The CCRIF modelled wind speeds were generally consistent with, though somewhat higher than, surface wind speed estimates from the NOAA-NHC H*WIND algorithm, which rationalises all actual wind speed measurements collected on the ground and from flights and satellites. We note that the H*WIND algorithm produces single wind footprints at a point in time; Figure 4 and subsequent H*WIND footprints in this document are CaribRM's extrapolation of a number of single footprint maps into a continuous footprint map consistent in format to the CCRIF model output. We note also that H*WIND estimates only surface winds over the open ocean, and therefore it does not include over-land friction and topographic effects (which the CCRIF model fully recognises).

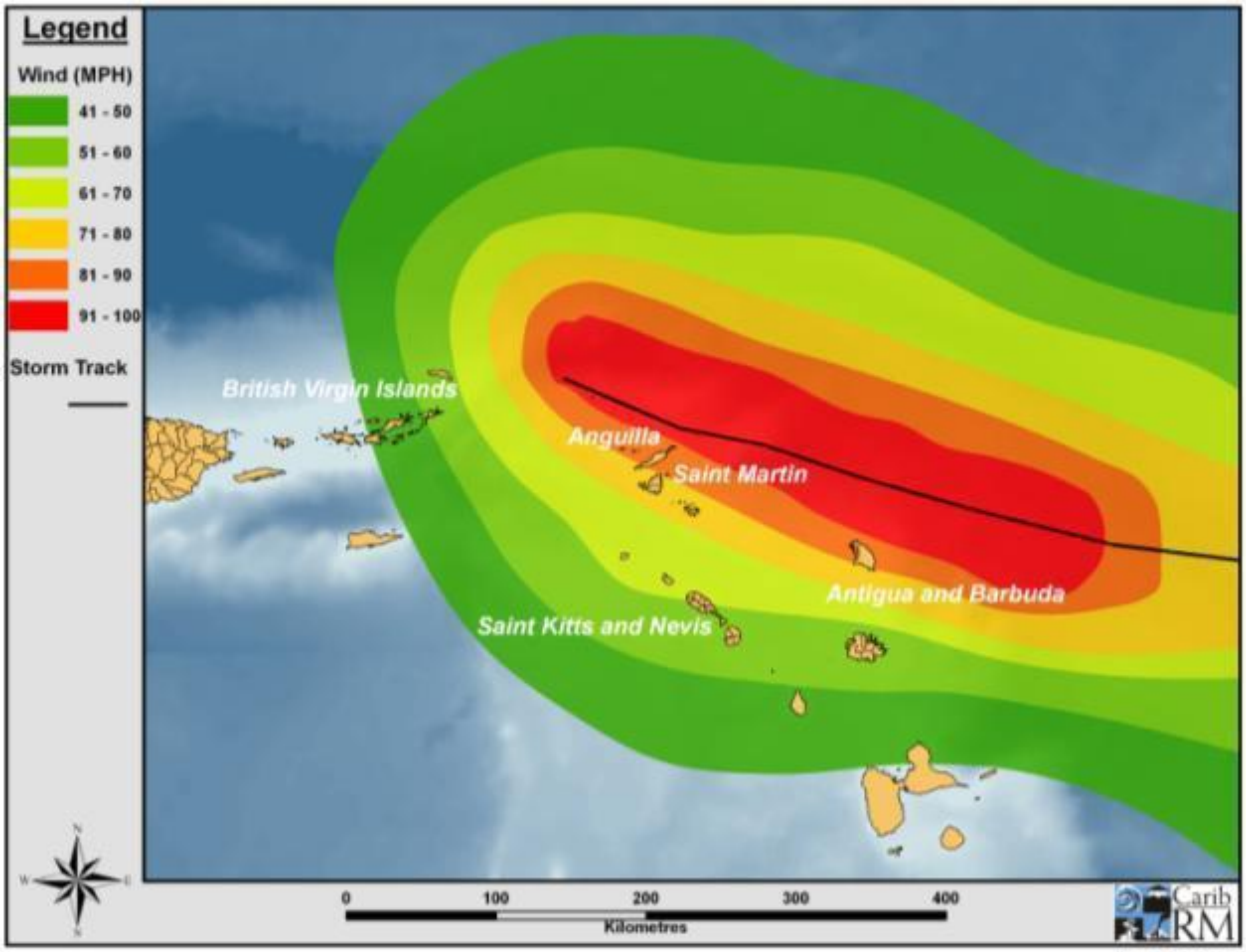



**Figure 4** H*WIND peak surface wind estimate for Earl as it skirted the northern-most Leeward Islands. Data to 1330 UTC on 30 August. *Source: NOAA-NHC and CaribRM*.

NOAA-NHC wind estimates for Anguilla indicated peak 1-minute sustained surface winds of 80 to 90 mph, somewhat lower than local reports of measured 88mph and estimated 100+mph winds. Wind footprint estimates from the CCRIF model show peak winds at Category 2 (96 to 110 mph) across all of Anguilla. This indicates that the KAC model was slightly more accurate at estimating the actual winds observed in Anguilla when compared to the close correlation with on-the-ground measurements.

As expected for the level of modelled wind speed, the CCRIF loss model generated small government losses in Antigua & Barbuda and St Kitts & Nevis, both significantly below their trigger levels, while the loss in Anguilla was much more substantial, and triggered their policy.

Damage reports from the non-triggering countries, Antigua & Barbuda and St. Kitts & Nevis, indicated that rainfall-induced localised flooding was the main impact. In their post-flood assessment, the Caribbean Institute of Meteorology and Hydrology (CIMH) reported, "The primary economic losses [in Antigua and Barbuda] as a result of flooding were to the road network and private residences." Such flood impacts/losses are not represented in the modelled loss results.

High waves and localised storm surge of several metres affected all of the northern Leeward Islands. However, the explicit modelling of coastal damage and loss in CCRIF's 2G model had greatest influence in Anguilla, where the vast majority of economic activity is exposed to coastal hazards. As a low-lying island, Anguilla is impacted by coastal storm surge and wave damage, which have long-term detrimental impacts on the tourism-based economy.

Actual damage included some major roof loss, as well as flooding of government and other buildings. Power lines were downed across the island, and coastal damage was significant, including infrastructural damage to hotels, many beached vessels and beach erosion (Figures 5, 6 and 7). Local authorities reported the occurrence of 10-foot waves in some areas. Some of the important structures affected by the hurricane were the Supreme Court building and the Department of Lands and Survey building. The CCRIF model output indicated a total ground-up loss of ~US$38 million in Anguilla. This was driven largely, as indicated earlier, by the losses in coastal areas as a result of storm surge.

**Figure 5** Example of damage to a hotel. *Source: CIMH.*

**Figure 6** Example of beach erosion. *Source: CIMH.*

**Figure 7** Example of beached vessels.
*Source: Ministry of Finance, Government of Anguilla.*

Rainfall associated with Tropical Cyclone Earl was heavy, with around 175mm (7 inches) reportedly measured in Antigua. Figure 8 shows the rainfall as estimated from the Tropical Rainfall Measurement Mission (TRMM) satellites; note that this only utilises data to 0900 UTC on 30 August so does not reflect full rainfall for Barbuda and northward. Peak storm total rainfall above 250mm (10 inches) appears possible, with even higher totals likely at high elevations.

Although there was some heavy rainfall it was also clear that rainfall was not the major driver of losses experienced in Anguilla. This was supported by the CIMH report which indicates that "the antecedent conditions and rainfall intensity associated with Tropical Cyclone Earl was not conducive to significant flooding ... and excess rainfall associated with Tropical Cyclone Earl was not critical for Anguilla." The report went on to state that "As a baseline, persons interviewed refer to the Omar event in 2008 which was associated with significant rainfall amounts and led to flood waters as high as 10 feet which took days to recede." Therefore infrastructural damage as a result of flooding was minimal. Reports from the Ministry of Infrastructure in Anguilla indicate that the flood waters were relatively low and were in the range of two feet and rapidly subsided.

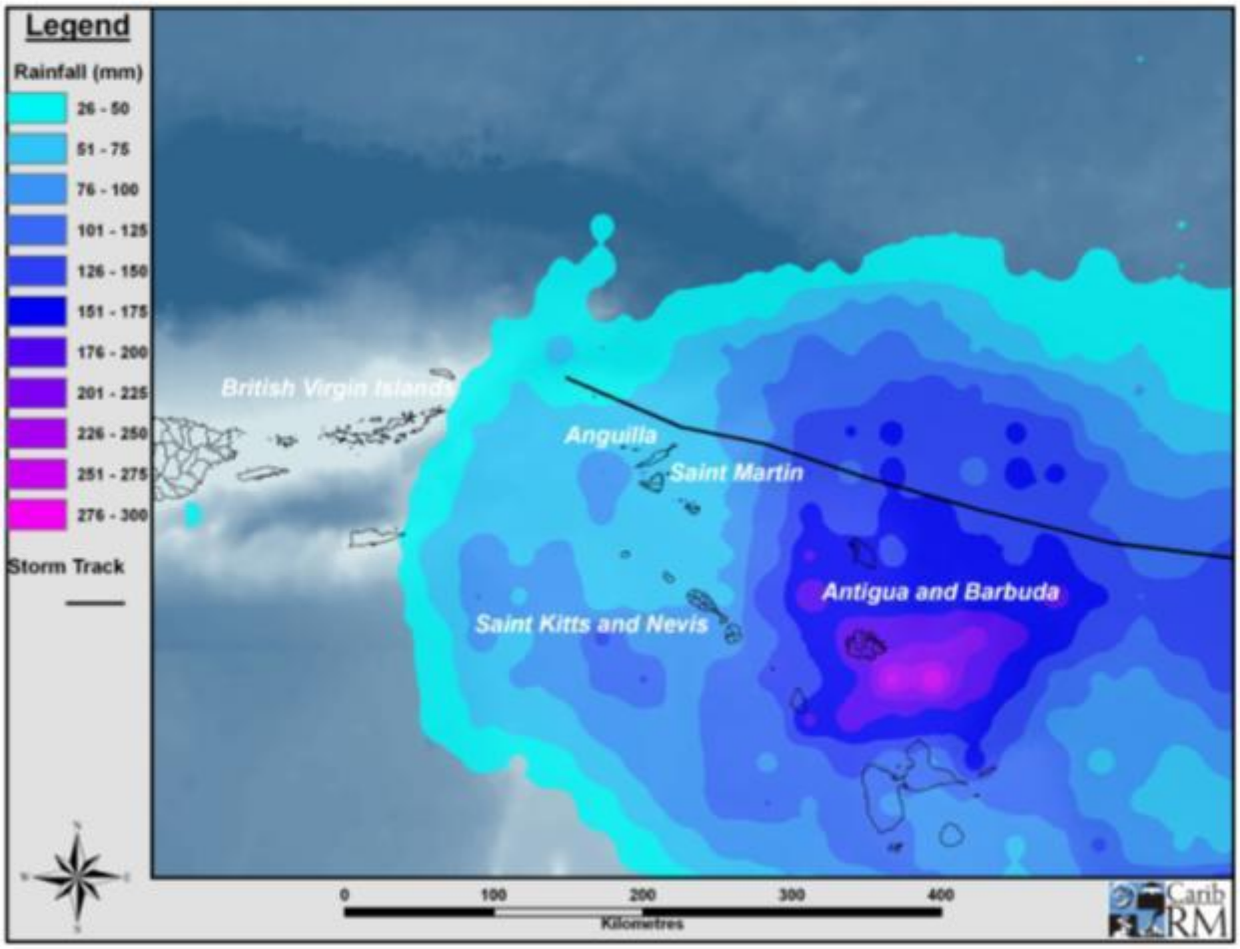



**Figure 8** TRMM rainfall totals for TC Earl. Data from 0000 UTC on 29 August to 0900 UTC on 30 August. *Source: NASA/JSA.*

The northeastern section of Anguilla lies within a low-lying catchment area known as The Keys. The area is essentially a conduit for the discharge of a significant volume of water into Island Harbour. As a result, moderate rainfall events often lead to flooding in this area and hence overflows across coastal roads. As a result of Tropical Cyclone Earl, the main coastal road which acts as a tributary to residential and tourism-related infrastructure was significantly damaged and rendered impassable as a result of the flood waters. This situation was further exacerbated by the fact that culverts in the area are essentially inadequate and incapable of dealing with any significant amount of water. A recommendation from the CIMH report was that “the structures in Island Harbour be designed to carry at least 1 in 25 year runoff since the main roadway along the coast is essential to economic activity.” This highlights an important issue which most Caribbean islands are faced with: the capacity of existing infrastructure to cope with these types of events.

In Antigua & Barbuda and St Kitts & Nevis, less severe localised flooding and some tree damage were reported but these territories suffered no major losses.

In terms of on-the-ground data, it should be mentioned that due to the dispersed nature of the weather station network in Anguilla, it is impossible to capture a true representation of the rainfall variability which was/is experienced across the island. This situation is further hampered by the fact that the island does not have a long historical record of rainfall data and when that data exists there are often temporal discontinuities which create severe challenges for enhanced analytical work such as frequency analysis. An absence of geospatial data is also of concern when attempting to analyse the impacts of hydro-meteorological events on the island. Likewise it is important for countries to undertake post-event assessment of losses. The information garnered through these activities is critical in refining the CCRIF model and building an accurate picture of county vulnerabilities.

Despite this, the CCRIF model generally appears to have performed fairly well, particularly with the inclusion of storm surge impacts which would have driven a significant portion of the losses induced by Tropical Cyclone Earl in Anguilla.

For more information on the impact of rainfall associated with Hurricane Earl, please see the CCRIF website for the *Antigua, Anguilla and British Virgin Island Post-flood Assessment* report prepared by the Caribbean Institute of Meteorology and Hydrology (CIMH).

### *2.1 Utilisation of CCRIF Funds*

CCRIF made early contact with key officials in Anguilla after the passage of Earl. Contacts in the Ministry of Finance indicated that the US$4,282,733 was used to capitalise a special recovery fund whose expenditure was controlled by a specially-convened committee to ensure transparency and sound fiscal control.

Apart from assisting with financing general recovery efforts, some of the funds released by CCRIF were also used to purchase upgraded weather monitoring data-capture technology for the airport. This now allows the airport to receive a Common Alerting Protocol (CAP) feed which is linked to a warning system and which is in turn utilised by the Department of Disaster Management.

Also, two portable weather systems for the eastern and western end of the island were purchased with the funds and are to be managed and monitored by the disaster management office. Contact persons in that office have indicated that these portable stations have been critical in enhancing the monitoring of a number of weather-related phenomena *i.e.* pressure, wind direction, wind speed, etc.

This enhancement of the infrastructural capacity in Anguilla to collect key meteorological data is important in informing an increased understanding of hydro-meteorological risks which the country faces. In support of these measures, CCRIF also provides its member countries with real-time storm impact forecasts from the Real-Time Forecasting System (RTFS). Senior officials from the Department of Disaster Management indicated that the RTFS clearly had an impact on reducing damage levels and also helped to prevent loss of life as the storm passed over Anguilla by providing a context for detailed and accurate early warning.

# 3 TROPICAL DEPRESSION 16

***Although commonly referenced in direct association with Tropical Cyclone Nicole, the rainfall event which resulted in significant damage and loss of life in Jamaica in late September 2010 was a separate and distinct meteorological event, linked only loosely to Nicole itself and referenced as Tropical Depression 16.***

TD 16, which became Tropical Cyclone Nicole, emerged in the northwestern Caribbean Sea on 28 September as a disorganised area of cloudiness and thunderstorms and was partially related to remnants of Tropical Storm Matthew and a monsoonal low pressure system which was present in the area. The system was generally poorly defined but generated torrential rainfall and thunderstorms, particularly in the eastern and southern sections as it moved slowly to the northeast towards the Bahamas.

Sustained wind speeds associated with the system did not exceed 40 mph with its lowest pressure being measured at 996 mbar. Thus, the winds and ocean hazard parameters associated with Nicole were well below Tropical Storm force in the region of the closest CCRIF member countries (the Bahamas, the Cayman Islands and Jamaica, see Figure 9) so this event did not qualify as a triggering event under CCRIF's tropical cyclone policies with these countries.

As Tropical Storm Nicole moved towards the Bahamas and away from Jamaica, a remnant low developed in the region around Jamaica. This event, as indicated earlier, resulted in significant damage and loss of life in Jamaica.

The system was particularly associated with intense rainfall which resulted in significant flooding. The on-the-ground rainfall data from the Jamaica Meteorological Service, provided in a news release on 29 September showed that rainfall accumulations in excess of 4 inches (100 mm) had been recorded over a 12-hour period at various weather stations across the island. Data from NASA/JSA TRMM characterising this event indicated that as much as 20 inches (500 mm) of rain fell in the southern parishes of St Elizabeth, Manchester, Clarendon, St Catherine and St Andrew over a 72-hour period from 27 September to 30 September, thereby confirming the intensity of the rainfall associated with the system. These TRMM-based estimates were later informally validated by local data sources.

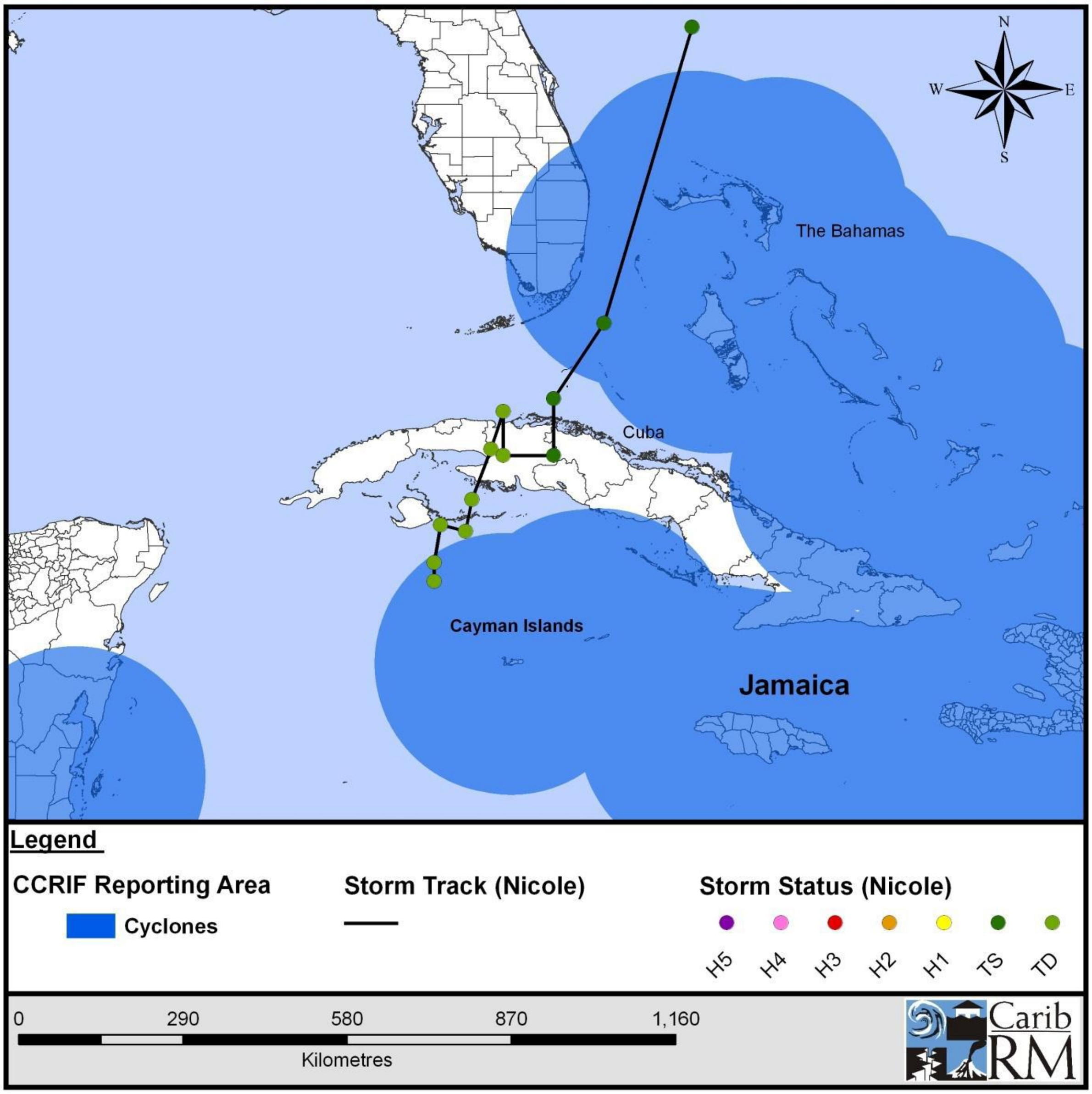



**Figure 9** Track for Tropical Cyclone Nicole. *Source: NOAA/NHC*.

Figure 10 shows the estimated rainfall totals for Nicole over Jamaica from the Tropical Rainfall Measurement Mission satellite ensemble.

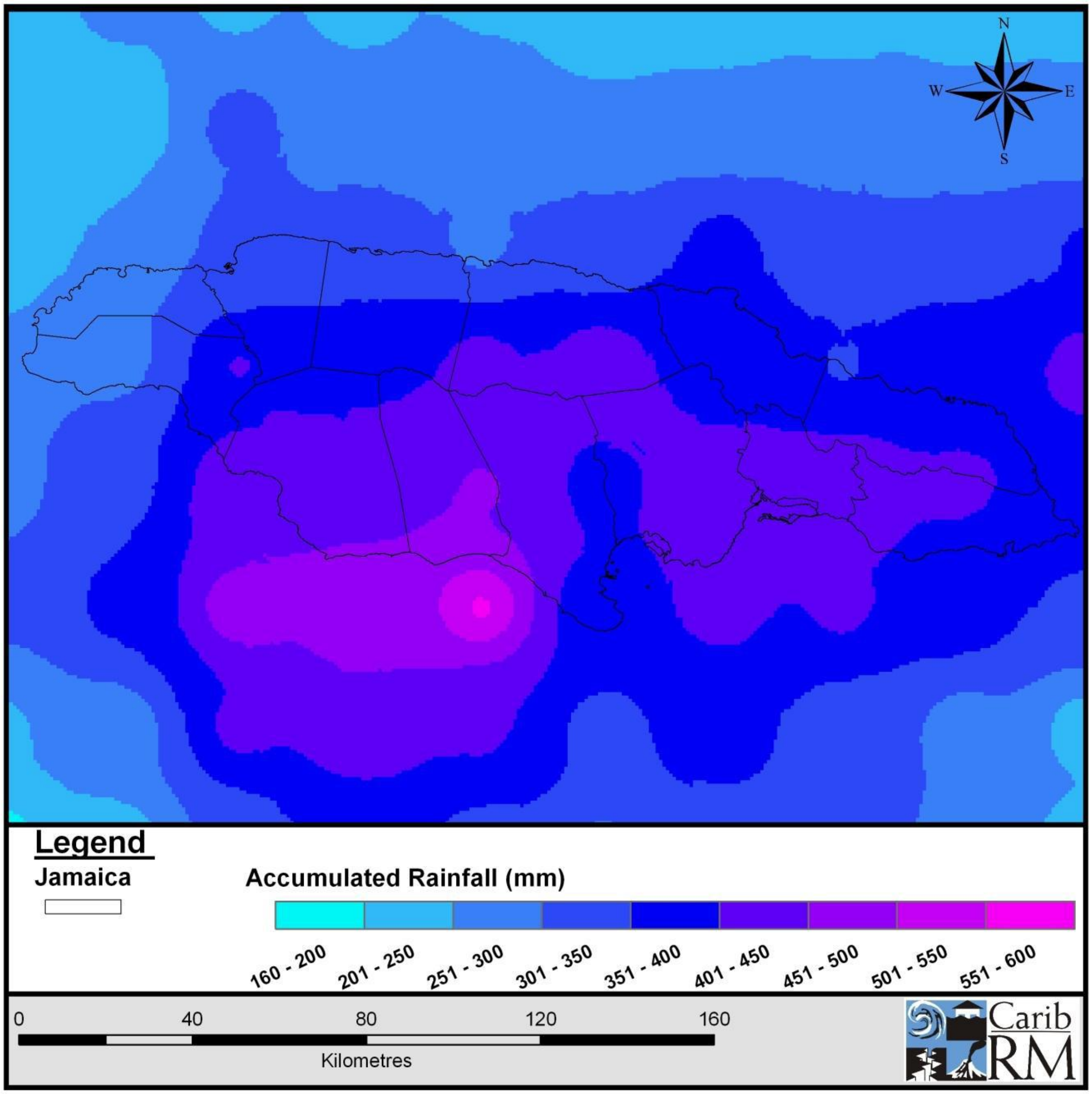



**Figure 10** TRMM rainfall totals for Nicole. *Source: NASA/JSA TRMM.*

Jamaica's Prime Minister indicated that preliminary assessments estimate that the floods cost the government at least US$150 million. Assessments carried out by the Ministry of Transport and Works and the Department of Local Government indicate that the damage to the road network, drainage systems, river protection and associated infrastructure will require US$123 million to restore. US$19.7 million will also be required to initiate immediate clearance and works on roads that had been damaged or infrastructure that posed some danger to life and property. Figures 11 to 14 are photographs illustrating various aspects of damage incurred in Jamaica.

**Figure 11** Damaged Bridge.
*Source: Weather.*

**Figure 12** Barbican Road.
*Source: Matthew Pragnell, CGMG.*

**Figure 13** Flooded roads.
*Source: Weather Channel/Karyn Kay.*

**Figure 14** Debris on roads.
*Source: Matthew Pragnell, CGMG.*

Loss of farm roads was estimated at US$5.8 million and loss of crops and livestock was estimated at US$5.8 million. Damage to schools island-wide was estimated at US$1.16 million and damage to health facilities at US$1.14 million. While reports indicate that tourist arrivals during the period were not adversely affected, significant damage was done to beaches and buildings in Negril which was estimated at over US$1 million. Additionally, the National Water Commission estimated the damage to its systems and installations at US$3.13 million. The National Works Agency also incurred damages of ~US$3 million.

News reports indicated that a number of bridges were destroyed and roads seriously damaged as a result of flooding associated with the heavy rainfall. There were no reports of significant damage to commercial properties, but many residential areas flooded. The electricity supply was disrupted due to downed trees and poles and the Jamaica Public Service Company activated its emergency operations centres across the island to restore power to some 170,000 customers in affected areas.

This event provided an interesting lesson for CCRIF and Jamaica as it highlighted the imposing impacts and costs which natural disasters continue to have on Caribbean countries. Although this event did not become a tropical cyclone until well after passing Jamaica, it still had a significant physical and human impact which was/is further pronounced by the delicate fiscal situation of the country.

The fact that the system was able to inflict such damage also brought to the fore some of the core challenges faced by Caribbean governments as they relate to the capacity of existing infrastructure to cope with such events, which are becoming more common. CCRIF is designed to address much larger catastrophe events and this system did not qualify as such an event and had not even reached the magnitude of a tropical cyclone. The risk spectrum imposed by natural disasters on Caribbean countries range from the more frequent, less intense events to the less frequent but larger and more catastrophic events. The rains associated with Tropical Cyclone Nicole highlight the urgent need for a more holistic approach to effectively managing all of these risks.

# 4 TROPICAL CYCLONE RICHARD

***The estimates from the CCRIF 2G model were generally consistent and closely correlated with on-the-ground estimates relating to wind speeds and the general impact of Tropical Cyclone Richard on Belize. Although the loss estimate from the model was slightly lower than the direct loss estimates released by the Government, the difference was not significant in the context of catastrophe model loss estimates. The Government of Belize's policy with CCRIF was not triggered by Tropical Cyclone Richard as modelled losses fell just below the 30-year return period attachment point they had selected.***

Tropical Cyclone Richard began as a tropical wave on 13 October 2010 over the northern coast of Venezuela. By 24 October it had become a hurricane, making landfall in Belize as a Category

1 storm, just 20 miles south of the former capital and most populous city, Belize City. Figures 15 and 16 provide images of Tropical Cyclone Richard as it was about to make landfall in Belize.

**Figure 15** NOAA satellite image of Tropical Cyclone Richard about to make landfall in Belize.

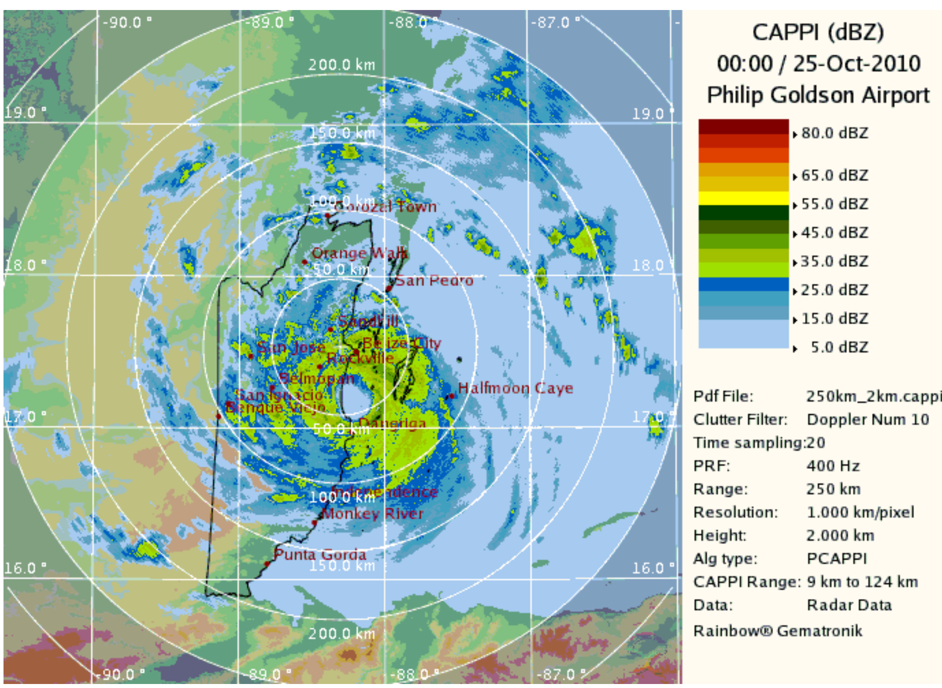



**Figure 16** Radar image of Tropical Cyclone Richard.

The wind footprint below, one of the outputs from the CCRIF 2G model, shows that Richard achieved the minimal requirements of a defined event under the CCRIF Policy by having winds of greater than 39mph in only one member state, Belize.

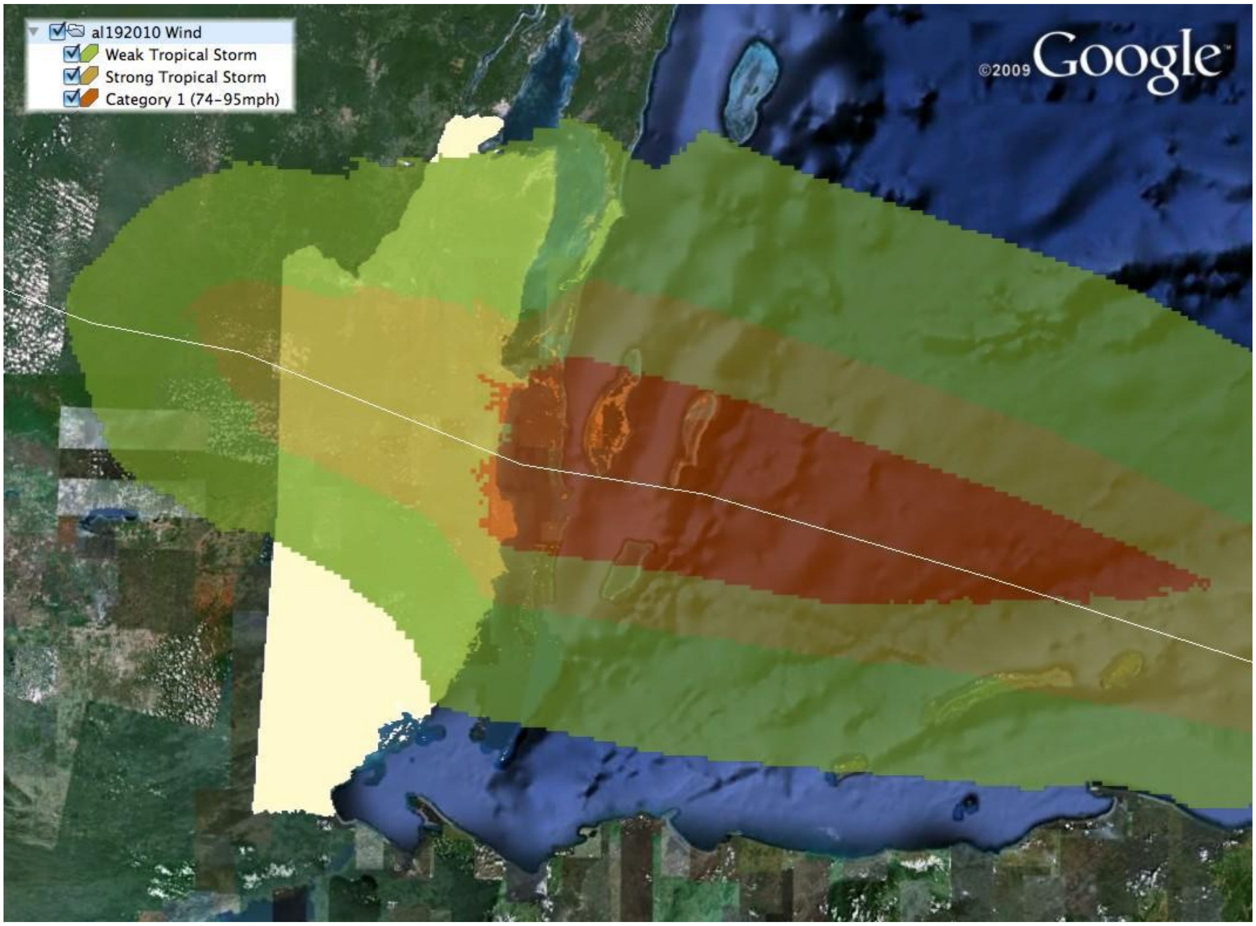



**Figure 17** CCRIF model wind footprint for TC Richard making landfall in Belize.

For Belize, modelled wind speed at the coast was minimal hurricane-force (75-80 mph) but fell rapidly as the cyclone moved inland. According to NHC, the maximum wind speed associated with Richard at landfall was estimated at ~90mph, with the highest winds being estimated close to Belize City.

Figure 18 below shows the H*WIND peak surface wind estimate for Richard about an hour after landfall, moving over Belize.

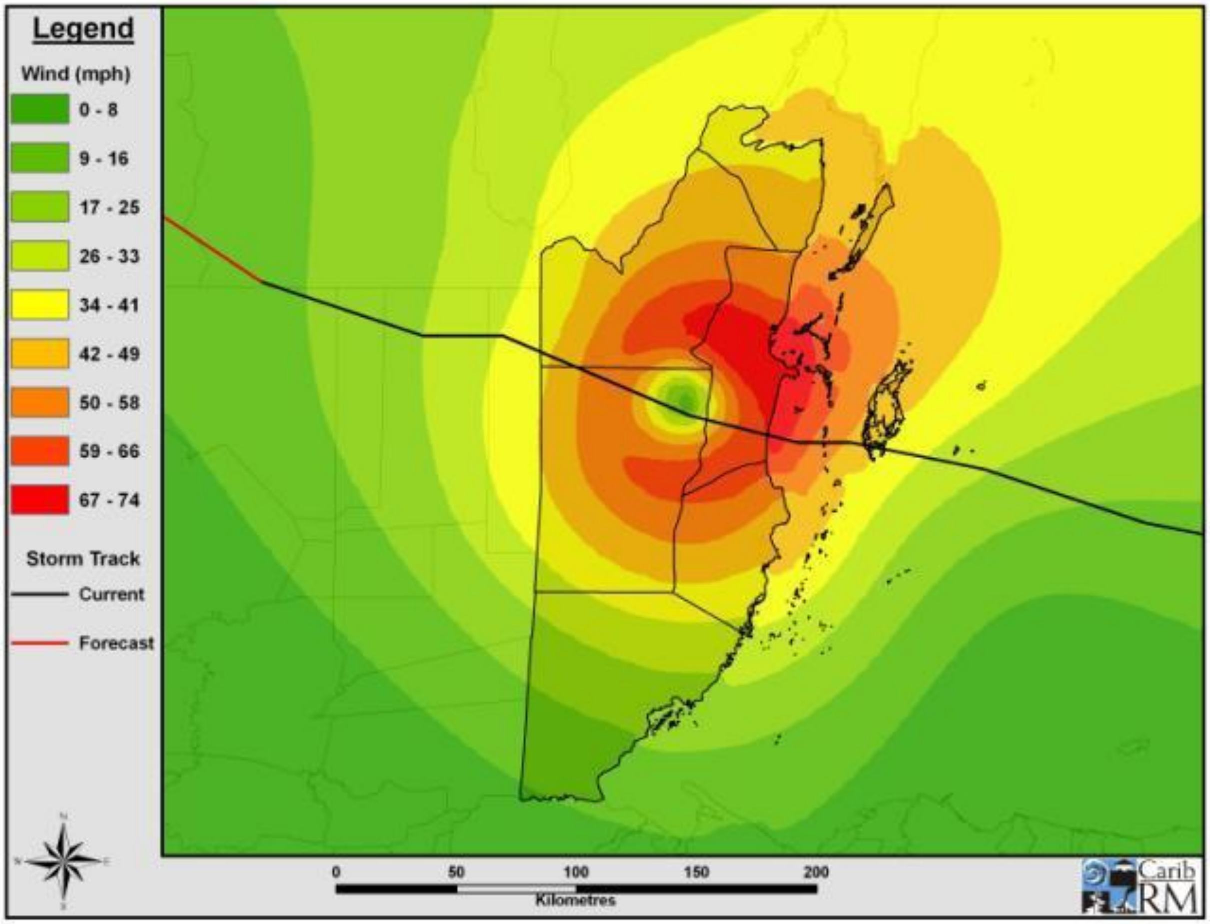



**Figure 18** H*WIND peak surface wind estimate for Richard over Belize, 24 October 2010. *Source: NOAA-NHC.*

The peak H*WIND 1-minute sustained wind speed estimate for Belize was 76 mph, although this was estimated about an hour after landfall.

The CCRIF modelled wind speed is generally consistent with surface wind speed estimates from NOAA-NHC's H*WIND algorithm. Unofficial surface wind speed measurements were consistent with the minimal hurricane force winds which were felt on land in Belize. Reports suggest that Hurricane Richard had sustained winds of 90 mph when it made landfall 20 miles south of Belize City, with hurricane force winds extending 20 miles from the centre and tropical storm force winds extending 105 miles from the centre.

Wind approximations from the CCRIF model and H*WIND estimates both correspond with actual meteorological data from Belize.

The loss estimate generated in the 2G model was US$19.5 million. This figure was somewhat lower than a total direct loss estimate released by the government of Belize of approx. US$25.2 million, which was based on a preliminary reports of damages and included a significant proportion of agricultural losses, some of which would have been from rainfall and which would not have been reflected in the CCRIF modelled loss estimate.

Although the CCRIF loss model generated a substantial government loss in Belize, this loss was below the country's chosen trigger level (which was set at the 30-year return period) so no payout was due.

The Government of Belize released BZ$3 million (~US$1.6 million) for immediate emergency response and relief efforts. Although there were no reports of deaths, there were reports of infrastructural damage. Reports indicated considerable damage in areas close to landfall, with downed power lines and trees observed and damage to roads and building apparent with some flooding occurring in low-lying areas.

In Belize City, where there are many wood and tin structures, it was estimated that thousands of homes lost their roofs or suffered severe damage with reports of blown-off roofs or entire structures being blown off their silts which hold them above flood-prone land. Due to the unstable nature of these structures, they are particularly vulnerable to high winds. Damage to the road networks within the broad impact zone was minimal. The Ministry of Works indicated that all repair needs could be accommodated under their normal maintenance program.

The coastal areas bore the brunt of the impact associated with Richard. Field assessment teams confirmed the destruction of all major tourism-related piers in Belize City; these included the Radisson Hotel & Marina Pier, Princess Hotel & Marina Pier and the water taxi terminal pier. Some beach erosion was also reported in coastal areas.

In terms of rainfall, an accumulated rainfall measurement of 67.8mm was recorded at a Belize City weather station. TRMM data also suggests that rainfall totals were relatively low. Thus most of the damage incurred from Tropical Cyclone Richard was from wind with some coastal flooding from storm surge also causing some damage.

Figures 19 to 22 show some of the displacement and damage resulting from Tropical Cyclone Richard.

**Figure 19** *Source: Associated Press.*

**Figure 20** *Source: Associated Press.*

**Figure 21** *Source: Associated Press.*

**Figure 22** *Source: Associated Press.*

# 5 TROPICAL CYCLONE TOMAS

***Tropical Cyclone Tomas had the greatest impact on CCRIF member countries during the 2010-2011 policy year. The system triggered CCRIF policies in Barbados, Saint Lucia and St. Vincent & the Grenadines and resulted in payouts of US$8.5 Million, US$3.2 Million and US$1.2 Million to the respective countries. The performance of the CCRIF 2G model was generally acceptable with close correlations to the NOAA-NHC wind speed data and the TRMM rainfall data. Although there was some concern expressed about the significantly lower payout received by the Government of Saint Lucia relative to their losses and in comparison to the payout received by the Government of Barbados, it is important to indicate that in the case of Saint Lucia, most of the damage which occurred was a result of the heavy rainfall and secondary induced hazards such as landslides. Both rainfall and landslides are not included in the current CCRIF Tropical Cyclone coverage. Also of importance is the fact that the coverage selections made by the various countries in terms of their attachment and exhaustion points and coverage limits would have played a significant part in determining the payouts which were received. These parameters are selected by countries and define the policies purchased by the respective governments and essentially are key determinants of when a policy is triggered or not and at what level.***

In its passage through the Eastern Caribbean, Hurricane Tomas achieved the minimal requirements of a defined event under the CCRIF Policy by having winds of greater than 39 mph in four member states in the eastern Caribbean: Barbados, Saint Lucia, St Vincent & the Grenadines, and Grenada. Grenada is included due to the tropical storm wind footprint just touching Carriacou, the northernmost part of Grenada sovereign territory.

Figures 23, 24 and 25 provide satellite/radar images of Tropical Cyclone Tomas as it passed over Barbados, Saint Lucia and St. Vincent & the Grenadines.

**Figure 23** NOAA satellite image of Tropical Cyclone Tomas.

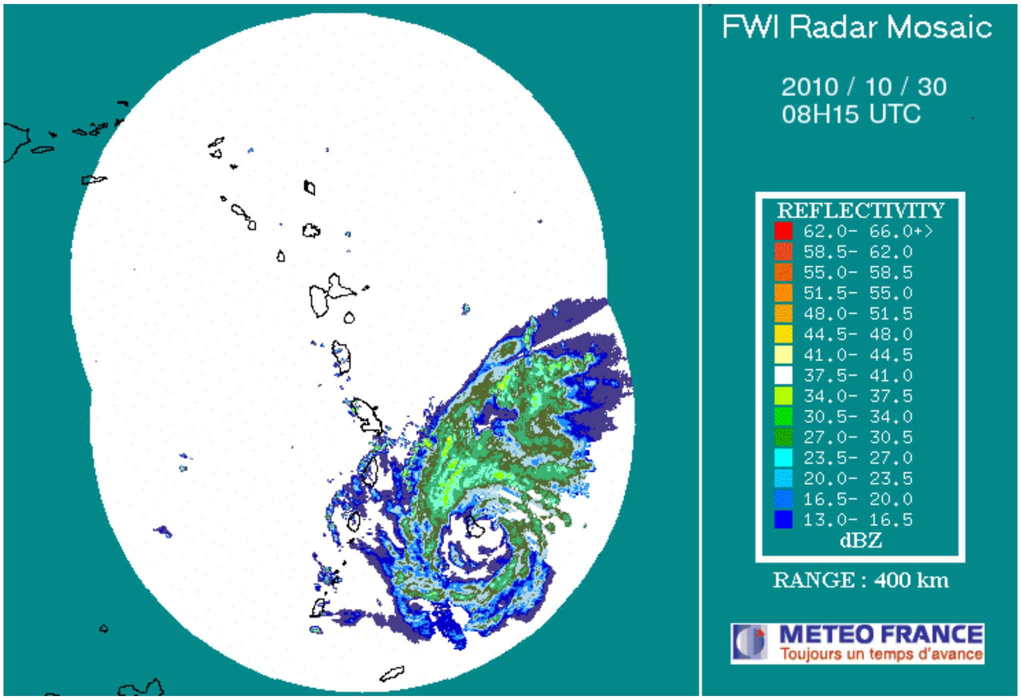



**Figure 24** Radar image of Tropical Cyclone Tomas over Barbados
*Source: MeteoFrance.*

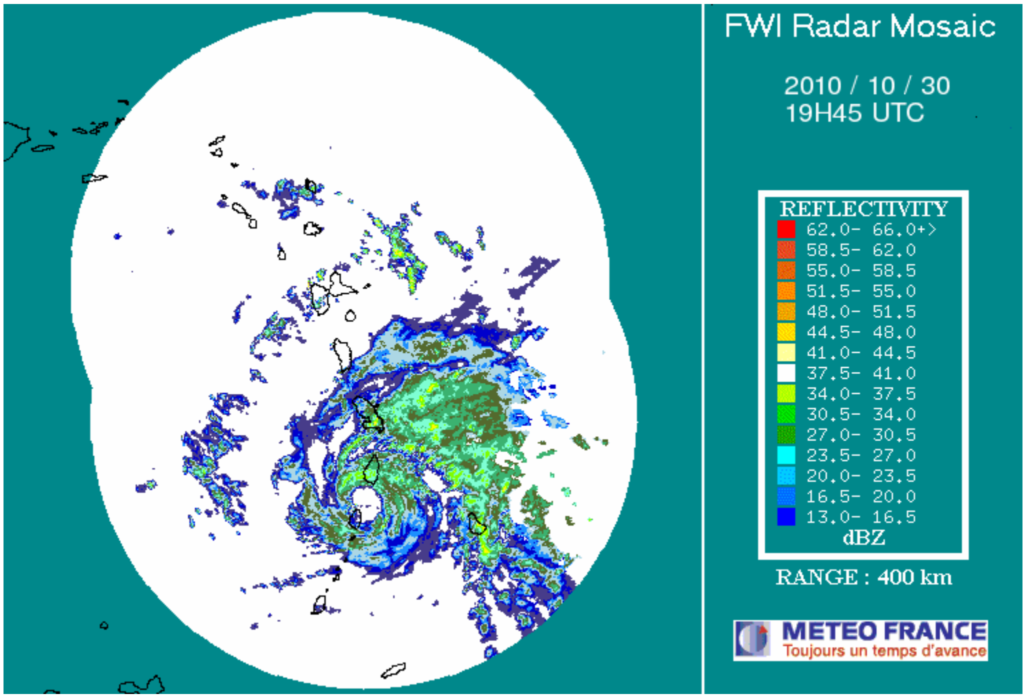



**Figure 25** Radar image of Tropical Cyclone Tomas over Saint Lucia and St. Vincent & the Grenadines. *Source: MeteoFrance.*

Barbados was the first island impacted by Tomas. As can be seen in the CCRIF model wind footprint (Figure 26), the entire island was affected by severe tropical storm-force winds, with gusts to hurricane force.

Ground data from Barbados, consistent with model estimates, suggest sustained tropical storm-force winds at between 60 and 75 mph across most of the island, with peak gusts of 110 mph recorded near the southern tip of the island. St. Vincent & the Grenadines also reported winds of 75 mph when Tomas passed near that territory. Tomas affected the southern part of Saint Lucia as a Category 1 hurricane with reported maximum sustained winds of 90 to 95 mph with higher gusts.

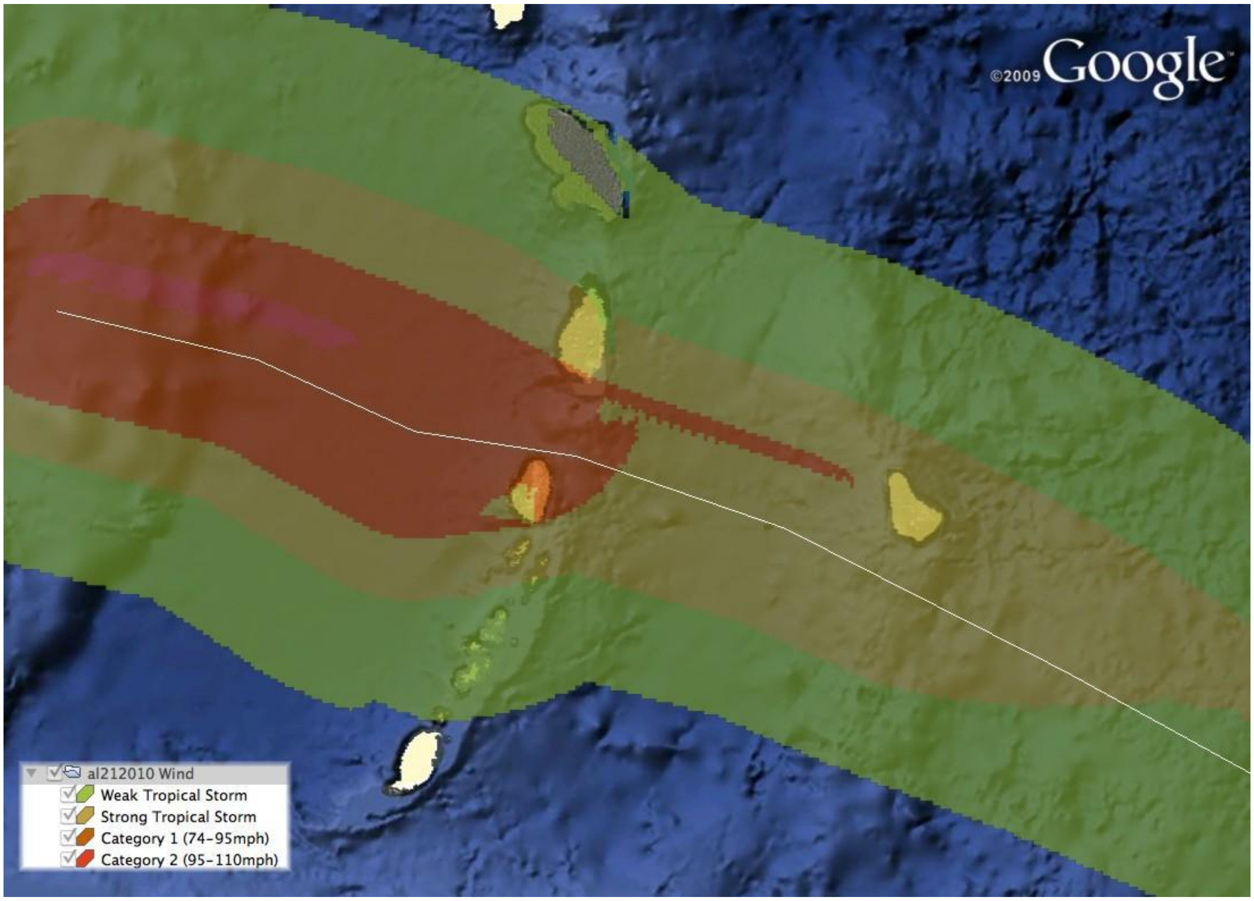



**Figure 26** CCRIF wind footprint of Tomas' passage through the Eastern Caribbean.

NOAA-NHC wind estimates for Barbados, Saint Lucia and St. Vincent & the Grenadines, as indicated in the H*WIND produced, suggested peak 1-minute sustained surface winds of 61-70 mph (Figure 27) for all three of the islands. NHC deemed it likely that surface wind speeds of hurricane strength would have been felt on the island of St Vincent and in southern Saint Lucia, with hurricane-strength gusts possible across all three affected countries. According to NHC, tropical storm-force winds may have been felt also in the northernmost part of the country of Grenada, on the island of Carriacou. This is consistent with the few surface measurements available.

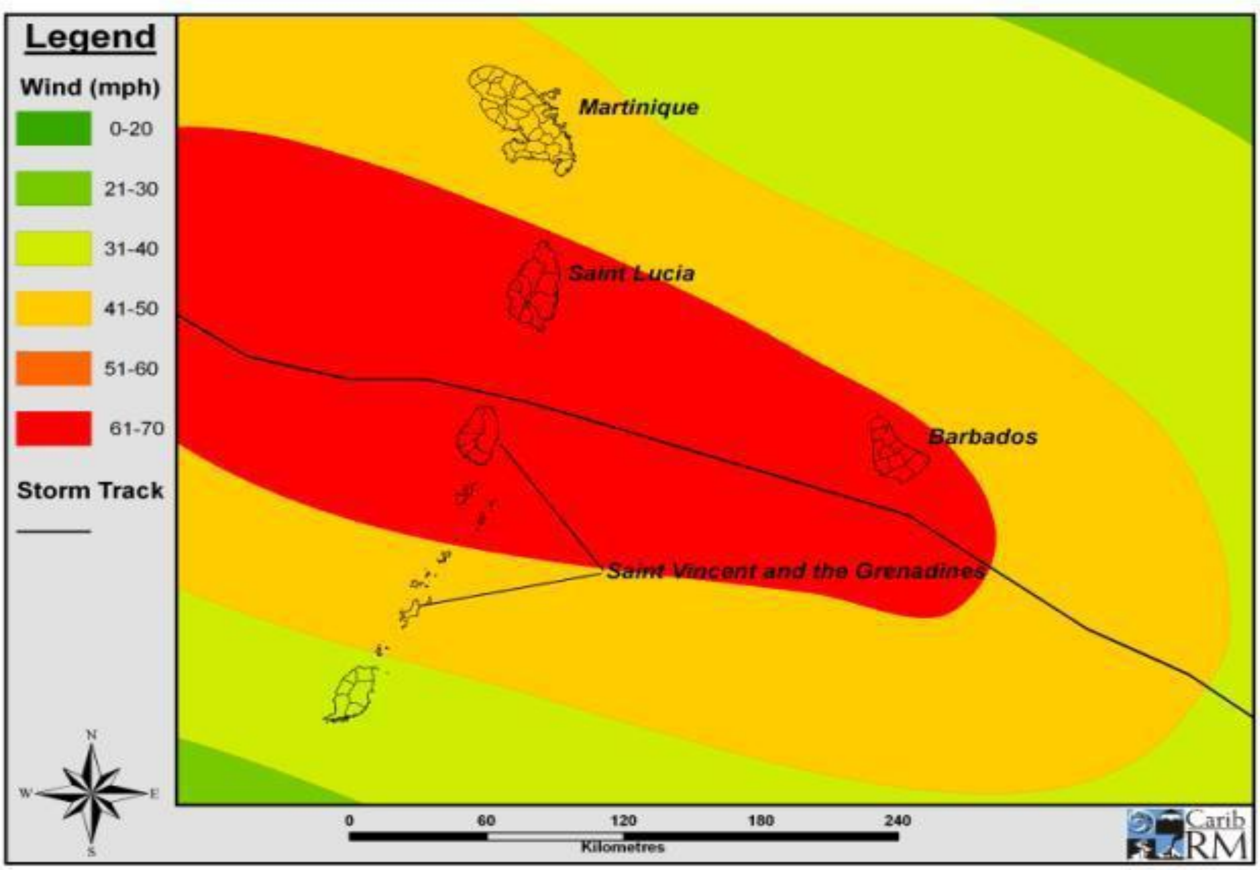



**Figure 27** H*WIND peak surface wind estimate for Tomas, October 2010. *Source: NOAA-NHC and CaribRM.*

The CCRIF model wind speeds are generally consistent with surface wind speed estimates from NOAA-NHC, as well as ground estimates for all three territories. However, relatively few data points were available to make this analysis.

After impacting the Eastern Caribbean and weakening to a tropical storm in the Caribbean Sea, Tomas re-strengthened to a hurricane as it approached Jamaica, Haiti and the southern islands of the Bahamian chain, including the Turks & Caicos Islands.

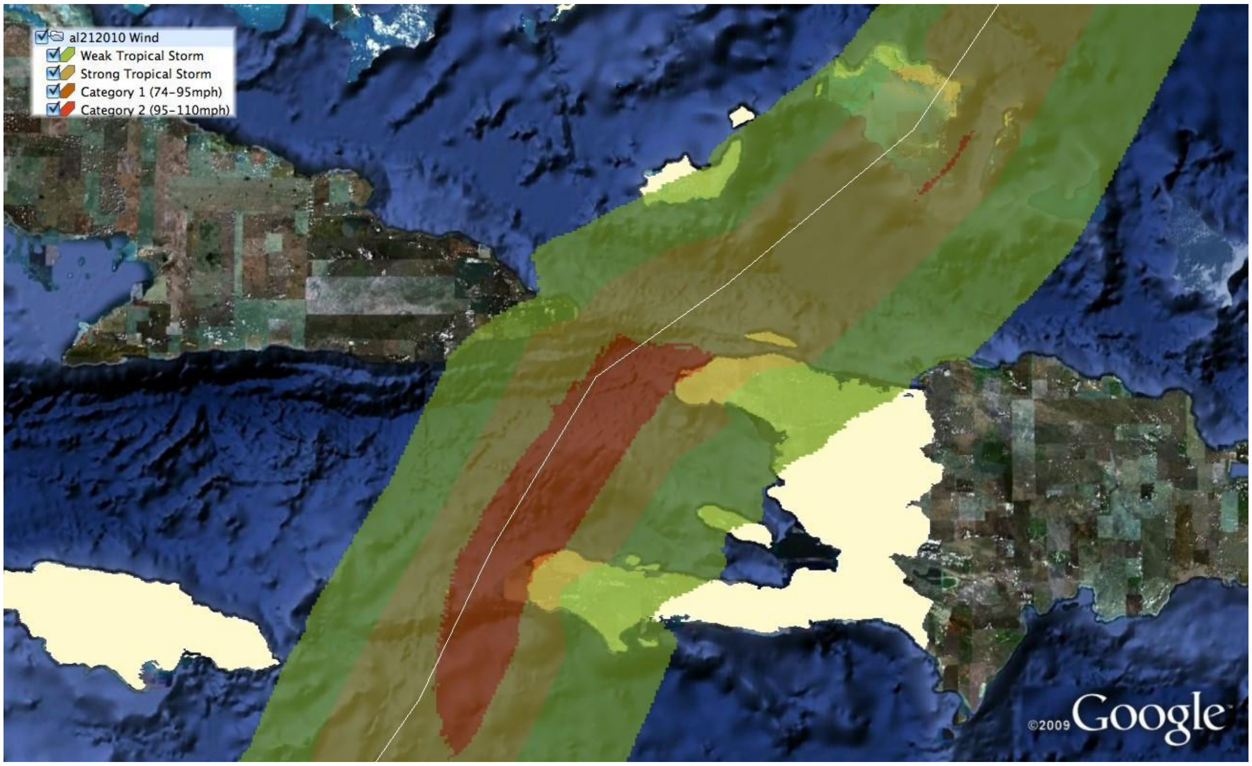



**Figure 28** CCRIF wind footprint of Tomas' passage through the Northern Caribbean.

As can be seen in Figure 28 above, the tropical storm wind footprint does not quite touch the extreme eastern end of Jamaica, so Tomas was not a qualifying event there. Hurricane-force winds just grazed the extreme western ends of Haiti's southwest and northwest peninsulas, while the Bahamas and the Turks & Caicos Islands were affected only by tropical storm-force winds. The CCRIF modelled hazard corresponds very closely to National Hurricane Centre wind field estimates.

In terms of losses, the CCRIF model generated substantial government losses in Barbados, Saint Lucia and St Vincent & the Grenadines. Barbados endured the biggest actual loss by dollar amount (as it is a significantly bigger economy than the other two) as well as the biggest loss relative to GDP (just over 1.5%), the latter due largely to the fact that near-hurricane force winds affected the entire island and due also to high coastal exposure. Due to the track of Tomas directly over the island, these winds persisted at a high level for a relatively long time. Storm surge and wave action were also significant.

Both Saint Lucia and St Vincent & the Grenadines endured modelled losses of around half of one percent of GDP. It is important to note that although the damage in Saint Lucia was significant, these losses were largely driven by rainfall which would not have been covered under the CCRIF policy and which would have induced secondary hazards such as flooding and landslides which caused even further devastation.

For Haiti, the loss estimate in the CCRIF modelled loss was ~US$15 million. While economic losses in Haiti will likely be significantly higher than the CCRIF estimate, much of that impact will have been caused by the rainfall aspects of Tomas, which are not modelled in the CCRIF loss model.

The CCRIF model estimated losses of less than US$1 million each for the Bahamas and Turks & Caicos Islands. In both of these territories, the modelled loss is below the threshold that can be reasonably documented on the ground. While damage did occur in both territories, it appears to have been light.

Rainfall totals of between 7 and 12 inches (175 to 300 mm) were recorded across the countries of Barbados, Saint Lucia and St. Vincent & the Grenadines (Figure 29) thereby resulting in general flooding as well as damage to the agricultural sector in these countries.

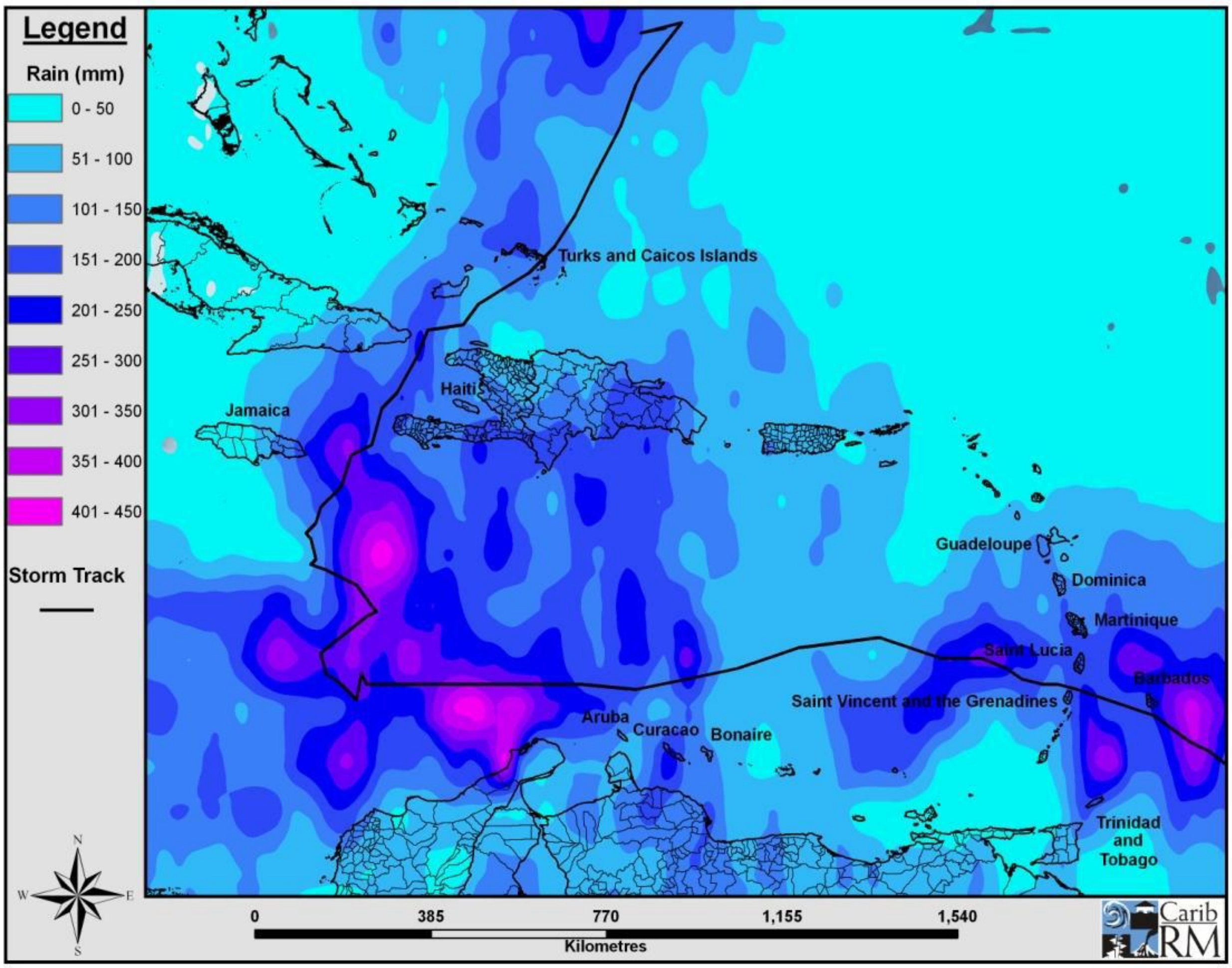



**Figure 29** Accumulated rainfall totals 00Z 29 Oct 2010 to 21Z 7 Nov 2010. *Source: TRMM.*

Tomas was an extreme rainfall event on the island of Saint Lucia, with 533mm of rainfall being recorded in Castries in 24 hours. This excessive rainfall coupled with high winds caused the Government of Saint Lucia to issue a declaration of a disaster on Sunday, 31 October 2010.

The impact of Tomas across Barbados, Saint Lucia, St. Vincent & the Grenadines and Haiti and the CCRIF response are explored further in the following country subsections.

## *5.1 Barbados*

Barbados suffered significant damage to the housing stock, with official figures indicating an estimated repair cost of at least BDS$37M (US$18.5M) just for this sector. The CCRIF payout to the Government of Barbados as a result of Tomas was US$8,560,247, thereby being a significant contribution towards addressing some of the costs associated with recovery efforts.

As indicated earlier, Tropical Storm Tomas resulted in residential and infrastructural damage with thousands of residents being left without electricity and water supply for most of the day. Some residential areas in Bridgetown were very hard-hit, with reports of house collapses as well as widespread roof loss or damage. Local reports indicate that many roads were left impassable as a result of felled trees, poles and other debris.

Electrical power was severely disrupted as a result of the storm, particularly by the many downed trees, which caused widespread outages across the island. At 7.00pm on 30 October, over 60% of the island was still without electricity but within 10 days most of the supply had been restored.

Storm surge was relatively low, but there was some coastal damage caused by wave action, including significant damage to the Wharf Road, one of the main access roads to Bridgetown.

Although the Grantley Adams International Airport was closed for most of 30 October, the tourism sector appears to have suffered only marginally from Tomas and may even benefit from the influx of visitors originally destined to Saint Lucia.

## *5.2 Saint Lucia*

As a result of the damage inflicted by Tropical Cyclone Tomas, Saint Lucia’s policy with CCRIF was triggered and a payout of US$3,241,613 was made to the Government.

According to Isaac Anthony, Permanent Secretary/Director of Finance for the Government of Saint Lucia, the funds received from their CCRIF payout were used primarily to remove the significant amounts of debris and silt generated by Hurricane Tomas and deposited in towns and villages throughout that island. This also involved the unblocking of roads in order to restore the smooth flow of traffic especially in the rural areas. Some of the money was also used for emergency repairs to roads, and retaining walls, etc.

Reports from Saint Lucia indicated that Hurricane Tomas inflicted severe damage, with the south of the island bearing the brunt of its impact. Residential, infrastructural and agricultural damage was extensive, with disruptions to the road network also being significant. Felled trees were visible across the island and flooding was recorded. Significant damage to livestock and the banana crop occurred. Seven people were confirmed dead as a result of the hurricane.

Two main bridges were left impassable as was the West Coast road. The disruption essentially resulted in the northern section of the island being cut off from the south of the island. This had serious economic implications as the international airport is located in the south of the island and the tourist locations are concentrated primarily in the north of the island.

The entire population of 181,000 was impacted by disruption of the water supply which still requires extensive repairs.

Preliminary estimates of damage to the banana industry range between 80% and 90% with a potential weekly income loss up to EC$2.0 million (~US$741,000) over the next six month period. Also, damages to the fishing industry was estimated at EC$1.5 million (~US$556,000).

### *5.3 St. Vincent & the Grenadines*

CCRIF made a payment of US$1,090,388 to the Government of St. Vincent & the Grenadines as their policy was triggered as a result of Tropical Cyclone Tomas. Prime Minister Hon Ralph Gonsalves said that the early CCRIF payment facilitated the "urgent restoration of services and clearing of the affected areas."

The damage which occurred in St Vincent was localised to the north of the island. This resulted in major differences between weather recordings collected in the north of the island and those (more numerous) in the south. According to the final post-assessment report released by CIMH, the localised nature of the impact resulted in differences in rainfall between the E.T. Joshua airport in the south of the island and the Dumbarton station in the north of the island which recorded 79.9mm and 140.2mm in rainfall respectively. The latter value was closely correlated to the TRMM records.

In terms of damage and losses, the Prime Minister indicated that the damage would amount to "millions of dollars." Government estimates indicate that approximately 1,200 dwelling houses in St Vincent were damaged to varying degrees by Tomas, mainly in areas on the outskirts of the capital, Kingstown. Seven government buildings were damaged and over 1,100 people were forced to seek refuge in shelters. The Prime Minister added that it would cost the Government "an average of EC$30,000 (US$11,173) to repair each of the 300 houses severely damaged by the storm."

The agriculture sector was also hit hard, with estimated losses in this sector exceeding EC$67 million (US$25 million). Most of the banana and plantain crops were destroyed with many fruit trees being blown down. There were no reports of deaths, although several cases of injuries were reported.

Also, the island-wide power supply was severely disrupted.

### *5.4 Haiti*

Haiti was spared a direct hit from Tomas but some areas still sustained up to 12 inches (300 mm) of rain with flooding occurring in the northwest and southwest peninsulas and some flooding in Port-au-Prince. The excessive rainfall further added to the worsening cholera crisis which the country was struggling to control. Several refugee camps were flooded including in Les Cayes, Jacmel and Gonaïves.

Figures 30 to 39 provide a montage of some of the damage which occurred in Barbados, Saint Lucia and St. Vincent & the Grenadines as a result of Tropical Cyclone Tomas.

**Figure 30** Barbados.
*Source: CaribRM.*

**Figure 31** Barbados.
*Source: Nation Newspaper.*

**Figure 32** Barbados.
*Source: Nation Newspaper.*

**Figure 33** Barbados.
*Source: CaribRM.*

**Figure 34** Saint Lucia
*Source: CaribRM.*

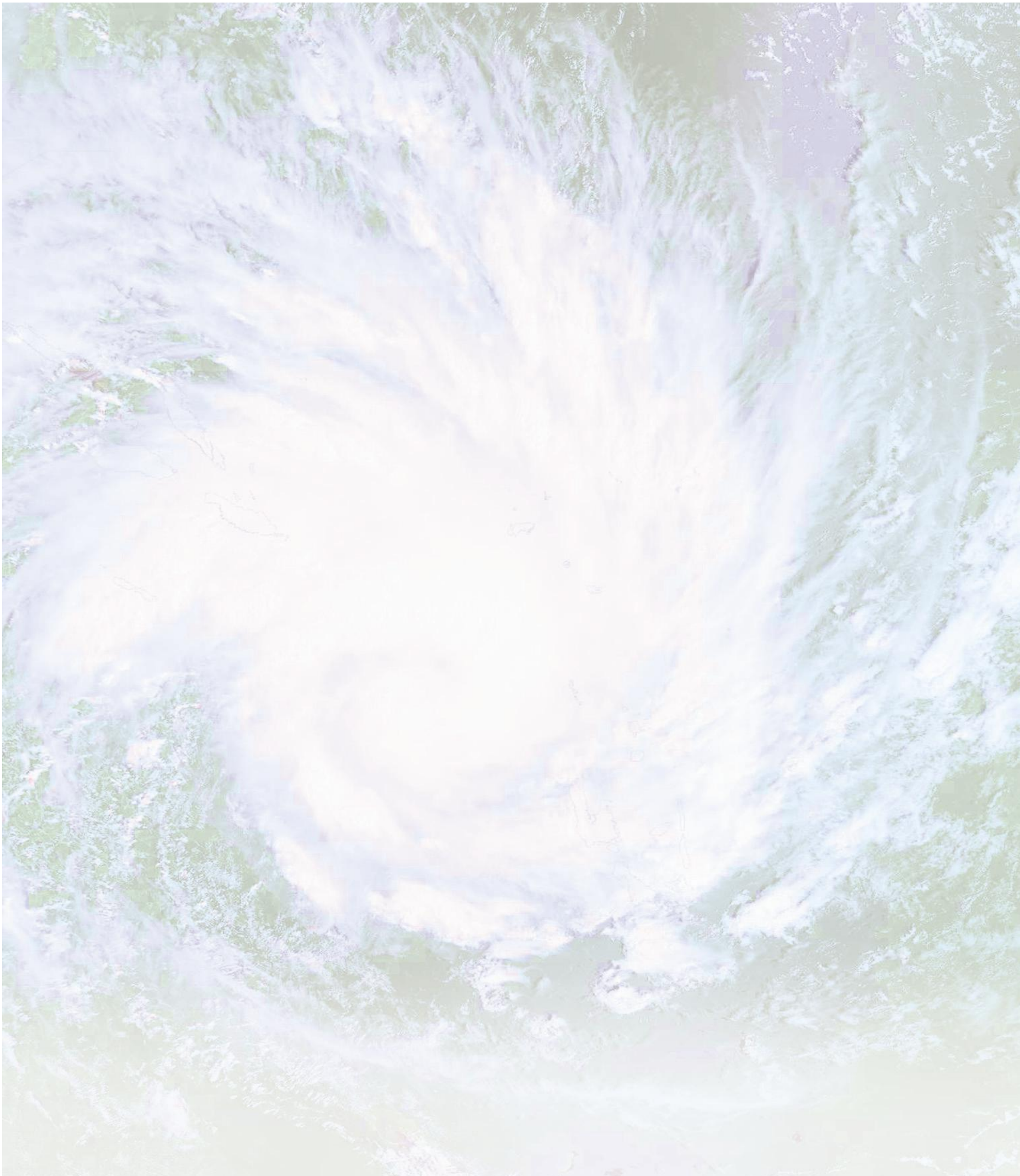
**Figure 35** Saint Lucia.
*Source: CaribRM.*

**Figure 36** Saint Lucia
*Source: CaribRM*

**Figure 37** Saint Lucia
*Source: CaribRM*

**Figure 38** St. Vincent.
*Source: CIMH.*

**Figure 39** St. Vincent.
*Source: CIMH.*



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