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An uncommon geomorphological crisis — Dominica Coastal system response and adjustments in the aftermath of Hurricane Maria (September 2017 episode)

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1. Objectives

Analysing the physical impact of Hurricane Maria on the Dominican coastline is relevant to the TIREX 2017 research project funded by the ANR OURAGANS - a national grant devoted to the study of hurricanes. TIREX (*Transfert des apprentIssages de Retours d'EXpériences scientifiques pour le renforcement des capacités de réponse et d'adaptation individuelles et collectives dans un contexte de changement climatique*) refers to the use of scientific feedback to encourage better response and adjustment from the civilian population as well as the local and national authorities in a context of climate change ; it focuses on the north area of the West Indies during 2017 hurricane season.

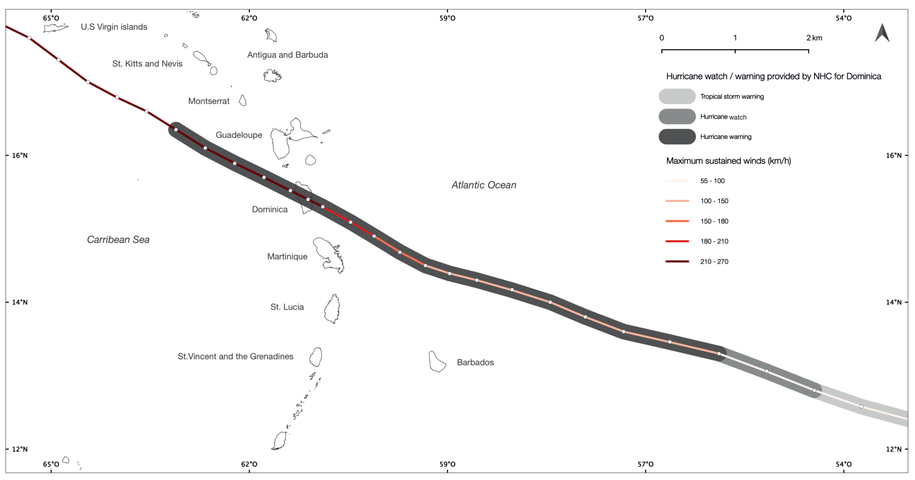


Figure 1 - Maria Hurricane track with winds speed and watch or warning levels for Dominica. Sources : ibtracs / NHC, NOAA, 2018 - GADM, 2019 (BATTUT, 2019)

2. The event

The 2017 Atlantic hurricane season is undoubtedly one of the most active and devastating ever recorded. Hurricane Maria ranks as the deadliest of the six strongest hurricanes of the season causing about 3,000 fatalities as recently reported. It started as a tropical wave off the West African coast before turning into a category 5 hurricane in less than 18 hours just before making landfall on the island of Dominica in the evening of the 18th of September 2017 (fig. 1). It stroke the island going from the south-east to the north-west and wrecked considerably this small island developing state (1.3 billion American Dollars loss or 224% of the 2016 gross domestic product). It affected seriously a population already made vulnerable by the passing of Hurricane Erika in 2015.

3. A diachronic and comparative approach for sedimentary responses analysis

In Dominica, hurricane Maria impacts have been studied through a comparative and diachronic approach on several sediment cells and watersheds across the island (fig. 5) displaying different signs of anthropisation (fig. 4). Their resilience was assessed a year and a half after the event. The use of aerial footage (fig. 3) and topomorphological data analysis made on field (fig. 2) have been put forward thanks to a cartographic translation in order to emphasize morphosedimentary response at different moments in time.

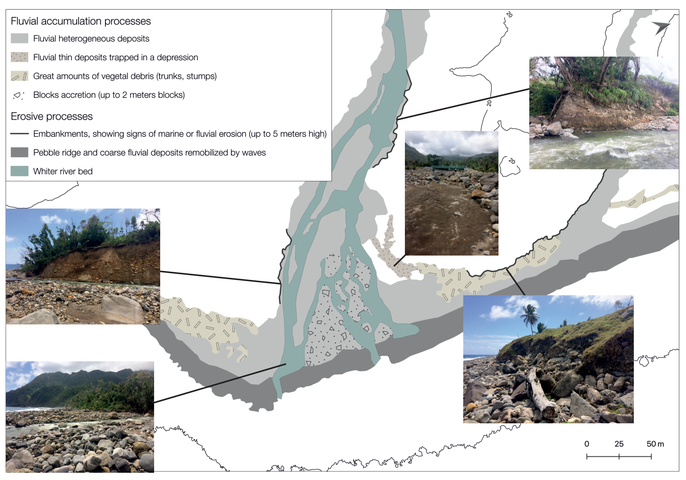


Figure 2 - Geomorphological cartography of Whiter river mouth in Pointe Mulâtre made with field observations and high resolution aerial views (BATTUT, 2019).

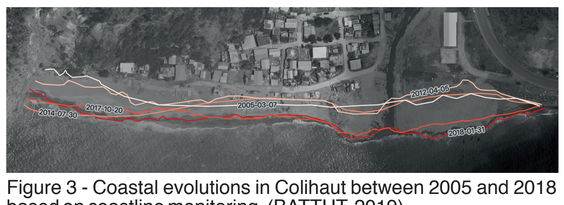
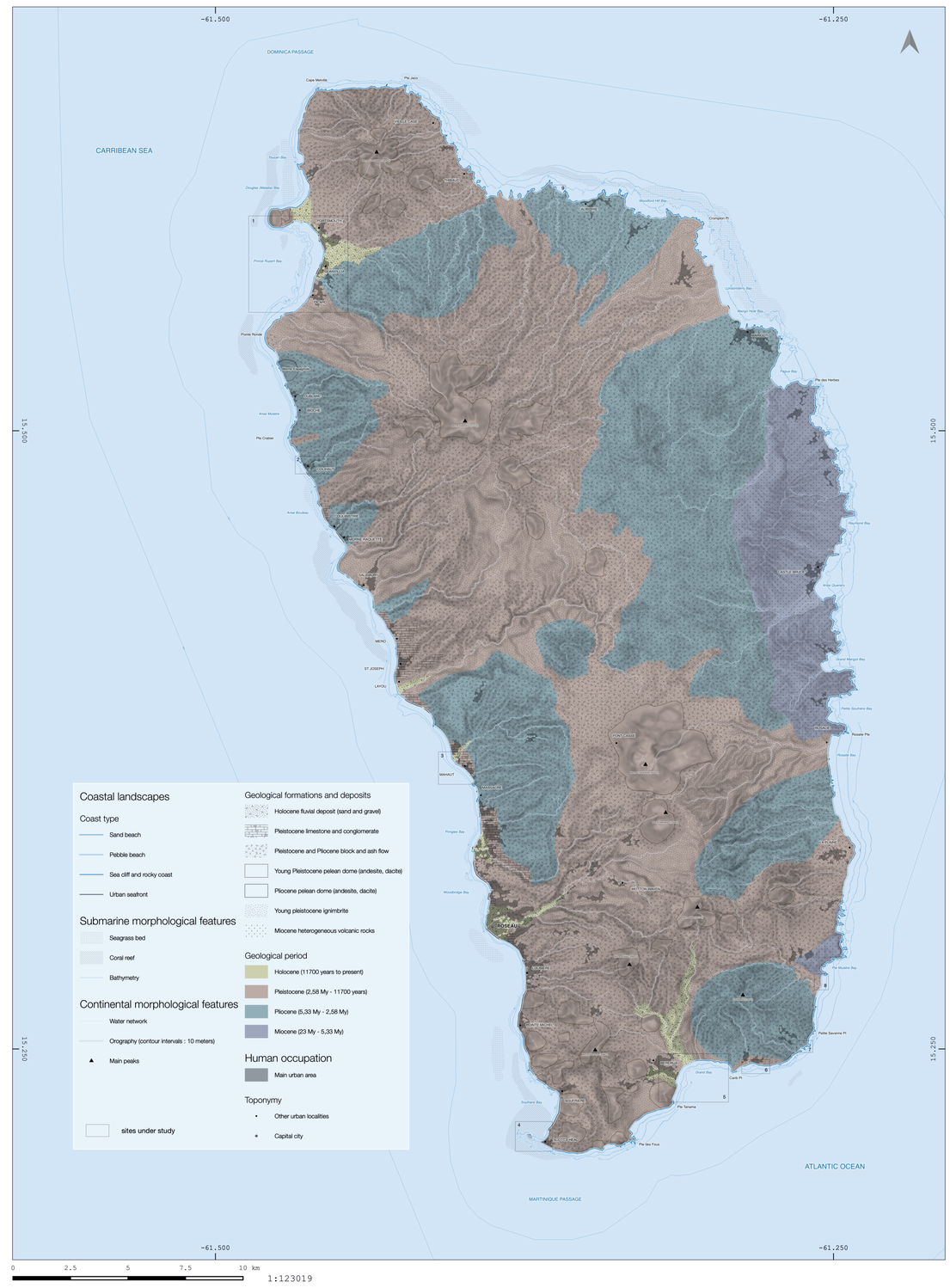


Figure 3 - Coastal evolutions in Colihaut between 2005 and 2018 based on coastline monitoring. (BATTUT, 2019)

Sedimentary cell	Morphological nature	Average sediment size	Human occupation level of seafront
Grand Bay	Bay	Pebble	Few houses
Colihaut	Small bay	Pebble	Coastal village
Mahaut	Small bay	Pebble	Coastal village
Pointe Mulatre	Small bay	Pebble	Very few houses
Petite Savanne Bay	Creek	Block	No occupation
Font Saint Jean	Small bay	Block	Small coastal village
Number One beach	Beach at the upper end of a bay	Sand	No occupation
Portsmouth Bay	Large bay	Sand	Second island city
Scott's Head	Small bay with tombolo	Pebble	Coastal village

Sites show a large range of shapes, materials and occupation levels so as to be well representative of Dominican coasts.

Figure 4 - Sites under study and their general features.



sources : OSM, 2019 - Bing Aerial / Microsoft, 2019 - Dominica topographic map 1/50 000 / Dominica Government, 2006 - LIDAR imagery / Lands & Surveys Division, Dominica Governement, 2018 - SRTM 1 / USGS, 2019 - SRTM + 200m bathymetry / Natural Earth Data, 2019 - CHARIM GIS DATABASE / updated by Dominica Government, 2019 - Field observations between March and April 2019

BATTUT, 2019

Figure 5 - Geomorphological map of Dominica and sites under study location (BATTUT, 2019). 1 - Portsmouth bay 2 - Colihaut 3 - Mahaut 4 - Scott's Head 5 - Grand bay 6 - Fond Saint Jean 7 - Petite Savanne bay 8 - Pointe Mulâtre 9 - Number one beach.

4. Binary sedimentary responses to Maria hurricane: from accretion to erosion

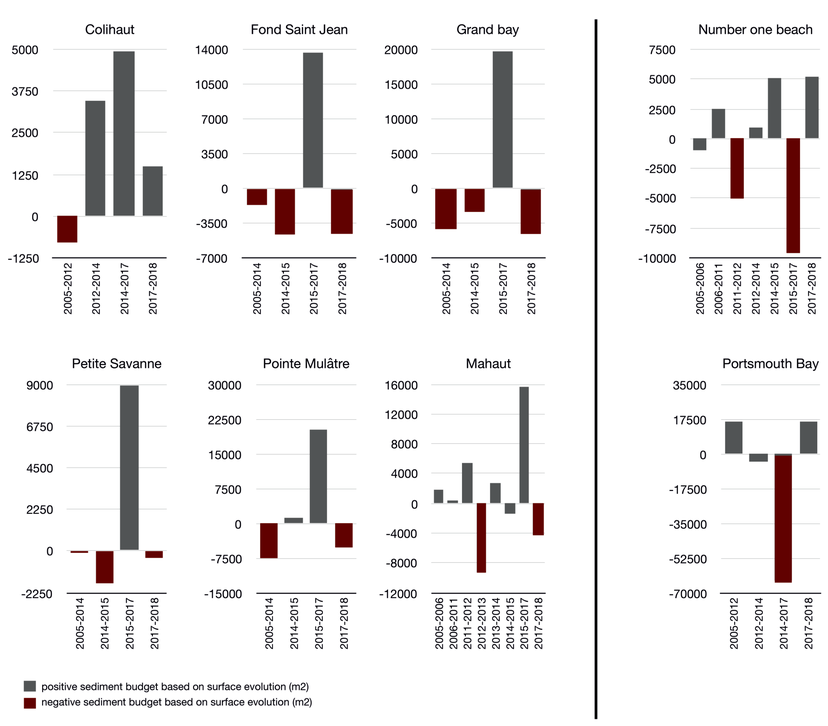


Figure 6 - Sediment balance in 8 different sites between 2005 and 2018 based on evolution surface (m2) (BATTUT, 2019).

The results show that coast evolutions are mainly due to fluvial processes rather than marine dynamics. Heavy rains caused major landslides (fig. 10) and flooding while enabling organic materials and debris to flow downstream towards the mouths. This phenomenon of extreme sedimentation accounts for major morphological alterations such as land elevation, sedimentary progradation, and river alvulsion. Contrary to the idea according to which hurricanes generally make coastlines recede, in the case of Dominica island, large amounts of input materials of heterogenous granulometry have generally contributed to a considerable accretion in sediment cells (fig. 6). Besides, large amounts of wooden debris washed away into the sea and reshaped by the cyclonic swell intensified the impact of the waves on the coastline and accumulated on supratidal parts of beaches.

Only two studied sites showed erosive processes signs (fig. 6).These locations are low lying sandy beaches with estuaries. Contrary to most of the sites, they include low gradient rivers. Erosion was mainly due to cyclonic waves that transported sediments towards the subtidal zone, causing the beach profile to retreat (fig. 9).

5. Erosive dynamics appearing on low lying sites with low gradient rivers and fine materials

Figure 7 - Erosion induced by Hurricane Maria in Lagoon, Portsmouth (BATTUT, 2019)

Figure 8 - Erosive processes and damages on seafront urbanization in Scott's Head and Picard (BATTUT, 2019).

Figure 9 - Washover deposits on Number one beach (BATTUT, 2019).

Erosive signs were observed in Portsmouth bay and Number one beach (fig.7 & 8). Their orographic settings are rare on the island of Dominica where slopes are particularly steep, even in coastal areas. Large low plains at the back of the seafront determine rivers declivity and their sediment load. On these sites, hurricane impacts were mainly induced by marine processes like waves impact and sediment erosion. Urbanized seafronts have suffered very high destructions as reflective erosion damaged sea walls and buildings (fig. 8).

6. Coastal sedimentary accretion as a result of upstream extreme sedimentation processes

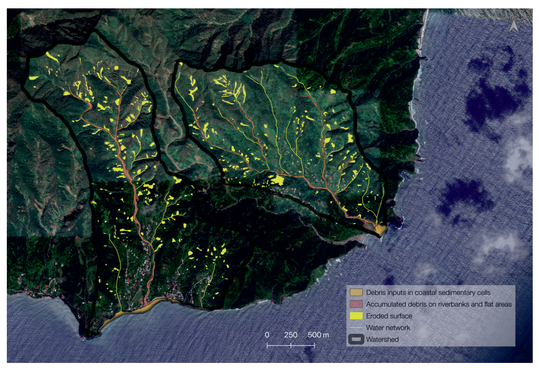


Figure 10 - Sedimentation processes in Fond Saint Jean (west) and Petite Savanne (east) watersheds. (BATTUT, 2019).

Figure 11 - Morphological evolutions in Fond Saint Jean bay between 2005 and 2017. (BATTUT, 2019).

Figure 12 - Coarse deposits in Petite Savanne. (BATTUT, 2019).

In some areas, the coastline has considerably moved forward and more than 70 meters have been reclaimed from the sea. Heterogeneous sedimentary inputs (fig. 12) modified the main river mouth causing its progression (fig. 11). Some of the sediments have been redistributed along the shoreline in the sediment cell and built up the beaches.

Figure 13 - Large block on Pointe Mulâtre river mouth.

7.Coastal resilience

Period	Maria			Post Maria		
Site	L	2015-sep/oct 2017	S/L	sep/nov 17-nov/jan 18	S/L	E
Mahaut	1110	15649	14	-4355	-4	-27,8 %
N1 beach	390	-9573	-25	5190	13	54,2 %
Fond St Jean	960	13719	14	-4440	-5	-32,4 %
Grand bay	1430	19626	14	-6529	-5	-33,3 %
Pointe Mulâtr e	1520	20213	13	-5150	-3	-25,5 %
Colihaut	480	4939	10	1504	3	30,5 %
Petite Savanne	130	8952	69	-344	-3	-3,8 %
Ports-mouth/? Bay	4920	-64110	-13	16183	3	25,2 %
Mean	1368	1177	12	-1765	0	-24,6 %

From left to right : Figure 14 - Maria and Post Maria sediment balances in the studied sites (L is the length of the sediment cell, S/L is the evolution surface related to the length of the cell (expressed in m^2 per linear meter) - Figure 15 - Post Maria coastline adjustments in Fond Saint Jean - Figure 16 - Post Maria adjustments on Lagoon beach, Portsmouth (BATTUT, 2019)

8. Conclusion

Paroxystic events like hurricane Maria are able to disrupt coastal morphological equilibria and set a new one that is different from the previous one. Impacts are strongly related to the coast morphological settings and to human occupation. In dominica, extreme sedimentation processes mainly implied significant accretion on coastal systems. Longer observations (several years after the event) would allow to determine if these tendancies will be sustained. Some indicators show that coasts tend to restore previous morphological settings one year and a half after the event. This evolution depends on the next hurricane seasons and future events intensity.