Allá viene el temporal: Major hurricanes in Puerto Rico between 1851 and 2019

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Summary: *In 2017, Puerto Rico was impacted by two major hurricanes: Irma passed northeast of the island as a category-5 hurricane while María made landfall as a category 4. Two decades had passed since the island's residents had experienced the direct hit of a category-3 hurricane; almost no-one had experienced firsthand the impacts of hurricanes with the intensities of Irma and María. In this article we present an analysis of land-falling major hurricanes in Puerto Rico between 1851 and 2019. We describe and discuss such hurricanes in terms of their spatiotemporal characteristics, rapid intensification, and hits across the island. The information provided allows for broader knowledge, understanding, and discussion of exposure and associated vulnerability to cyclonic-related hazards in Puerto Rico, specifically, and the Caribbean region, more generally.*

Keywords
HURRICANES EXPOSURE INTENSIFICATION PUERTO RICO

Introduction

Temporal, temporal, allá viene el temporal.
Temporal, temporal, allá viene el temporal.
¿Qué será de mi Borinquen, cuando llegue el temporal?
¿Qué será de Puerto Rico, cuando llegue el temporal?

Excerpted lyrics from Puerto Rican folk song (plena)

This *plena* [genre of Puerto Rican music] was composed in commemoration of the passage of Hurricane San Felipe II, a category-5 hurricane that hit Puerto Rico in 1928. The catastrophic winds of this *temporal* [tropical cyclone] reached 265km/h and remained on land for at least 12 hours, leaving destruction and desolation after its passage (Castro-Rivera, 2018). Part of the Puerto Rican folklore, the *plena* reminds us that, while such extreme events are of low occurrence, the island and its residents are not exempt from experiencing them.

During the hurricane season of 2017, in a span of two weeks, Puerto Rico was impacted by two major hurricanes with similar intensities to those of San Felipe II: hurricanes Irma and María. Hurricane Irma passed at about 70km northeast of Puerto Rico as a category-5 hurricane on September 6, while Hurricane María made landfall on September 20 as a powerful category 4, with winds of 249km/h. Hurricane Irma caused damage, loss of lives and property, and interruption of basic services (water, electricity, and communications) in many municipalities of Puerto Rico (Cangialosi *et al*., 2018). Hurricane María, however, caused massive destruction across the entire island and exacerbated the impacts previously caused by Hurricane Irma. María's trajectory, from southeast to northwest, along with its intense winds and rainfall (Ramos-Sharrón & Arima, 2019), resulted in the collapse of telecommunications, the lack of basic services such as water and electricity for months (even a year in some places), the collapse of roads, the destruction of houses, agricultural losses, floods, landslides, changes in the landscape (and its forests and vegetation), and changes to coastal geomorphologic features, among others (Barreto-Orta *et al*., 2019; Lugo, 2019; Kwasinski *et al*., 2019; Pasch *et al*., 2019). Between 3,000 and 5,000 people were estimated to have died as direct and indirect consequence of the hurricane (George Washington University, 2018; Kishore, *et al*., 2018). Hurricanes Irma and María occurred within a context of dire economic and social conditions resulting from decades of economic recession, austerity measures imposed by the US Government, and poor infrastructure and provision of basic services (Benach *et al*., 2019). Such conditions certainly affected preparedness and recovery and, ultimately, amplified the disasters' impacts.

Prior to 2017, it had been almost two decades since Puerto Rico had experienced the direct hit of a major hurricane (category-3 Hurricane Georges in 1998), and nearly 90 years since it had been hit by the aforementioned Hurricane San Felipe II. Many are the historical, social, human, economic, political, and institutional factors that explain why hazards become disasters (Wisner *et al*., 2012); this was evident in Puerto Rico with hurricanes Irma and María. Knowledge and awareness about hazards and disasters constitute part of the human resources necessary to deal with them (Smit & Wandel, 2006; Wisner *et al*., 2012). Regarding the 2017 season, it was common to hear people on the island saying how inexperience with, and lack of knowledge about, major hurricanes constituted, among many other things, a limitation to preparedness.

Objectives

In this article we present an analysis of land-falling major hurricanes in Puerto Rico during a 169-year period, from 1851 to 2019. A major hurricane is one classified as category 3 or higher on the Saffir-Simpson scale (NOAA, 2019a). We summarize the spatio-temporal characteristics of the hurricanes, determine and describe processes of rapid intensification experienced previous to their landfall, and provide the results of a spatial analysis of hits across municipalities once the hurricanes were passing over the island. Before presenting the methods and findings of the study, we provide an overview of major hurricanes in the Atlantic basin and the insular Caribbean during the 169-year study period; Puerto Rico, of course, is situated within that regional context.

This article adds to other resources that provide hurricane-related information and their impacts from a historical perspective in Puerto Rico (e.g., Ramírez de Arellanos, 1932; Salivia, 1972; Quiñones, 1992; Colón-Torres, 2009; Miner-Sola, 2010; Caldera-Ortiz, 2017; Schwartz, 2018). In our case, however, we only address exposure: one element of vulnerability related to characteristics such as magnitude, frequency, duration, and areal extent of hazards that create perturbations (Adger, 2006). Exposure is also associated with biophysical vulnerability (Brooks, 2003), and although the article does not discuss specific factors influencing social vulnerability to cyclones, the information provided allows for a broader knowledge, understanding, and discussion of vulnerability to cyclonic-related hazards in Puerto Rico, specifically, and the Caribbean region, more generally.

Major hurricanes in the Atlantic basin and landfalls in the insular Caribbean: A brief overview

Based on our analysis of compiled National Oceanic and Atmospheric Administration [NOAA] tropical cyclone tracks for the Atlantic basin from 1851 to 2019, a total of 1,614 tropical storms and hurricanes developed within the basin, 317 of which became major hurricanes at some point during their trajectory (López-Marrero & Castro-Rivera, 2019a). In 137 of the 169 analyzed hurricane seasons, there was at least one cyclone per season that developed into a major hurricane. The hurricane season with the highest number of major hurricanes was that of 1961 (with 7 hurricanes), followed by the seasons of 1926, 1933, 1950, 1964, 1996, 2004, and 2017, with 6 major hurricanes in each case. On the other hand, the seasons of 1930, 1961, 1894, and 1926 had the highest percentages of major hurricanes (more than half of the cyclones): 67percent, 64percent, 57percent, and 55percent, respectively.

In 54 of the 169 hurricane seasons, at least one major hurricane made landfall in at least one country of the insular Caribbean (López-Marrero & Castro Rivera, 2019a). In fact, of the 317 major hurricanes in the Atlantic basin, 62 made landfall on various Caribbean islands as major hurricanes. The islands that received the most major hurricane landfalls were Cuba (25 hurricanes: thirteen category 3, ten category 4, and two category 5), the Bahamas (20 hurricanes: ten category 3, eight category 4, and two category 5), and Puerto Rico (nine hurricanes: five category 3, three category 4, and one category 5) (Figure 1).

While category 4 and 5 hurricanes are the ones that least frequently occur, six seasons and eleven hurricanes have been particularly notable in the Caribbean region since 1851 (López-Marrero & Castro-Rivera, 2019a). In 1926, three major hurricanes directly hit Cuba and the Bahamas: one hit Cuba (category 4), while all three hit the Bahamas (one as category 3 and two as category 4). Two years later, in 1928, a major hurricane (known in Puerto Rico as San Felipe II) hit four island groupings as category 4 or 5: Guadalupe (category 4), Puerto Rico (category 5), Turks and Caicos (category 4), and the Bahamas (category 4). In 1932, three hurricanes hit three territories with winds of such magnitudes: the Bahamas (category 5), Puerto Rico (category 4), and Cuba (

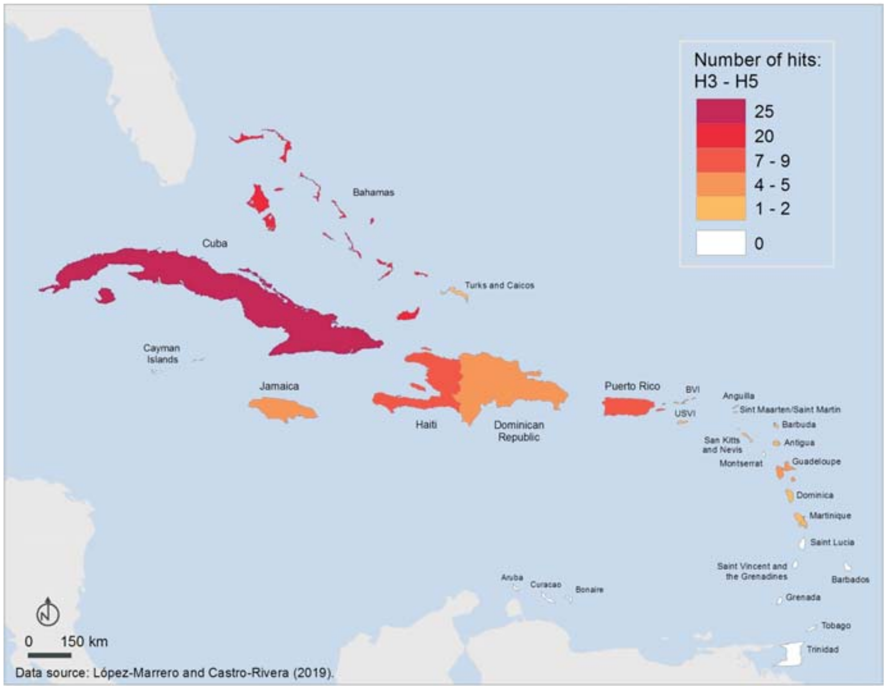

FIGURE 1: Major hurricane hits in the insular Caribbean by country, 1851–2019.
(Colour figure available on the article's digital version)

category 4). In 1979, Hurricane David hit Dominica (category 4), the Dominican Republic (category 5), and Haiti (category 4).

More recently, the 2017 and 2019 hurricane seasons have been highlighted as extraordinary in terms of both meteorological standards and socio-economic impacts. In 2017, the passages of hurricanes Irma and María made that season unique for the Caribbean, and the Atlantic basin more generally (Ngenyam-Bang *et al*., 2019). Irma hit four island groupings as a category 5 hurricane: Barbuda, Sint Maarten/Saint Martin, the British Virgin Islands, and Cuba. Hurricane María, in contrast, directly struck Dominica as category 5 and Puerto Rico as category 4 (very close to category 5). Rarely have two category 4 or 5 hurricanes made landfall in the region in the same year (with the exceptions of 1926 and 1932, as previously described). At the time, Hurricane Irma was the strongest hurricane in the Caribbean Sea on record (with winds of 298 km/h, which was close to the record of 306km/h set in 1969 by Hurricane Camille and in 1980 by Hurricane Allen in the Atlantic basin). In addition, Irma was the strongest hurricane to hit the Leeward Islands (Ngenyam-Bang *et al*., 2019). The 2017 season was also characterized by major back-to-back hurricanes in the region: Irma, José, and María. Two years later, during the 2019 season, another category-5 hurricane, Dorian, directly impacted the Bahamas (specifically Abaco and Grand Bahamas), where it remained stationary for about 24 hours. Dorian reached winds of 298 km/h, thus matching Irma's record, but it possessed a lower atmospheric pressure (910 mb; 4 units less than Irma). Hurricanes of these two seasons caused massive destruction and devastation, loss of life and property, disruption to daily lives and well-being, major economic damages in cases setting back years of economic development, and unprecedented human displacements in the Caribbean region (Sullivan, 2017; Cangialosi *et al*., 2018; Hinojosa & Meléndez, 2018; Ngenyam-Bang *et al*., 2019; Pasch *et al*., 2019; Thomas & Benjamin, 2019).

Data compilation and analysis

We compiled tropical cyclone tracks for the Atlantic basin between 1851 and 2019 using the Hurricane Research Division database [HURDAT] and the Historical Hurricane Tracks dataset, both part of the National Oceanic and Atmospheric Administration (NOAA, 2019b & NOAA, 2019c). We used the year 1851 as a starting point because the two sources provide data from that year onward. These sources are commonly used to summarize cyclone activity and spatio-temporal patterns of occurrence (e.g., Zandbergen, 2009; Ortiz-Royero, 2012). The tracks were obtained in Geographic Information Systems [GIS] format and contained information on centre (eye) location, date (day, month, year), and wind intensity.

Using a GIS layer with the boundaries of Puerto Rico, we created a subset of these tracks to select the tropical storms and hurricanes whose centres passed over the island. Based on wind intensity information, we classified each cyclone according to its maximum category during its trajectory over the island according to the Saffir-Simpson hurricane scale. We created an additional subset containing the trajectories of hurricanes that made landfall on the island as major hurricanes. This dataset of major hurricanes was the one we used for analysis in the present article.

To determine if the hurricanes experienced rapid intensification, we calculated wind speed changes for each hurricane along its trajectory prior to landfall. For this, we examined data points provided by the NOAA dataset (NOAA, 2019c), consisting of periods of 6-hour intervals, until reaching a total of 24 hours. Rapid intensification is defined as an increase in maximum sustained winds of a tropical cyclone of at least 30 knots (56km/h) in a 24-hour period or less (NOAA, 2019a). If the sum of the magnitude of wind change was greater than or equal to 30 knots in 24 hours or less, then the hurricane was noted as experiencing rapid intensification. In such cases, the magnitude of the intensification was also noted, both in terms of changes in wind speed and category in the Saffir-Simpson scale. Additionally, the coordinates of the 'end point' where the intensification occurred were recorded. With this, we are not suggesting that intensification happens at a specific point. Based on the data used, the specific location where intensification takes place along 6-hour interval segments is not possible to determine. We decided to record the location where the rapid intensification was completed. With the coordinates of this end point, and the coordinates of the point of landfall of each hurricane, we calculated an estimate of the linear distance of each intensification relative to the island.

To calculate the number of hits at the municipal level, the GIS trajectories (line format including hurricane category information) for each major hurricane were imposed on the GIS layer containing the boundaries of Puerto Rico's municipalities (polygon format). For the purpose of this article, a 'hit' is used interchangeably with landfall and occurred when the centre (eye) of a hurricane moved through a municipality. In a GIS environment, and as obtained from the NOAA database, the trajectory (line) of a hurricane, in turn, is defined by connecting the points where the hurricane centre was estimated to have passed. Our definition for 'hit' is similar to the definition of 'hit' in Zandbergen's (2009) analysis of hurricane and tropical storm hits in the United States at the county level. Puerto Rico is composed of 78 municipalities, which constitute the second-order administrative division at which emergency management (including cyclone response) takes place. Municipalities are, however, the first responders in the case of disasters, hence the decision of selecting such scale of analysis. We are aware of the margin of error of hurricane tracks and associated GIS data; however, the analysis is based on the best available historical records and information and is useful for identifying regional patterns within the island, which is our interest.

Results and discussion

Major hurricanes in Puerto Rico

A total of 32 cyclones made landfall in Puerto Rico between 1851 and 2019. Of the 32 cyclones, nine were major hurricanes: five were category 3, three were category 4, and one was category 5. Four of these hurricanes (San Ciriaco, San Felipe II, Georges, and Hugo) originated in the Atlantic Ocean, while the remaining five originated closer to the Caribbean Sea (Figure 2). Of the four originating in the Atlantic, three did so close to the coast of West Africa: San Felipe II, Hugo, and Georges. Tropical cyclones that originate at such locations in the Atlantic Ocean (close to the coast of Africa) tend to be large, intense, and damaging storms; their passages over warm and open waters are favourable conditions for their development. Hurricane San Felipe II in 1928, for instance, originated as a tropical depression on the coast of Senegal. It became a category 4 hurricane at its landfall on Guadeloupe and continued its trajectory through the Caribbean as a major hurricane, making landfall on three other island groupings (Puerto Rico, category 5; Turks and Caicos Islands, category 4; and the Bahamas, category 4) and causing devastation throughout the region (Salivia, 1972; López-Marrero & Castro-Rivera, 2019a).

Once making landfall, most of the hurricanes (eight of the nine) moved through the entire island; their trajectories from southeast to northwest or from east to west were of impact throughout the territory. One of the hurricanes, Hugo, moved through the northeastern portion of the island. After landfall, three of the nine major hurricanes weakened to hurricanes of lower wind velocities: San Narciso (category 3 to category 1), San Felipe I (category 3 to category 2), and Georges (category 3 to category 2) (Figure 3). Multiple variables can influence changes in the intensity of a tropical cyclone while it is

FIGURE 2: Trajectory of major land-falling cyclones in Puerto Rico. The hurricanes are identified by number and named as known locally (up to the hurricane of 1932): 1. San Narciso (1867); 2. San Felipe I (1876); 3. San Roque (1893); 4. San Ciriaco (1899); 5. San Felipe II (1928); 6. San Ciprián (1932); 7. Hugo (1989); 8. Georges (1998); 9. María (2017).
(Colour figure available on the article's digital version)

encountering land, including, for example, changes in environmental conditions that fuel the system and maintain its structure, like lack of moisture and heat (Castro-Rivera & López-Marrero, 2018). Two hurricanes (San Roque and María) became non-major hurricanes right after leaving the island, while four (San Ciriaco, San Felipe II, San Ciprián, and Hugo) continued as major hurricanes over the island and upon leaving it. Small land size and hurricane intensity itself might influence the latter tendency. Regarding land mass size and distance from coast, however, some major hurricanes in the United States hit far inland counties; that is, those hurricanes did not diminish in strength until far inland (Zandbergen, 2009). Each atmospheric system and the environmental conditions that influence its development are, however, unique and should be analyzed individually.

The geographic position of Puerto Rico within the Atlantic basin exposes it to tropical cyclones from June through November; however, most of the major hurricanes hit the island in August and September: two in August and six in September. Hurricane San Narciso, in contrast, made landfall on October 29, the latest landfall date of all the major hurricanes on record that have hit Puerto Rico. In terms of interval of arrival, the shortest interval between two major hurricanes was four years, between Hurricane San Felipe II in

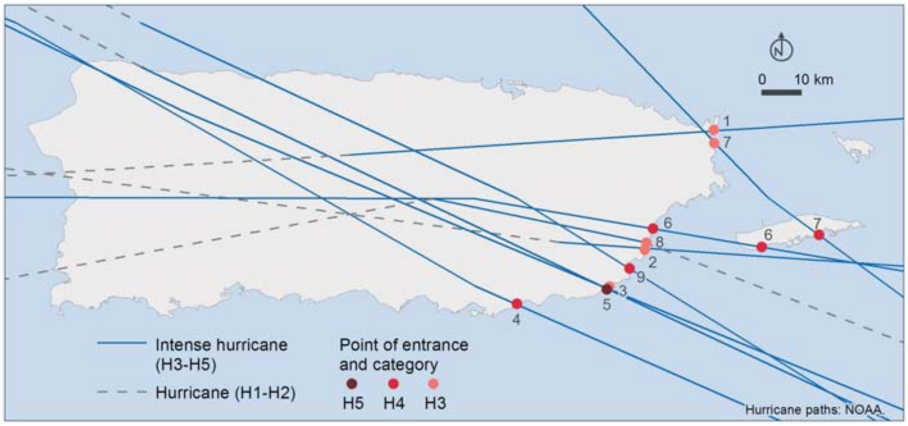

FIGURE 3:Point of entrance, hurricane intensity, and trajectory of major land-falling cyclones in Puerto Rico. The point of entrance of each hurricane is identified by number: 1. San Narciso (1867); 2. San Felipe I (1876); 3. San Roque (1893); 4. San Ciriaco (1899); 5. San Felipe II (1928); 6. San Ciprián (1932); 7. Hugo (1989); 8. Georges (1998); 9. María (2017).
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1928 and Hurricane San Ciprián in 1932; while the longest interval was 57 years, between hurricanes San Ciprián (1932) and Hugo (1989).

Cyclone rapid intensification

All of the major hurricanes that hit Puerto Rico during the study period experienced rapid intensification prior to making landfall. Most of the cyclones manifested this intensification in the Caribbean Sea (Figure 4), rising as much as four units in the Saffir-Simpson scale. This was the case of Hurricane María, which intensified from a category-1 to a category-5 hurricane prior to its landfall on the island (Table 1).

Hurricane San Narciso (1867) is the first major hurricane on record to show rapid intensification; its intensification of 74km/h, from tropical storm to category-3 hurricane, occurred at approximately 389km east-northeast of its point of landfall in northeastern Puerto Rico (Figure 4 and Table 1). Hurricane María had the greatest magnitude of intensification, from a category 1 to a category 5, with an increase of its sustained winds of 130km/h at about 594km southeast of Puerto Rico. Meanwhile, Hurricane San Roque (1893) underwent rapid intensification closest to the island. It intensified from a category 1 to a category 3 at about 113km southwest of Puerto Rico, impacting it with winds of such magnitude. Hugo (1989), in contrast, experienced the most distant rapid intensification, at about 1,221km to the southeast of the island. It intensified from a category 2 to a category 5, with a subsequent decrease in sustained wind prior to making landfall on the island-municipality of Vieques as a category 4, and later on the main island as a category

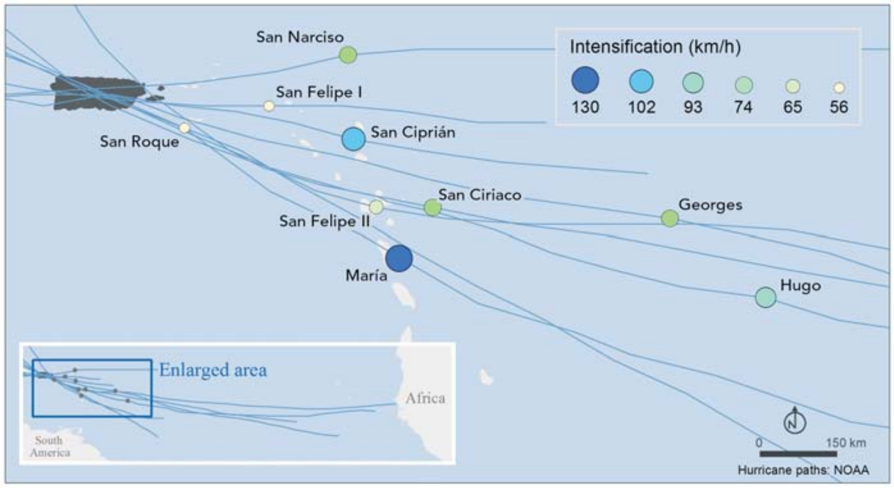

FIGURE 4: Magnitude of intensification of major land-falling cyclones in Puerto Rico. The points show the location where the rapid intensification was completed; this is, the 'end point' of the intensification process. (Colour figure available on the article's digital version)

TABLE 1: Summary of rapid intensification characteristics of major land-falling cyclones in Puerto Rico

Hurricane	Year	Intensification (km/h)	Change in category*	Distance from Puerto Rico (km)
San Narciso	1867	74	TS to H3	389
San Felipe I	1876	56	H1 to H3	254
San Roque	1893	56	H1 to H3	113
San Ciriaco	1899	74	H1 to H4	631
San Felipe II	1928	65	H2 to H4	510
San Ciprián	1932	101	TS to H3	393
Hugo	1989	93	H2 to H5	1,221
Georges	1998	74	H2 to H4	1,043
María	2017	130	H1 to H5	594

NOTE: TS = Tropical storm, H = Hurricane.*

3. The case of Hugo demonstrates that rapid intensification does not necessarily imply a more intense impact on a territory; impact depends, among other things, on the distance at which the intensification occurs and the atmospheric conditions that the system encounters during its trajectory.

When rapid intensification occurs, a cyclone that was, for example, a tropical storm can become a major hurricane in a period of 24 hours or less (as was the case of San Narciso and San Ciprián) or intensify its winds by more than 100km/h (as happened with San Ciprián and María). Moreover, while some systems intensify through their trajectories across the open waters of the Atlantic Ocean (in the case of the Atlantic basin), some undergo rapid intensification closer to a territory (as was the case of Puerto Rico with San Roque and San Felipe I). Typically, systems that undergo rapid intensification are associated with high rates of forecast error (Bhatia *et al*., 2019). Cyclones that intensify rapidly are more challenging in terms of forecasting and preparedness. Additionally, more intense hurricanes could result in systems that are more resistant to local conditions that could otherwise decrease their strength. All of these situations can result in greater amounts of damage and loss, and more challenging hazard management and disaster response, heightening, ultimately, peoples' vulnerability.

While our results show that rapid intensification has occurred in hurricanes as long ago as San Narciso in 1867, it appears that the magnitude of such intensifications might be increasing, as has been shown by several recent hurricanes locally in the Caribbean region (as was the case of Hurricane María in 2017), and more widely in the Atlantic basin (as were the cases of the hurricanes Irma in 2017 and Michael in 2018). Some studies, in fact, show that the magnitudes of intensifications have increased during the last three decades in some regions of the Atlantic basin (Balaguru *et al*., 2018), while others suggest that the number of storms that intensify rapidly could increase substantially by the end of the 21st century (Emanuel, 2017). The intensity and intensification of hurricanes are influenced by a variety of factors operating at various scales. However, more and more studies are pointing to the possible association of more frequent major hurricanes and higher magnitudes of intensification to warmer sea temperatures and anthropogenic-induced climate change (e.g., Bathia *et al*., 2018; Murakami *et al*., 2018; Bathia *et al*., 2019).

Major hurricane hits by municipality

More than half (50 out of 78) of the municipalities of Puerto Rico were hit by a major hurricane at least once during the study period (Figure 5). The municipalities of the interior of the island reported the greatest number of hits, the municipality of Ciales having received the greatest number (6 hits). The remaining 28 municipalities did not have a direct hit by a major hurricane, particularly those on the southwestern portion of the island.

While major hurricanes have generally made landfall in the coastal municipalities in southeastern Puerto Rico, interior municipalities have been more exposed. In addition to receiving the hits of hurricanes moving from southeast to northwest, they also receive the direct impact of hurricanes moving east to west. Moreover, while coastal, low-lying areas receive the first hit by the storms and experience the combined effects of strong

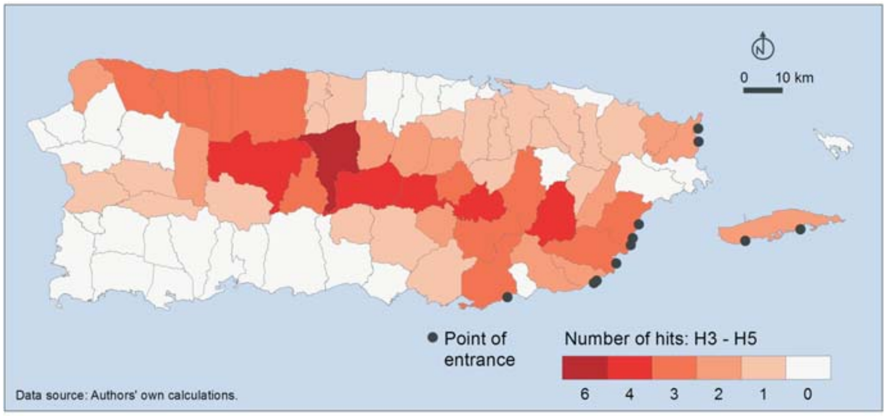

FIGURE 5:Major hurricane hits by municipality, 1851–2019. (Colour figure available on the article's digital version)

winds, storm surge, and flooding, interior municipalities possess several characteristics that make them and their residents highly vulnerable as well. In terms of physical environmental conditions, for instance, high elevations and steep topography make them more susceptible to landslides (Bessette-Kirton *et al*., 2019), while higher elevations can also receive the impact of stronger winds and gusts. In the case of Hurricane María, the National Hurricane Center noted in its final report that wind gusts of category-5 intensities were possibly recorded in higher elevations (Pasch *et al*., 2019).

The socio-economic status of interior municipalities also results in high vulnerability. Compared to coastal municipalities, interior municipalities tend to have higher poverty rates and higher proportions of the elderly and population with disabilities which have particular needs (Padilla-Elías *et al*., 2016; Centro de Información Censal, 2017; López-Marrero & Cámara-Torres, 2019). Also, many interior municipalities and their communities are at a longer distance from major cities and services, which influences their access to goods and services for disaster preparedness and recovery. After Hurricane María, for instance, the length of time without basic services such as water and electricity in 'remote' areas was longer than in areas closer to major cities (Kishore *et al*., 2018). Preexisting social, economic, and human conditions and inequalities limit people's capacities to deal with hazards and disasters; these conditions result in varying vulnerabilities and impacts to disasters (López-Marrero & Wisner, 2012). In the case of Puerto Rico with the passage of Hurricane María, such unequal impacts were evident (García-López, 2018).

The western portion of the island (particularly the southwestern region) received fewer hits by major hurricanes; in some cases, no direct hits. This historical pattern could create a false sense of security by residents and managers of such municipalities, or a tendency to minimize the potential impacts of a major hurricane. Unusual hurricane trajectories (e.g., west to east), including those of major hurricanes could and have happened, as was the case of Hurricane Lenny (1999), which passed as a major hurricane south of Puerto Rico. We must remember, additionally, that exposure and vulnerability are not determined solely by hurricane track and direct hits (the 'eye' of the storm). While areas near the eye are characterized by severe meteorological conditions of great cloudiness with intense rainfall and winds, the whole area of the system must be considered regarding potential impacts. The different quadrants of hurricanes are typically associated with certain atmospheric conditions. For instance, the most violent winds are typically located in the left front quadrant, while the right front quadrant can produce torrential rains and very strong winds (Castro-Rivera & López-Marrero, 2018). Lastly, we cannot forget the non-land-falling cyclones, which can and have caused great damage and impacts (López-Marrero & Castro-Rivera, 2019b).

Concluding remarks

Between 1851 and 2019, nine major hurricanes made landfall in Puerto Rico. All of these hurricanes underwent rapid intensification prior to landfall and six of them retained their strength as major hurricanes throughout their passage over the island. Rapid intensification events have occurred since the beginning of the record keeping used in this analysis, but the frequency and magnitude of such intensifications might be increasing according to some studies. For instance, Bathia *et al*. (2018), Murakami *et al*. (2018), and Bathia *et al*. (2019) suggest that warmer sea temperatures and associated climate change may produce more intense hurricanes and cyclones with higher probabilities of undergoing rapid intensification. Under such circumstances not only might we have more frequent intense hurricanes, but also ones that are more resistant to local conditions that could, otherwise, decrease hurricanes' intensity after landfall. These possibilities pose many challenges for forecasting and preparedness, and could result in catastrophic disasters. The warming Caribbean is not an exception (Taylor *et al.*, 2012; Burgess *et al*., 2018). Hence, the need to prepare for scenarios of more extreme events, some of them at short notice, is crucial.

We must be aware of and plan for the various atmospheric hazards we are exposed to, not only the intense and extreme ones. While certainly major hurricanes have been catastrophic in Puerto Rico and elsewhere, those of lower magnitudes and different trajectories (including the non-land-falling cyclones) have also had significant impacts. Hence, we underscore the importance of considering all types of cyclonic hazards when promoting preparedness measures and developing management plans in Puerto Rico, other countries in the Caribbean, and other regions exposed to cyclones. Finally, we stress that not all geographic areas and populations are similarly exposed; nor are they equally vulnerable to cyclonic-related hazards. To understand and attend to vulnerability we need to incorporate those elements associated with exposure and those associated with the human and social conditions that mediate social vulnerability and amplfy disaster impacts.

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