Evidence for higher tropical storm risks in Haiti due to increasing population density in hazard prone urban areas

Christian D Klose

Think Geohazards, 205 Vernon Street, Suite A, Roseville, CA 95678, USA

E-mail: christian@cdklose.com

Received 25 March 2011
Accepted for publication 4 November 2011
Published 29 November 2011
Online at stacks.iop.org/ERL/6/044020

Abstract
Since the 18th century, the Republic of Haiti has experienced numerous tropical cyclones. In 2011, the United Nations Global Assessment Report on Disaster Risk Reduction outlined that the worldwide physical exposure to natural hazards, which includes tropical storms and hurricanes in Haiti, increased by 192 per cent between 1970 and 2010. Now, it can be hypothesized that the increased physical exposure to cyclones that made landfall in Haiti has affected the country’s development path. This study shows that tropical storm risks in Haiti increased due to more physical exposure of the population in urban areas rather than a higher cyclone frequency in the proximity of Hispaniola island. In fact, the population density accelerated since the second half of the 20th century in regions where historically more storms made landfall, such as in the departments Ouest, Artibonite, Nord and Nord-Ouest including Haiti’s four largest cities: Port-au-Prince, Gonaïves, Cap-Haïtien and Port-de-Paix. Thus, urbanization in and migration into storm hazard prone areas could be considered as one of the major driving forces of Haiti’s fragility.

Keywords: tropical storm, cyclones, risk, exposure, vulnerability, fragility, Haiti, population

1. Introductory paragraph

The Republic of Haiti is situated on Hispaniola, a Caribbean island in the West Atlantic. It is one of the most vulnerable, fragile and least developed countries in the world with a human development index (HDI) ranking at 149 of 182 (values as of 2009) [1]. More than two-thirds of its population lives on less than two US dollars per day [1]. Its prevalent vulnerability index (PVI) ranged from 20–40% higher than the median of all Latin American countries [2]. Given these facts, one could hypothesize that increasing hazards risks due to tropical cyclones may have contributed to the country’s fragility. This research study, however, shows evidence that the physical exposure of the Haitian population to tropical cyclones can be considered as one factor of Haiti’s fragility, where today the most densely populated regions of Haiti are more exposed to tropical storms than less populated parts of the country.

2. Frequency of tropical cyclones

On average, Haiti is exposed to one tropical storm or hurricane every other year, which makes direct landfall on Hispaniola island. Moreover, annual or decadal frequencies of these storms tend to remain constant in Haiti’s proximity (figure 1) or further north in the Gulf of Mexico [3, 4]. Figure 1 also shows that hurricane intensities (i.e., category 3–5) have tended to increase since the 19th century, but without statistical significance. The few data points do not allow for any statistical significance testing.

Between 1850 and 2009, 72 tropical storms and hurricanes hit Hispaniola island, while 36 storms made landfall on the territory of Haiti (table 1). The country’s nine departments were differently affected due to the geographical distribution of the storm tracks. First, more than 50% of the storms passed Hispaniola island from west to east following (a) coastline extensions in the north and south and (b) topographic
Table 1. Departments of Haiti including their area, population size, number of observed storms that made landfall on Haiti’s territory between 1850 and 2009, the relative storm hit rate/frequency in comparison to all 72 observed storms that made landfall on Hispaniola island (see the appendix) and number of hospitals, health centers and dispensaries.

| Provinces          | Area km² | 1887 | 1919 | 1950 | 1982 | 2009 | Storms (1850–2009) | Hit rate % | Hospitals |
|--------------------|----------|------|------|------|------|------|--------------------|------------|-----------|
| Nord               | 2175     | 102  | 173  | 295  | 564  | 970  | 13                 | 0.18       | 53        |
| Ouest              | 4827     | 214  | 360  | 662  | 1552 | 3665 | 22                 | 0.31       | 209       |
| Center             | 3675     | 105  | 177  | 407  | 362  | 679  | 17                 | 0.24       | 44        |
| Sud                | 2794     | 86   | 146  | 255  | 503  | 705  | 11                 | 0.15       | 69        |
| Artibonite         | 4984     | 134  | 226  | 567  | 733  | 1571 | 23                 | 0.32       | 84        |
| Nord-Ouest         | 2176     | 39   | 74   | 168  | 294  | 663  | 18                 | 0.25       | 61        |
| Nord-Est           | 1805     | 85   | 143  | 244  | 190  | 358  | 11                 | 0.15       | 25        |
| Grand’Anse, Nippes | 3237     | 100  | 170  | 295  | 490  | 737  | 9                  | 0.13       | 55        |
| Sud-Est            | 2077     | 64   | 109  | 189  | 368  | 575  | 19                 | 0.26       | 35        |

* Data source: Almanach de Gotha [8].
* Data source: Institut Haïtien de Statistique et d’Informatique.
* Data source: Pan American Health Organization, 2000 data.

Figure 1. Frequency of tropical storms (TS) and hurricanes (H) that were observed in Hispaniola island’s proximity between 1850 and 2009 (longitude: 68–77; latitude: 16–22). Frequencies are plotted for each event group (TS, category H1–H5) observed during the periods 1850–99, 1900–49 and 1950–2009. (Source data: US National Oceanic and Atmospheric Administration.)

depressions, e.g., the plain of the cul-de-sac in the south of Haiti. This depression lies partially below sea level with Port-au-Prince, Haiti’s capital, at its western opening to the sea. Second, storms are more likely to hit flood planes, departments of lower elevation and with frequencies (hit rates) of >25% (e.g., Artibonite and Ouest). Third, departments in windward exposed mountainous regions are characterized by storm frequencies between 15–25% (e.g., Nord and Nord-Ouest). Eastern storms are less likely to make landfall in departments in leeward mountainous regions (e.g., Grand’Anse and Nippes). Here, storm frequencies do not exceed 15%.

3. Physical exposure of Haitians to storm hazards

In 1804, Haiti gained independence, while the Republic of France gave up its claims to its colony Saint Domingue. Since then, Haiti’s population has grown from 431,140 inhabitants to almost 10 million in 2009 (table 1). After Haiti’s foundation as a Republic, large-scale plantations of the former French colony were destroyed and the land was divided into small-scale subsistence farms [5]. Since then, farm holders operated their parcels with respect to environmental conditions, including, e.g., precipitation, run-off and soil texture. Until the second half of the 20th century, most Haitians lived in rural areas, which developed a societal resilience to cope with natural forces.

Although the population of each department in Haiti has been continuously growing during the last 200 years, its density km⁻², however, became more unequally distributed throughout the country since the second half of the 20th century (see figure 2(A) and table 1). In comparison, departments were more uniformly populated during the 19th century and, thus, Haitians were at less risk from tropical storm hazards. In 1887, population densities of departments Artibonite and Nord-Ouest, where generally more storms make landfall, were in the lower percentiles of country’s population density distribution (figure 2). Specifically, the box plots of figure 2(A) show the population density distributions of all departments in Haiti for certain years, which changed from an approximately symmetric distribution of $0 < \gamma < 0.5$ between 1887 and 1950 to a highly positive skewed distribution of $\gamma > 1.0$ between 1982 and 2009. Southern departments Grand’Anse/Nippes and the departments Center and Nord-Est experienced smaller population growth between 1850 and 2009. The population density in departments Grand’Anse/Nippes increased by a factor of 4 and in Nord-Est by a factor of 7. In contrast, the population density increased 17-fold in department Ouest, with Port-au-Prince as its capital, and 12-fold in department Artibonite, with Gonaïves as its capital (figure 2 and table 1).

Today, Haiti is the most densely populated country (326 people km⁻²) and poorest nation in the western hemisphere. Among Latin American and Caribbean countries, Haiti has one of the highest fertility rates (4–5%), and infant mortality rates of about 50 infants dying before reaching one year of age per 1000 live births [6]. Almost every year, tropical storms make hundreds and thousands of Haitians homeless and
claim lives. Severe storms have resulted in human fatalities and caused socio-economic damage. Hurricane George destroyed more than 75% of all the crops in Haiti in 1998, which, in turn, affected the country’s food supply. Furthermore, the 2004 hurricane Jeanne killed about 3000 Haitians and caused damages in the city of Gonaïves. For three days, more than three-quarters of the city’s area were flooded. More recently, tropical storms Gustav and Fay directly affected more than 800,000 people (10%) in Haiti in August and September 2008 [7].

Haitians, particularly in departments Ouest and Artibonite, are at 2–4 times higher risk of tropical storm hazards than other departments and than before the year 1950. Urbanization and migration have become predominant factors since the 1950s, shaping today’s nonuniform population density distribution within the entire country. Today, half of the residents in Port-au-Prince are migrants and were not born there [5, 9]. Moreover, 40% of the population between the ages of 20–30 migrate into cities from their birth towns in rural areas, for instance, from Nord-Est with the highest poverty rate and the lowest hospital density per area in the country, including health centers and dispensaries (see table 1).

4. Conclusions

Today, Haitians, particularly in Port-au-Prince and Gonaïves, are at 2–4 times higher risk of hazards associated with tropical cyclones than in other regions of the country and than before the second half of the 20th century. Specifically, population growth rates have accelerated in storm hazard prone areas, e.g., due to urbanization and migration, in departments Ouest, Artibonite, North and North-Ouest. Thus, despite high frequencies of tropical cyclones that make landfall in all departments of Haiti, many inhabitants have settled in major cities and live with higher risk of storm hazards, including in Port-au-Prince, Gonaïves, Cap-Haïtien and Port-de-Paix. The population of these four major cities accounts for at least 30% of Haiti’s total number of inhabitants. Thus, it can be anticipated that Haiti’s high number of affected people during storm hazard events and the country’s fragility may result from the increasing population in regions exposed to high storm hazards. Therefore, new legal and educational measures are needed to regulate urbanization in and migration into major cities of Haiti. This includes nature protection policies.

Appendix. Data acquisition of tropical storms and hurricanes

Spatial and temporal data of storms that directly hit Hispaniola island between 1850 and 2009 were analyzed (table A.1). Storm catalog data were provided by the US National Oceanic and Atmospheric Administration (NOAA). To avoid biases due to decadal variations of storms passing Hispaniola island, the resulting frequencies of table 1 include only storms that made landfall on Hispaniola that were counted between 1850 and 2009. These frequencies were used in this comparative study with the population densities of each department (figure 2).

Table A.1. Departments of Haiti and the years in which an observed storm made landfall in a department. Storms are indicated by ‘XX for the year within a century, including multiple counts for multiple storms within the same year. (Source data: US National Oceanic and Atmospheric Administration.)

| Department        | 19th century | 20th century | 21st century |
|-------------------|--------------|--------------|--------------|
| Nord              | ‘52, ‘76, ‘78, ‘86, ‘87, ’99 | ‘00, ‘09, ‘10, ‘16, ‘31, ‘32, ‘33, ‘48, ‘48, ‘75, ‘79 | ’05          |
| Nord-Ouest        | ‘52, ‘55, ‘76, ‘78, ‘83, ‘87 | ‘00, ‘09, ‘16, ‘33, ‘38, ‘75, ‘79, ‘87 | ’88          |
| Nord-Est          | ‘52, ‘55, ‘76, ‘87, ‘99   | ‘16, ‘38, ‘48, ‘75, ‘79, ‘87, ‘88 |              |
| Center            | ‘51, ‘55, ‘76, ‘83, ‘99   | ‘00, ‘01, ‘09, ‘30, ‘38, ‘79, ‘79, ‘98 |              |
| Ouest             | ‘51, ‘67, ‘78, ‘83, ‘86, ‘94, ‘99 | ‘00, ‘01, ‘08, ‘09, ‘10, ‘48, ‘58 | ’05, ’07, ’08 |
| Artibonite        | ‘51, ‘55, ‘76, ‘78, ‘83, ‘86, ‘87, ‘94, ‘99 | ‘01, ‘09, ‘30, ‘38, ‘48, ‘49, ‘79, ‘79, ‘98 | ’05, ’07, ’07 |
| Sud               | ‘78, ‘86       | ‘31, ‘32, ‘33, ‘48, ‘66 | ’07, ’08      |
| Sud-Est           | ‘78, ‘78, ‘86, ‘94, ‘99 | ’08, ‘10, ‘31, ‘33, ‘49, ‘55, ‘66 | ’07          |
| Grand’Anse and Nippes | ‘67, ‘86   | ‘09, ‘33       |              |
Specifically, spatial data are categorized with respect to the nine Haitian departments/regions that are named and summarized in table A.1. In order to determine the annual storm frequency that hit a department in Haiti between 1850 and 2009, all observed storms were cumulated. This number was then divided by the total number of 72 storms observed during this period on the Hispaniola island, including the territory of the Dominican Republic.

References

[1] United Nations Development Programme 2009 Human Development Report 2009. Overcoming Barriers: Human Mobility and Development (New York: Palgrave Macmillan) (available at http://hdr.undp.org/en/media/HDR_2009_Complete.pdf, last accessed 11 November 2011)

[2] Inter-American Development Bank (IDB) 2009 Indicators of Disaster Risk and Risk Management, 2009 Summary Report (RG-T1579/ATN/MD-11238-RG) (Washington, DC: IDB)

[3] Webster P J, Holland G J, Curry J A and Chang H R 2005 Response to Comment on ‘Changes in tropical cyclone number, duration, and intensity in a warming environment’ Science 311 1713

[4] Webster P J, Holland G J, Curry J A and Chang H-R 2005 Changes in tropical cyclone number, duration, and intensity in a warming environment Science 309 1844–6

[5] Verner D and Egset W (ed) 2007 Social Resilience and State Fragility in Haiti (Washington, DC: World Bank) (doi:10.1596/978-0-8213-7187-9)

[6] Brea J A 2003 Population dynamics in Latin America Popul. Bull. 58 1–36 (available at www.prb.org/Source/58.1PopulDynamicsLatinAmer.pdf)

[7] United Nations Development Programme 2009 Focus on Haiti: Key Statistics (New York: UNDP) (available at www.undp.org/cpr/working/HT/Haiti08.shtml, last accessed 11 November 2011)

[8] Almanach de Gotha 1891 vol 128 (Gotha: Justus Perthes) p 1207 (available at www.archive.org/details/almanachdegotha1891goth)

[9] Institut Haïtien de Statistique et d’Informatique 2004 Haitian Society Today: A Socio-Economic Status Report from the Survey of Living Conditions in Haiti (ECVH) Interim Cooperation Framework Identification Exercise Meeting (Port-au-Prince, May 2004)