Received 10 May 2014
Revised 8 August 2014
Accepted 5 September 2014

RESEARCH PAPER

Hurricane Sandy mortality in the Caribbean and continental North America

Michalis Diakakis
Faculty of Geology and Geoenvironment, School of Sciences, National and Kapodistrian University of Athens, Athens, Greece
Georgios Deligiannakis
Mineralogy – Geology Laboratory, Department of Natural Resources and Agricultural Engineering, Agricultural University of Athens, Athens, Greece, and
Katerina Katsetsiadou and Efthymios Lekkas
Faculty of Geology and Geoenvironment, School of Sciences, National and Kapodistrian University of Athens, Athens, Greece

Abstract

Purpose – Tropical storms pose a significant threat to population despite the noteworthy improvements in forecasting and emergency management. Following the effects of Hurricane Sandy in the continental North America (USA and Canada) and the Caribbean, the purpose of this paper is to examine the mortality caused by the hurricane, focussing on differences in human vulnerability between these two regions.

Design/methodology/approach – The authors developed a database of 233 deaths, consisting of variables that provided a description of the circumstances under which the fatal incidents occurred and demographic details of the victims.

Findings – Analysis of the database showed higher percentages of female and young victims in the Caribbean than in continental North America, where mortality increased progressively with age and the ratio of males to females was higher. The majority of deaths occurred outdoors especially during clean-up and in vehicle crashes related to the storm. Physical trauma and drowning were identified as the most common causes of death, followed by carbon monoxide poisoning, hypothermia and others, although substantially different percentages were recorded between the two regions. Overall, indirect deaths presented a higher percentage than direct ones. Among the latter, incidents caused by storm surge and tree falls showed the highest numbers. Power failure and car crashes were the most common cause of indirect incidents.

Originality/value – The paper provides a thorough analysis of the circumstances under which fatal incidents occurred. It identifies parameters that affected the vulnerability of human life to the storm and discusses the differences between the Caribbean and continental North America.

Keywords Caribbean, Disasters, Continental North America, Fatalities, Hurricane Sandy, Natural hazards

Paper type Research paper

1. Introduction

Central and North America's east coast is one of the most hazardous tropical cyclone zones in the world (Blake *et al.*, 2011), sustaining extensive human losses and economic damages (Rappaport and Fernandez-Partagas, 1995; Hebert *et al.*, 1996; Rappaport, 2000; Pielke *et al.*, 2008; Blake *et al.*, 2011). Although related fatalities were found

Disaster Prevention and Management
Vol. 24 No. 1, 2015
pp. 132-148

0965-3562
DOI 10.1108/DPM-05-2014-0082

to present a general decreasing trend (Rappaport, 2000; Czajkowski *et al.*, 2011), during the last decade catastrophic tropical cyclones like Katrina (Brunkhard *et al.*, 2008; Jonkman *et al.*, 2009), Ike (Zane *et al.*, 2011), Ivan (Ragan *et al.*, 2008), Irene (Avila and Cangialosi, 2011), Rita (Zachria and Patel, 2006) and others have affected North America (Blake *et al.*, 2011) and the Caribbean (Pielke *et al.*, 2003) with disastrous effects on public health.

Literature discusses the short- and long-term consequences of hurricanes and associated phenomena to human health (Rappaport, 2000; Ahern *et al.*, 2005; Alderman *et al.*, 2012). Several works analyze hurricane- and flood-related mortality (Lew and Wetli, 1996; Rappaport, 2000; Brunkhard *et al.*, 2008; Philen *et al.*, 1992; Ragan *et al.*, 2008; Zane *et al.*, 2011; Yeo and Blong, 2010; French *et al.*, 1983; Jonkman and Kelman, 2005; Ashley and Ashley, 2008b; Zahran *et al.*, 2008), exploring factors that affect vulnerability of individuals, on a single-event (Chowdhurry *et al.*, 1993; Bern *et al.*, 1993; Staes *et al.*, 1994; Lew and Wetli, 1996; Jonkman *et al.*, 2009) or on a multiple-event basis (Rappaport, 2000; Ashley and Ashley, 2008a; Czajkowski *et al.*, 2011).

Regarding the age of the victims, most studies (Combs *et al.*, 1996; Bern *et al.*, 1993; Rappaport, 2000; Ragan *et al.*, 2008; Brunkhard *et al.*, 2008; Jonkman *et al.*, 2009) find a progressively increasing mortality rate with age. Philen *et al.* (1992), Bern *et al.* (1993) and Yeo and Blong (2010) found that very young individuals (younger than ten years old) show high mortality rates as well. This conclusion is consistent with the findings of Coates (1999), Fitzgerald *et al.* (2010) and Ashley and Ashley (2008b) for flood-related fatalities. Increased vulnerability in these age groups is attributed either to their physical inability to flee (Bern *et al.*, 1993) or the propensity for risk taking among the youthful (Coates, 1999).

Regarding the gender of the victims, most studies conclude that males show an increased representation (French *et al.*, 1983; Combs *et al.*, 1996; Lew and Wetli, 1996; Rappaport, 2000; Yale *et al.*, 2003; Ashley and Ashley, 2008b; Ragan *et al.*, 2008; Jonkman *et al.*, 2009) attributed to their involvement in riskier activities. However, Bern *et al.* (1993), Pradhan *et al.* (2007), Jonkman *et al.* (2009) and Yeo and Blong (2010) suggest that in certain cases, females are proved to be equally or even more vulnerable than males.

Regarding the activity of the victims at the time of the incident, it is suggested that a significant percentage of deaths caused by hurricanes and flooding are vehicle related (French *et al.*, 1983; Bern *et al.*, 1993; Staes *et al.*, 1994; Rappaport, 2000; CDC, 2000; Yale *et al.*, 2003; Drobot *et al.*, 2007; Ashley and Ashley, 2008a). An important portion of incidents occur indoors (Lew and Wetli, 1996; Jonkman *et al.*, 2009), during evacuation efforts (Lew and Wetli, 1996; Jonkman *et al.*, 2009), while repairing property or public utilities (Philen *et al.*, 1992) or while individuals are engaged in recreational activities (Rappaport, 2000).

The literature discusses a number of different etiologies of death. Drowning and physical traumas present the highest percentages (Combs *et al.*, 1996; Rappaport, 2000; Jonkman *et al.*, 2009; Czajkowski *et al.*, 2011) among hurricane-related fatalities. A significant amount of fatalities is associated with electrocution (Combs *et al.*, 1996; Philen *et al.*, 1992), carbon monoxide poisoning (Lew and Wetli, 1996; Ragan *et al.*, 2008), heart attacks (Combs *et al.*, 1996; Philen *et al.*, 1992; Jonkman *et al.*, 2009) and burns (Ragan *et al.*, 2008).

Rappaport (2013) suggests that storm surge is the most dominant cause of fatal incidents, although previous research highlighted an increasing trend of freshwater-related fatalities after 1970 (Rappaport, 2000; Czajkowski *et al.*, 2011). However, Hurricane Katrina was a notable exception of this trend (Jonkman *et al.*, 2009). Deaths due to rough seas have seen a reduction mainly due to improvements in

forecast and evacuation procedures (Philen *et al.*, 1992). Fatal incidents caused by excessive winds and storm induced landslides are also acknowledged in the literature (Rappaport, 2000; Yeo and Blong, 2010). Indirect deaths caused by car crashes (Combs *et al.*, 1996; Lew and Wetli, 1996; Yale *et al.*, 2003), falling trees (Rappaport, 2000; Schmidlin, 2009), falls from height (Combs *et al.*, 1996) occurring during repair works or disaster clean-up efforts (Combs *et al.*, 1996) have been also recorded. An important portion of fatalities includes deaths connected with cardiovascular incidents and other medical conditions (Combs *et al.*, 1996; Lew and Wetli, 1996). Finally, several cases are connected to hurricane disaster-related suicides (Lew and Wetli, 1996; Ragan *et al.*, 2008).

From 23 October to 31 October 2012 the late-season tropical system "Sandy" developed in the west Atlantic and traveled through the Caribbean, hitting the Bahamas, Cuba, Jamaica, Puerto Rico, the Dominican Republic and Haiti. The system progressed northwards toward the eastern seaboard of the USA and was steered inland due to an interaction with an upper-level low (Molthan and Jedlovec, 2013). The system then progressed inland with its center passing north of Atlantic City, NJ, inducing extensive damages and numerous fatalities across its course. Although preventive measures were put in place and early warning was issued, the hurricane had a severe impact on public health.

The objective of this paper is to develop a systematic record of fatalities caused by Hurricane Sandy, to examine the conditions under which fatal incidents occurred, focussing on possible differences between the Caribbean and the continental North America.

2. Data and methods

2.1 Data

Given the lack of an official systematic record summing up all fatalities induced internationally by Hurricane Sandy, data for this work were collected by a variety of sources (Table I). Apart from information contained in the official records of each country, additional information from international organizations, the press and local authorities (e.g. police sources) had to be collected, in order to develop a systematic record with adequate details. In total, 379 reports and descriptions of fatal incidents were retrieved from official sources and 321 from the press (Table I). To determine that a fatality was related to Hurricane Sandy, apart from the information given by the official sources, the description of each incident was studied in detail. A fatality was included in the database only if it was caused by the actual physical forces of the disaster or their direct consequences, or by certain unsafe or unhealthy conditions, displacement, property damage, personal loss or stress, loss or disruption of services that were created by these forces, based on the criteria set by Combs *et al.* (1999) for disaster fatalities.

2.2 Methodology

In accordance with the approach proposed by Legome *et al.* (1995), Jonkman and Kelman (2005) and used by several other authors (e.g. Rappaport, 2000; Jonkman *et al.*, 2009), a database was developed to link all available information on each fatal incident. The database included all deaths that were directly or indirectly attributable to the storm. Long-term health effects caused by Hurricane Sandy were not examined in this work due to lack of available data. Each entry of the database corresponded to one

Country	Sources	No. of fatalities retrieved	No. of fatalities reported in more than one sources
Bahamas	RBPF (2012b)	1	1
	RBPF (2012a)	1	1
	OCHA (2012)	2	2
	Stebner and Edwards (2012)	1	1
	Cockerton (2012)	1	1
Canada	Toronto Police (2012)	1	1
	Sarnia Police (2012)	1	1
	Ministry of Energy (2012)	1	1
	Dobson (2012)	1	1
Cuba	Estado May or Nacional de la Defensa Civil, Cuba (2012)	11	11
	OCHA (2012)	11	11
	PAHO (2012)	11	11
	Juventud Rebelde (2012)	11	11
Dominican Republic	OCHA (2012)	2	2
	Hoy (2012)	2	2
Haiti	Direction de la Protection Civile (2012)	10	10
	OCHA (2012)	54	48
	Agence Haitienne de presse (2012), Alter Presse (2012a, b, c), Haiti En Marche (2012a) Haiti En Marche (2012a,b), Trenton (2012)	48	48
Jamaica	OPDEM (2012)	2	2
	CDEMA (2012)	2	2
	Robinson (2012)	1	1
	North Coast Times (2012)	1	1
Puerto Rico	AP (2012)	1	1
	OCHA (2012)	1	1
USA	Blake *et al.* (2013)	147	147
	CDC (2012)	117	117
	CDC (2013)	4	4
	CBS (2012), Keller (2012), Weiss and Gardiner (2012), Philly (2012), Raynolds (2012), CNN (2012)	138	138
	Murti *et al.* (2013), Howland *et al.* (2013)	116	116

Table I. Sources of information on mortality induced by Hurricane Sandy per country and the number of fatalities obtained from each source

fatality and consisted of several variables that provided a detailed description of each incident. Every entry was given a value or a classification in each of these variables. Duplicates were identified and eliminated based mostly on the victim's name. In 52 cases, where the name was not available, specific details of the incident (such as its exact location, cause of death, the gender or the activity of the victim, etc.) were used to distinguish duplicate entries. The structure of the database and the variables used to describe each fatal incident are presented in Figure 1.

The database was developed in three modules. The first module contained information on the date of the incident and details on the exact location, including the county or parish, the state and the country that the incident occurred. The second module contained details on the names, the exact age and the gender of the decedents. The third module contained information on the incident itself, including the activity of the victims at the time of the event, the cause of death and a brief description of the

etiology of the incident, or the circumstances, or the natural phenomenon that lead to each fatality. This module contained also details about the incident's proximity to the coastline.

With regard to the activity of victims, possible classifications include the general course of actions followed by the victims before the fatal incidents, such as: walking outdoors, staying indoors, using a vehicle, being on a boat, doing recreational activities, evacuating a location, attempting a rescue or attempting a repair. Regarding the cause of death, possible classifications include drowning, burns, asphyxiation, heart attack (caused during the disaster and attributed directly to the events), physical trauma (i.e. physical injuries sustained during storm or related to it), electrocution, gas poisoning and hypothermia.

A brief description of the phenomenon or the cause of each fatal incident was also recorded in the database. Fatalities were classified as direct or indirect using the classification method of Combs *et al.* (1999), adopted also by CDC (2013).

According to this method, fatalities were classified as "direct" when caused by the actual physical forces of the tropical storm (i.e. the wind, rain, flooding, storm surge, rough seas,) or direct consequences of these forces (i.e. building collapses, tree falls, landslides, air-borne debris) (Combs *et al.*, 1999). On the other hand, fatalities were classified as "indirect" when caused indirectly by unsafe or unhealthy circumstances that were created as a result of the storm. These conditions include the loss of disruption of usual services, personal losses, disruption of an individual's lifestyle (Combs *et al.*, 1999). Such circumstances included accidents occurring during clean-up operations, car crashes, suicides, electrocutions, falls in the dark due to power shortage, deaths connected with medical conditions and power failures related to the hurricane. Based on this distinction, indirect deaths were not connected directly to the actual forces of the storm, but instead they were secondary outcomes of specific situations or circumstances caused by the hurricane (e.g. power failure).

The formation of the database allowed the development of a systematic inventory based on data fragmented in several reports, standardization of information and easy

Database structure

	Variable	Details
Module 1 : General Details	Reference number	*For reference purposes*
	Date	*Date of the incident*
	Exact Location	*Exact location of the incident*
	County	*County, parish or department, state and country in which the incident occurred*
	State	
	Country	
Module 2: Victim Details	Name	*Name, age, and gender of the deceased*
	Age	
	Gender	

	Variable	Possible classifications
Module 3 : Incident and surroundings details	Activity of victim	*- Walking (Pedestrian)* *- Being indoors* *- On a boat* *- Using a vehicle* *- Recreational (Sports)* *- Evacuating a location* *- Attempting a rescue* *- Attempting a repair* *- Involves in clean-up*
	Cause of death	*- Asphyxiation* *- Burns* *- Drowning* *- Heart attack* *- Physical Trauma* *- Electrocution* *- Gas poisoning* *- Hypothermia*

	Variable	Possible classifications
Module 3 : Incident and surroundings details	Cause of incident	*- Building collapse* *- Rough seas (open sea drowning)* *- Landslide* *- Wind gust* *- Airborne debris* *- Freshwater flooding* *- Tree/limb fall* *- Seawater surge* *- Car accident* *- Heart attack* *- Contact with power lines* *- Suicide* *- Power failure related*
	Distance from the coast	*Distance from the coastline*

Note: Variables are presented on the left column of each module, whereas explanation and possible classifications are presented on the right columns in italics

Figure 1.
Structure of the database in three modules containing variables that provide details on each incident, including its location, its timing, the surrounding environment and details of the victims and their activities

cross-reference, comparison and quantitative analysis. After its completion, the characteristics of the fatal incidents were quantified. The whole record was linked to a GIS database through which the locations of the fatalities were mapped.

2.3 Data quality and uncertainties

Due to the importance of the disaster, multiple international, national and local organizations, along with the international media, recorded parts of the storm's impact on human lives. Data were collected from multiple sources with an overall completeness rate of 91.1 percent, as information was missing for 322 out of a total of 3,617 database entries.

All fatalities included in this study were reported as caused by Hurricane Sandy, by the relevant official organizations in each country that is civil protection, emergency management or other state agencies. Inconsistent or incomplete data were found in certain cases including:

(1) Minor discrepancies in fatality numbers reported in the USA (CDC, 2013; Blake *et al.*, 2013). These discrepancies were associated with the timing of data collection by the agencies in question and in differences in the criteria used to determine whether a fatality was connected or not to the hurricane.

(2) Missing data regarding certain incidents in Haiti.

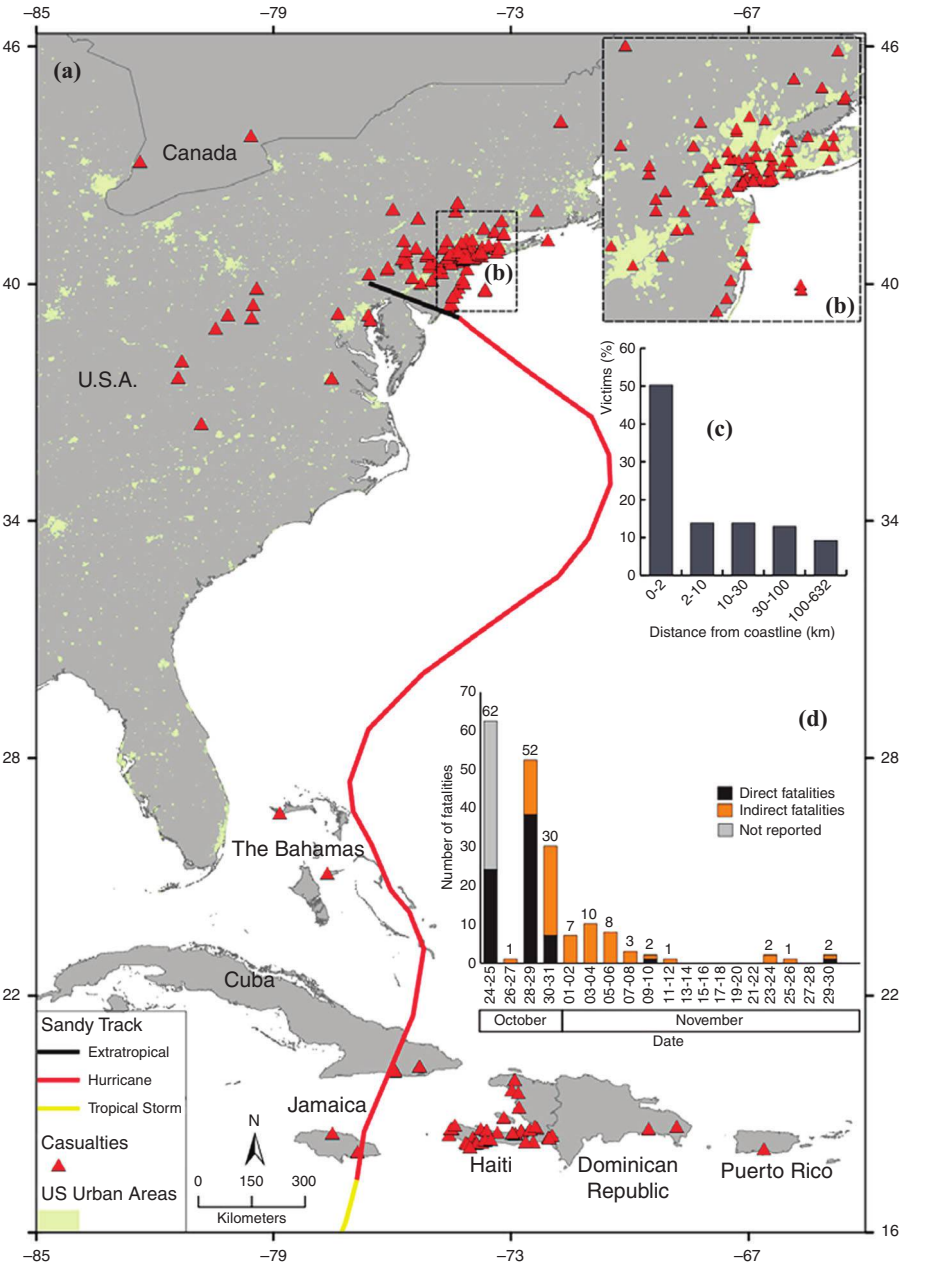
Although press articles have been used before in the study of natural hazards (Llasat *et al.*, 2009; Diakakis *et al.*, 2012) to diminish any uncertainties deriving from the subjectivity connected to the non-scientific nature of press articles, the variables selected to describe the incidents were specifically chosen in a way that they would not be subject to the reporter's opinion. In addition, information for the majority of fatalities (227 out of the total 233 or 97.4 percent) was cross-referenced between at least two independent sources to assure accuracy. Information from different sources was checked for inconsistencies. Although the vast majority of incidents presented no conflicting information between different sources, in the few cases where differences were found, more than three independent sources were used to clarify any contradicting data.

Finally, it should be noted that locations marked in the database concern the sites where the incidents took place, even when a victim died on route to or at another location.

3. Results and discussion

A total of 233 fatalities related to Hurricane Sandy were identified occurring in eight countries including Cuba (11), Jamaica (two), Haiti (54), the USA (159), Canada (two), Bahamas (two), Puerto Rico (one) and the Dominican Republic (two). Deaths occurred in various locations along the path of the hurricane, spanning from 24 of October 2012 to 28 November 2012 (Figure 2), long after the storm subsided, as victims passed away after long hospitalization or were fatally injured during clean-up operations.

The majority of fatal incidents (67.3 percent of total) were recorded in nine states of the eastern US, with New York (71), New Jersey (43) and Pennsylvania (15) suffering the largest number of casualties. A large portion of incidents occurred near the coast as it was found that approximately half of the fatalities were recorded within < 2 km from the coastline (Figure 2c).



Source: According to Blake *et al*. (2013)

Figure 2.
(a) Map presenting the spatial distribution of deaths caused by Hurricane Sandy during October and November 2012, with; (b) a detailed overview of their location around the urban areas of New York and; (c) the distribution of the victims against their distance from the coastline and the track of the hurricane

The temporal distribution analysis of fatal incidents (for 181 deaths for which the date was possible to determine) showed that the majority of fatalities occurred between the 24 and 31 October (Figure 2d) and after that their numbers gradually reduced. The two peaks in the graph represent the dates when Hurricane Sandy made landfall to Caribbean (24 and 25 October) and the USA (29 October), respectively. Direct fatalities, attributed to the forces of the hurricane, appear to occur mostly on the days that the hurricane hit land. On the contrary, indirect deaths increase in percentage in the days following landfall.

Among the victims, males accounted for 122 deaths (52.4 percent of total fatalities), whereas females recorded 65 cases (27.9 percent of total), indicating a male/female ratio of 1.87:1. In 46 occasions (19.7 percent of total) the gender was not reported (Figure 3). Comparison of the victim's gender ratio with the weighted average ratio of the population of the eight countries, which equals 0.97:1 (Central Intelligence Agency, 2014), shows that males are overrepresented among the victims. The ratio of male to female victims in the USA and Canada was found to be 2:1, whereas the same ratio for the rest of countries was calculated at 1.4:1, indicating a higher mortality rate for women in the Caribbean, but still smaller than the 1.02:1 recorded in Hurricane Katrina (Jonkman *et al.*, 2009).

Examination of the age distribution of the victims showed an increase of fatalities with age (Figure 3). The average age of victims in all eight countries, based on 185 individuals, was calculated at 54.1 years old, considerably smaller than that of Hurricane Katrina (69.0) (Brunkhard *et al.*, 2008). However, a noteworthy difference was identified in the average victim age between the countries of the Caribbean (32.8 years old) and of the North America (59.2 years old).

In general, mortality showed an increase with age (Figure 3a), especially in the USA and Canada (Figure 3b), although this trend was not recorded in the Caribbean (Figure 3c). The overall trend is acknowledged in the literature (Rappaport, 2000) and is attributed to an increased vulnerability with age to the various hazards of a storm, including lack of physical power, will and ability to flee a hazardous situation. Increased mortality in young ages has been recorded in previous works (Mooney, 1983) as a result of various social parameters that can lead to increased vulnerability of youngsters (Alderman *et al.*, 2012).

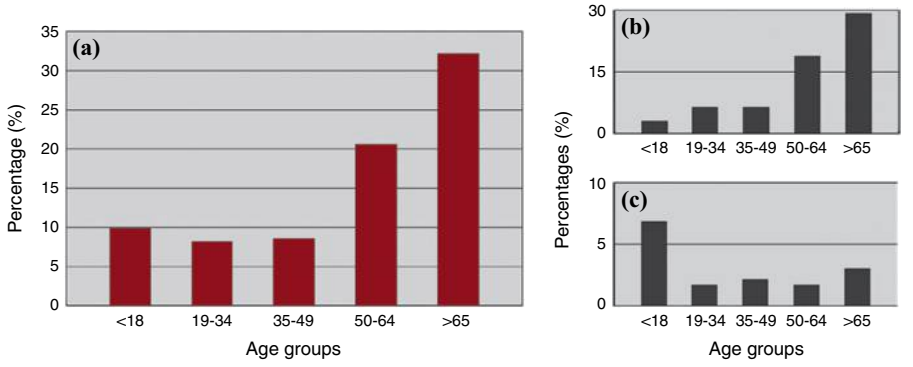


Figure 3. Distribution of Hurricane Sandy victims in relation with their age

Notes: (a) All countries; (b) continental North America (USA and Canada); (c) the Caribbean (Bahamas, Haiti, Cuba, Dominican Republic, Jamaica, Puerto Rico)

Regarding the activity of the victims at the time of the incident, we found that individuals that passed away indoors presented the highest percentage (41.6 percent), followed by individuals involved in the clean-up operations, pedestrian victims, individuals using a vehicle and others (Table II). Information on the activity of the victims was available for 165 cases (70.3 percent of the total). Deaths inside buildings present a higher percentage in comparison with Hurricanes Katrina and Rita (Jonkman *et al.*, 2009), where approximately one-third of the fatalities occurred indoors. On the contrary, vehicle-related fatalities present in this case unusually low percentage in comparison with the literature findings (French *et al.*, 1983; Bern *et al.*, 1993; Staes *et al.*, 1994; Rappaport, 2000; Ashley and Ashley, 2008b). Indoor fatalities are characterized by victims of average age of 60.7 years old, whereas outdoor deaths record an average of 47.1 years old. One explanation, although there is no evidence for or against it, is a difficulty or an unwillingness of older people to evacuate, recorded also in the literature (Ahern *et al.*, 2005; Brunkhard *et al.*, 2008). Furthermore, it was found that Caribbean countries present more outdoor fatalities, showing a 1:1.2 ratio of indoor to outdoor deaths. On the contrary, in the USA and Canada the majority of Sandy fatalities were recorded indoors at a ratio of 1:0.8 (indoor to outdoor deaths). Although there is no specific evidence, this disparity is possibly attributed to a higher percentage of people staying indoors during the disaster in the USA. This in turn is possibly ascribed to the way individuals in different countries appreciate risk, the different time of the day that hurricane made landfall and differences in the instructions issued by the respective emergency management authorities in each country. For instance, people could be more inclined to stay indoors during the storm, if they were instructed to do so by local authorities or if they believed that they would be safer than outdoors.

Regarding the decedents involved in clean-up activities, 12 out of 20 were cleaning streets or their own property, five were trimming trees and three were shoveling snow. Ten individuals were hit by a tree or a branch during this process, two were inadvertently self-injured using heavy tools, two were involved in a vehicle accident, one person had an asthma crisis and two were involved in other accidents. All three individuals who died during shoveling suffered a heart attack.

Regarding their cause of death, physical trauma presented the highest percentage, followed by drowning, poisoning (mainly from carbon monoxide), hypothermia, heart attack, asphyxiation, electrocution and burns in smaller percentages (Table II). In 19.7 percent of cases the cause of death was not reported. This study is in agreement with

Table II. Distribution of fatalities with respect to their activity and cause of death

Activity	No. of cases	%	Cause of death	No. of cases	%
Stayed indoors	97	41.6	Physical trauma	87	37.3
Involved in clean-up	20	8.7	Drowning	51	21.9
Using a vehicle	16	6.0	Poisoning	15	6.4
Walking	14	6.9	Hypothermia	10	4.3
Evacuating a location	6	2.6	Heart attack	7	3.0
Attempting a repair	5	2.1	Asphyxiation	6	2.6
Doing sports	4	1.7	Electrocution	6	2.6
Being on a boat	2	0.9	Burns	5	2.2
Attempting a rescue	1	0.4	Not reported	46	19.7
Not reported	68	29.1			
Total	233	100.0	Total	233	100.0

the literature findings (Rappaport, 2013) suggesting that drowning deaths account for about a quarter of the total. However, the percentage of water-related incidents appear much smaller than in previous disasters (Rappaport, 2013). Comparison between the Caribbean and continental North America showed a difference in the primary cause of death. While in the Caribbean countries drowning and physical trauma recorded percentages of 57.1 and 28.6 percent of local fatalities, in the continental North America they showed values of 24 and 45.2 percent, respectively. In addition, while in continental North America cases of burns, electrocutions, heart attacks, hypothermia and carbon monoxide poisoning accounted for 28.8 percent of fatalities, these causes of death in the Caribbean show a substantially smaller percentage (3.6 percent).

Regarding the circumstances or the phenomenon that led to the fatal incident, 106 deaths were directly attributable to the storm's forces, whereas 87 were found to be connected to the storm indirectly. Among direct deaths, incidents related to storm surge presented the highest percentage (17.2 percent), followed by tree falls caused by the wind, freshwater flooding, building collapses, rough seas and others (Table III). High percentages of tree falls indicate that a considerable portion of deaths occurred as a result of excessive wind, recorded also in previous cases (Ashley and Ashley, 2008b; Schmidlin, 2009). Offshore deaths are still present although in significantly reduced number compared to previous decades as suggested by Rappaport (2000).

Among indirect deaths, the study indicates that a large number of incidents were related to power outages (19.7 percent of total), followed by car crashes, medical conditions (e.g. heart attacks), tree or limb falls caused during clean-up, contact with power lines and other accidents (Table III). Other accidents include individuals who passed away due to misuse of heavy equipment during or after the storm.

Based on this analysis, it is evident that certain circumstances are recording surprisingly high number of deaths such as tree or limb falls and accidents during clean-up, which recorded 32 and 20 fatalities, respectively. In total, 46 fatalities were attributed to power outages, including individuals who first, were poisoned by carbon monoxide due to indoor use of a power generator; second, fell in the dark; third, experienced a prolonged exposure to low temperatures due to lack of working heating equipment; fourth, died due to fires created by candles; fifth, died due to failure of their respiration assisting equipment; and finally, individuals who lost their lives in a traffic accident due to not working traffic lights (Table IV). Similar incidents have been reported in the literature (Philen *et al.*, 1992).

Direct fatalities			Indirect fatalities		
Cause	No. of cases	%	Cause	No. of cases	%
Seawater surge	40	17.2	Power failure related	46	19.7
Tree/limb fall	24	10.3	Car accident	15	6.4
Freshwater flooding	18	7.7	Tree/limb fall	8	3.4
Building collapse	12	5.1	Heart attack	7	3.0
Rough seas	4	1.7	Contact with power lines	5	2.1
Landslide	3	1.3	Other accidents	5	2.1
Wind gust	3	1.3	Suicide	1	0.5
Air-borne debris	2	0.9			
Total	106	45.5	Total	87	37.3

Table III. Distribution of deaths caused by Hurricane Sandy with respect to the cause of fatal incidents

Examining interconnectedness between the activity, the cause of death and the cause of incident, we found that outdoor cases recorded higher percentages of fatalities caused by physical trauma (57.4 percent), heart attacks (8.8 percent) and electrocution (10.3 percent), than indoor incidents, where drowning, gas poisoning, hypothermia and asphyxiation deaths were more abundant (Figure 4a).

The most common cause of death among direct fatalities was drowning (47.2 percent), followed by physical trauma (36.8 percent) and other types in much lower percentages (Figure 4b). In the case of indirect deaths, physical trauma was the most common cause of death (46 percent) followed by poisoning (17.2 percent), hypothermia, heart attacks, electrocution and burns (Figure 4b). Drowning presented particularly small percentage (1.1 percent) among indirect fatalities.

In general, direct fatalities record a higher ratio of indoor to outdoor cases than indirect (Figure 4c). More specifically, in the case of direct deaths, the most common activity was staying indoors (50 percent of cases), followed by walking (10.4 percent) and using a vehicle (5.7 percent). Among indirect deaths, staying indoors recorded also the highest percentage (49.4 percent of cases), followed by individuals engaged in clean-up activities (20.7 percent), vehicle-related incidents (11.5 percent) and others.

Table IV.
Distribution of power failure-related deaths caused by Hurricane Sandy

Cause	No. of cases	%
Gas poisoning from the use of power generators	14	6.0
Falls in the dark	13	5.6
Prolonged exposure to low temperatures	10	4.3
Fire-related incidents	5	2.1
Failure of respiration assisting equipment	3	1.3
Traffic light-related incidents	1	0.4
Total	46	19.7

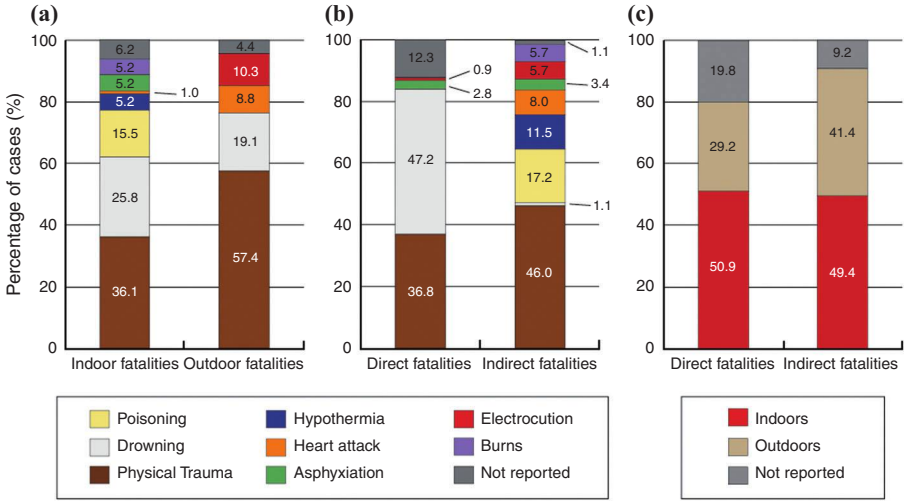


Figure 4.
Differences in distribution of causes of death

Notes: (a) Between indoor and outdoor environments; (b,c) direct and indirect fatalities

4. Conclusions

This work provides an overview of fatalities caused by Hurricane Sandy in North America and the Caribbean during October and November 2012, analyzing the conditions under which fatalities occur.

The study identified 233 deaths most of which occurred mostly in coastal areas, < 2 km from the seashore, clustering mostly around the USA, New York and New Jersey and in various locations in Haiti. Males and elderly people showed higher percentages among the victims, although differences were recorded in victims' demographics, as in the Caribbean youngsters and females showed higher mortality rates. Male to female ratio among the victims was calculated at 1.87:1, significantly higher than in the case of Hurricane Katrina (1.02:1). Mortality rate was found to increase with age, a trend identified also in previous disasters (e.g. Hurricanes Katrina and Rita). The average age of the victims was calculated at 54.1 years old, considerably smaller than that of Hurrricane Katrina, with the Caribbean region recording a significantly smaller average. Regarding the activity of the victims at the time of the incident, indoor deaths showed the highest percentage, followed by individuals involved in the clean-up operations, pedestrian victims, vehicle-related incidents and individuals involved in other outdoor activities. Indoor fatalities occurred in a higher proportion in continental North America and among older victims and recorded a higher percentage in comparison to Hurricanes Katrina and Rita, where approximately one-third of the fatalities occurred indoors. Vehicle-related fatalities recorded unusually low percentage in comparison with the literature findings. Physical trauma presented the highest percentage among different causes of death, followed by drowning, poisoning (mainly from carbon monoxide), hypothermia, heart attack, asphyxiation, electrocution and burns in smaller percentages. However, locally in the Caribbean, drowning was the primary cause of death accounting for over half of fatalities. Although this study's results are in agreement with the literature findings about the percentage of drowning deaths, the percentage of water-related incidents in total appear much smaller than in previous disasters. Offshore deaths are present, but in significantly reduced numbers compared to previous decades.

Overall, this work is a contribution to the body of knowledge regarding mortality caused by tropical cyclones. Its findings, together with the ones of similar studies cited, can provide useful insights for civil protection professionals. The study stresses once more the diversity of unsafe conditions and the complexity of events and mechanisms that can lead to risk for human life. Examination of mortality shows that risk is increased not only during, but also for a period after landfall. Although the majority of deaths were directly connected with the hurricane forces (i.e. storm surge, flooding, excessive winds), the study shows that indirect fatalities associated with power failure, vehicle accidents and clean-up efforts, can reach comparable numbers.

This indicates that our society should take the risk of indirect deaths under careful consideration during prevention planning. Loss or disruption of usual services like electricity can result to harmful conditions. Civil protection authorities should enhance public education on hurricane protection by emphasizing the risks of power failure leading to carbon monoxide poisoning, falls in the dark, failure of respiratory equipment, lack of heating. Additionally, authorities should inform citizens about the hazards involved in clean-up operations. Research should continue to gather detailed information on how fatalities occur during tropical cyclones and develop systematic records that will highlight harmful circumstances and will have the potential to evaluate the impact of decisions or interventions made by civil protection professionals.

Continuous monitoring and comparison with historical disaster deaths is important to identify trends and new emerging hazards. Civil protection and emergency management organizations should focus their efforts in preventing the most common causes of fatal incidents. For instance, storm surge risk mitigation can benefit from an improved delineation of the areas under risk and an enhanced and clear communication to educate and warn the population within these areas.

Furthermore, results indicate a partly different impact of the disaster on different societies. Disparities were identified between the North American and the Caribbean countries, in the average age of the victims, their age distribution, their gender, in their activity at the time of the incident and the cause of death. Although more research is needed to examine the reasons behind these differences, collection of information from similar multinational catastrophes can provide a better understanding on the reasons behind these differences and has the potential to illustrate particular social characteristics that increase vulnerability of specific population groups.

References

Agence Haitienne de Presse (2012), "Dernier bilan humain de l'ouragan Sandy, selon les chiffres fournis par les differents correspondants de l'AHP: 12 morts et 3 disparus", Agence Haitienne de Presse, October 26, available at: https://web.archive.org/web/20121201034627/; www.ahphaiti.org/ndujour.html (accessed November 15, 2012).

Ahern, M., Kovats, R.S., Wilkinson, P., Few, R. and Matthies, F. (2005), "Global health impacts of floods: epidemiologic evidence", *Epidemiologic Reviews*, Vol. 27 No. 1, pp. 36-46.

Alderman, K., Turner, L.R. and Tong, S. (2012), "Floods and human health: a systematic review", *Environment International*, Vol. 47, pp. 37-47.

Alter Presse (2012a), "Haiti-Ouragan: Sandy fait au moins 3 morts et d'important degats", Alter Presse, October 25, available at: www.alterpresse.org/spip.php?article13601 (accessed November 15, 2012).

Alter Presse (2012b), "Haïti-Sandy: le bilan humain ne cesse de s'aggraver – au moins 44 morts et 12 disparus", Alter Presse, October 27, available at: www.alterpresse.org/spip.php?article13607 (accessed November 15, 2012).

Alter Presse (2012c), "Haiti-Sandy: le sud meurtri – au moins 14 morts", Alter Presse, October 25, available at: www.alterpresse.org/spip.php?article13609 (accessed November 15, 2012).

AP (2012), "Dos ahogados y 26 mil desplazados en el pavs por efectos del Huracan Sandy", press release, AP, October 26.

Ashley, S.T. and Ashley, W.S. (2008a), "The storm morphology of deadly flooding events in the United States", *International Journal of Climatology*, Vol. 28 No. 4, pp. 493-503.

Ashley, S.T. and Ashley, W.S. (2008b), "Flood fatalities in the United States", *Journal of Applied Meteorology and Climatology*, Vol. 47 No. 3, pp. 805-818.

Avila, L.A. and Cangialosi, J. (2011), "Tropical cyclone report, Hurricane Irene", Working Paper No. AL092011, National Hurricane Center, Miami, FL, August 21-28.

Bern, C., Sniezek, J., Mathbor, G., Siddiqi, M.S., Ronsmans, C., Chowdhury, A., Choudhury, A., Islam, K., Bennish, M., Noji, E. and Glass, R.I. (1993), "Risk factors for mortality in the Bangladesh cyclone of 1991", *Bulletin of the World Health Organization*, Vol. 71 No. 1, pp. 73-78.

Blake, E., Todd, B., Kimberlain, B., Berg, R., Cangialosi, J. and Beven, J. II (2013), "Tropical cyclone report Hurricane Sandy", Working Paper No. AL182012, National Hurricane Center, Miami, FL, October 22-29, 2012.

Blake, E.S., Rappapport, E.N. and Landsea, C.W. (2011), "The deadliest, costliest and most intense United States tropical cyclones from 1851 to 2006 (and other frequently requested

Hurricane facts)", working paper (NOAA Technical Memorandum NWS TPC-5), National Oceanic and Atmospheric Administration (NOAA), Miami, FL, April 17.

Brunkhard, J., Namul, A.G. and Ratard, R. (2008), "Hurricane Katrina deaths, Louisiana, 2005", *Disaster Medicine and Public Health Preparedness*, Vol. 2 No. 4, pp. 215-223.

CBS (2012), "Portrait of Sandy's victims becomes clearer", CBS, November 1, available at: www.cbsnews.com/news/portrait-of-sandys-victims-becomes-clearer/ (accessed November 15, 2012).

CDC (2000), "Morbidity and mortality associated with Hurricane Floyd – North Carolina, September-October 1999", Morbidity and Mortality Weekly Report, Centers for Disease Control and Prevention, Atlanta, GA, April 5.

CDC (2012), "Notes from the field: carbon monoxide exposures reported to poison centers and related to Hurricane Sandy – Northeastern United States", Morbidity and Mortality Weekly Report, Centers for Disease Control and Prevention, Atlanta, GA, November 9.

CDC (2013), "Deaths associated with Hurricane Sandy – October-November 2012", Morbidity and Mortality Weekly Report, Centers for Disease Control and Prevention, Atlanta, GA, May 24.

CDEMA (2012), "Situation report #3 – Hurricane Sandy", Caribbean Disaster Emergency Management, Green Hill, Barbados October 27.

Central Intelligence Agency (2014), "The World Factbook", Central Intelligence Agency, Washington, DC, available at: www.cia.gov/library/publications/the-world-factbook/ (accessed April 8, 2014).

Chowdhurry, S., Brody, S.M., Peacock, W.G., Vedlitz, A. and Himanshu, G. (1993), "Social vulnerability and the natural and built environment: a model of flood casualties in Texas", *Disasters*, Vol. 32 No. 4, pp. 537-560.

CNN (2012), "Superstorm Sandy's victims", CNN, November 8, available at: http://edition.cnn.com/interactive/2012/10/us/sandy-casualties/index.html (accessed November 15, 2012).

Coates, L. (1999), "Flood fatalities in Australia, 1788-1996", *Australian Geographer*, Vol. 30 No. 3, pp. 391-408.

Cockerton, P. (2012), "Hurricane Sandy: British investment banker dies in Bahamas trying to repair window shutter in storm", Mirror, October 27, p. 1, available at: www.mirror.co.uk/news/world-news/hurricane-sandy-british-investment-banker-1402057 (accessed November 15, 2012).

Combs, D.L., Parrish, R.G., Mcnabb, S.J. and Davis, J.H. (1996), "Deaths related to Hurricane Andrew in Florida and Louisiana, 1992", *International Journal of Epidemiology*, Vol. 25 No. 3, pp. 537-544.

Combs, D.L., Quenemoen, L.E., Parrish, R.G. and Davis, J.H. (1999), "Assessing disaster-attributed mortality: development and application of a definition and classification matrix", *International Journal of Epidemiology*, Vol. 28 No. 6, pp. 1124-1129.

Czajkowski, J., Simmons, K. and Sutter, D. (2011), "An analysis of coastal and inland fatalities in landfalling US hurricanes", *Natural Hazards*, Vol. 59 No. 3, pp. 1513-1531.

Diakakis, M., Mavroulis, S. and Deligiannakis, G. (2012), "Floods in Greece, a statistical and spatial approach", *Natural Hazards*, Vol. 62 No. 2, pp. 485-500.

Direction de la Protection Civile (2012), "Ouragan Sandy. Rapport de situation #5", Direction De La Protection Civile, Port Au Prince, October 27.

Dobson, C. (2012), "Lineman was 'one of the good guys' ", Sarnia Observer, November 2, p. 1, available at: www.theobserver.ca/2012/11/02/killed-hydro-worker-identified (accessed November 15, 2012).

Drobot, S., Gruntfest, E., Barnes, L., Benight, C., Schultz, D. and Demuth, J. (2007), "Driving under the influence of weather: perceptions of flash floods and vehicle safety", paper presented at 16th Conference on Applied Climatology, San Antonio, TX, January 14-18.

Estado Mayor Nacional de la Defensa Civil, Cuba (2012), "Loss of lives as a consequence of the passage of Hurricane Sandy", Estado May or Nacional de la Defensa Civil, Cuba, press release, October 25.

Fitzgerald, G., Du, W., Jamal, A., Clark, M. and Hou, X. (2010), "Flood fatalities in contemporary Australia (1997-2008)", *Emergency Medicine Australasia*, Vol. 22 No. 2, pp. 180-186.

French, J., Ing, R., Von Allmen, S. and Wood, R. (1983), "Mortality from flash floods: a review of national weather service reports, 1969-81", *Public Health Reports*, Vol. 98 No. 6, pp. 584-588.

Haiti En Marche (2012a), "Revue de la semaine 26 octobre 2012", Haiti En Marche, October 26, available at: www.haitienmarche.com/index.php?option=com_content&view=article&id=5890 (accessed November 18, 2012).

Haiti En Marche (2012b), "Sandy: bilan tougours a la hausse", Haiti En Marche, October 28, available at: www.haitienmarche.com/index.php?option=com_content&view=article&id=5895 (accessed November 18, 2012).

Hebert, P.J., Jarrell, J.D. and Mayfield, B.M. (1996), "The deadliest, costliest and most intense United States Hurricanes of this century (and other frequently requested Hurricane facts)", working paper (NOAA Technical Memorandum NWS-TPC-1), National Oceanic and Atmospheric Administration (NOAA), Coral Gables, FL.

Howland, R., Li, W., Madsen, A., Wong, H., Das, T., Matte, T., Stayton, C. and Begier, E. (2013), "Real-time mortality surveillance during and after Hurricane Sandy in New York City: methods and lessons learned", paper presented at the 141ST APHA Annual Meeting and Expo, Boston, MA, November 2-6.

Hoy (2012), "Dos ahogados y 26 mil desplazados en el pavs por efectos del huracan Sandy", Hoy, October 26, available at: www.hoy.com.do/el-pais/2012/10/26/452248/Dos-ahogados-y-26-mil-desplazados-en-el-pais-por-efectos-del-huracan-Sandy (accessed November 15, 2012).

Jonkman, S.N. and Kelman, I. (2005), "An analysis of the causes and circumstances of food disaster deaths", *Disasters*, Vol. 29 No. 1, pp. 75-97.

Jonkman, S.N., Maaskant, B., Boyd, E. and Levitan, M.L. (2009), "Loss of life caused by the flooding of New Orleans after Hurricane Katrina: analysis of the relationship between flood characteristics and mortality", *Risk Analysis*, Vol. 29 No. 5, pp. 676-698.

Juventud Rebelde (2012), "Informa la defensa civil pérdidas de vidas humanas por el paso del huracán Sandy", Juventud Rebelde, October 25, available at: www.juventudrebelde.cu/cuba/2012-10-25/informa-la-defensa-civil-perdidas-de-vidas-humanas-por-el-paso-del-huracan-sandy (accessed November 15, 2012).

Keller, J. (2012), "Mapping Hurricane Sandy's deadly toll", *New York Times*, November 17, p. 1, available at: www.nytimes.com/interactive/2012/11/17/nyregion/hurricane-sandy-map.html?partner=rss&emc=rss&smid=tw-nytimes&_r=0 (accessed November 21, 2012).

Legome, E., Robins, A. and Rund, D.A. (1995), "Injuries associated with floods: the need for an international reporting scheme", *Disasters*, Vol. 19 No. 1, pp. 50-54.

Lew, E. and Wetli, C. (1996), "Mortality from Hurricane Andrew", *Journal of Forensic Sciences*, Vol. 41 No. 3, pp. 449-452.

Llasat Botija, M.D.C., Llasat Botija, M. and Lopez, L. (2009), "A press database on natural risks and its application in the study of floods in Northeastern Spain", *Natural Hazards and Earth System Sciences*, Vol. 9 No. 6, pp. 2049-2061.

Ministry of Energy (2012), "Statement from Ontario minister of energy, Chris Bentley", press release, Ministry of Energy, Ontario, October 31.

Mooney, L.E. (1983), "Applications and implications of fatality statistics to the flash flood problems", *Proceedings of the 5th Conference on hydrometeorology, Tulsa, October 17-19*, pp. 127-129.

Molthan, A. and Jedlovec, G. (2013), "Satellite observations monitor outages from superstorm Sandy", *Eos, Transactions American Geophysical Union*, Vol. 94 No. 5, pp. 53-54.

Murti, M., Casey-Lockyer, M., Heick, R., Metzlufft, C., Yard, E., Wolkin, A. and Noe, R. (2013), "Hurricane Sandy mortality – US Northeastern states, October-November 2012", paper presented at the 141ST APHA Annual Meeting and Expo, Boston, MA, November 2-6.

North Coast Times (2012), "Family charges negligence, seeking compensation for electrocuted man", North Coast Times, November 14, available at: http://northcoasttimesjamaica.com/2012/11/family-charges-negligence-seeking-compensation-for-electrocuted-man (accessed November 15, 2012).

OCHA (2012), "Latin America and the Caribbean: Hurricane Sandy situation report no1", working paper, United Nations Office for the Coordination of Humanitarian Affairs, Panama, November 9.

OPDEM (2012), "Situation report #6 tropical report Sandy", working paper, Office of Disaster Preparedness and Emergency Management, Kingston, October 24.

PAHO (2012), "Hurricane Sandy, emergency operations center, situation report #1", working paper, Pan American Health Organization (PAHO), Regional Office of the World Health Organization, Washington, DC, October 30.

Philen, R.M., Combs, D.L., Miller, L., Sanderson, L.M., Parrish, R.G. and Ing, R. (1992), "Hurricane Hugo-related deaths: South Carolina and Puerto Rico, 1989", *Disasters*, Vol. 16 No. 1, pp. 53-59.

Philly (2012), "New Jersey Sandy deaths from falling trees, drownings and generators", Philly, November 2, available at: www.philly.com/philly/news/breaking/24_NJ_Sandy_deaths_from_falling_trees_drownings_generators.html (accessed November 15, 2012).

Pielke, R.A. Jr, Rubiera, J.L., Sea, C., Fernández, M.L. and Klein, R. (2003), "Hurricane vulnerability in Latin America and the Caribbean: normalized damage and loss potentials", *Natural Hazards Review*, Vol. 4 No. 3, pp. 101-114.

Pielke, R.A. Jr, Gratz, J., LandSea, C.W., Collins, D., Saunders, M.A. and Musulin, R. (2008), "Normalized hurricane damage in the United States: 1900-2005", *Natural Hazards Review*, Vol. 9 No. 1, pp. 29-42.

Pradhan, E.K., West, K.P. Jr, Katz, J., LeClerq, S.C., Khatry, S.K. and Shrestha, S.R. (2007), "Risk of food-related mortality in Nepal", *Disasters*, Vol. 31 No. 1, pp. 57-70.

Ragan, P., Schulte, J., Nelson, S.J. and Jones, K.T. (2008), "Mortality surveillance 2004 to 2005 Florida Hurricane-related deaths", *The American Journal of Forensic Medicine and Pathology*, Vol. 29 No. 2, pp. 148-153.

Rappaport, E.N. (2000), "Loss of life in the United States associated with recent Atlantic tropical cyclones", *Bulletin of the American Meteorological Society*, Vol. 81 No. 9, pp. 2065-2073.

Rappaport, E.N. (2013), "Fatalities in the United States from Atlantic tropical cyclones-new data and interpretation", *Bulletin of the American Meteorological Society*, Vol. 95 No. 3, pp. 341-346.

Rappaport, E.N. and Fernandez-Partagas, J.J. (1995), "The deadliest Atlantic tropical cyclones, 1492-1994", working paper (NOAA Technical Memorandum NWS NHC-47), National Oceanic and Atmospheric Administration (NOAA), Miami, FL, January.

Raynolds, E. (2012), "Death toll reaches 85 and is still rising following the devastation", *Daily Mail*, November 8, p. 1, available at: www.dailymail.co.uk/news/article-2226164/Hurricane-Sandy-victims-Ella-Norris-89-dies-daughters-arms-water-fills-Staten-Island-home.html/ (accessed November 21, 2012).

RBPF (2012a), "Police investigates death of male. Daily crime reports 2012", report, Public Affairs & Communications Office (PACO), Royal Bahamas Police Force, Nassau, Grand Bahama & Northern Bahamas, October 29.

RBPF (2012b), "Alleged drowning", report, Public Affairs & Communications Office (PACO), Royal Bahamas Police Force, Nassau, Grand Bahama & Northern Bahamas, October 29.

Robinson, C. (2012), "Man killed as boulder smashes bedward gardens house", *Jamaica Observer*, October 24, p. 1, available at: www.jamaicaobserver.com/news/Man-killed-as-boulder-smashes-Bedward-Gardens-house (accessed November 15, 2012).

Sarnia Police (2012), "Hydro worker killed in Sarnia while repairing storm damage", press release, Sarnia Police, Sarnia, October 31.

Schmidlin, T.W. (2009), "Human fatalities from wind-related tree failures in the United States, 1995-2007", *Natural Hazards*, Vol. 50 No. 1, pp. 13-25.

Staes, C., Orengo, J.C., Malilay, J., Rullan, J. and Noji, E. (1994), "Deaths due to flash floods in Puerto Rico, Implications for prevention", *International Journal of Epidemiology*, Vol. 23 No. 5, pp. 968-975.

Stebner, B. and Edwards, A. (2012), "British bank boss killed as he fell from roof while trying to repair window shutter when Hurricane Sandy tore through Bahamas", *Daily Mail*, October 27, p. 1, available at: www.dailymail.co.uk/news/article-2223916/Hurricane-Sandy-British-bank-boss-killed.html (accessed November 17, 2012).

Toronto Police (2012), "Police request witness assistance with sudden-death investigation, St. Clair Avenue West/Keele Street", press release, Toronto Police, Toronto, October 30.

Trenton, D. (2012), "Sandy gone, Caribbean mourns 58 dead, cleans up", *ABC News*, October 27, available at: https://web.archive.org/web/20121030071841/;http://abcnews.go.com/International/wireStory/sandy-caribbean-mourns-43-dead-cleans-17577607 (accessed November 30, 2012).

Weiss, M. and Gardiner, A. (2012), "Hurricane Sandy's death toll in New York climbs to 41", DNAinfo, November 2, available at: www.dnainfo.com/new-york/20121102/new-york-city/citys-death-toll-nears-50-after-hurricane-sandy (accessed November 15, 2012).

Yale, J.D., Cole, T.B., Garrison, H.G., Runyan, C.W. and Riad Ruback, J.K. (2003), "Motor vehicle-related drowning deaths associated with inland flooding after Hurricane Floyd: a field investigation", *Traffic Injury Prevention*, Vol. 4 No. 4, pp. 279-284.

Yeo, S.W. and Blong, R.J. (2010), "Fiji's worst natural disaster: the 1931 Hurricane and flood", *Disasters*, Vol. 34 No. 3, pp. 657-683.

Zachria, A. and Patel, B. (2006), "Deaths related to Hurricane Rita and mass evacuation", *Chest Journal*, Vol. 130 No. 4, pp. 124S.

Zahran, S., Brody, S., Peacock, W., Vedlitz, A. and Grover, H. (2008), "Social vulnerability and the natural and built environment: a model of flood casualties in Texas", *Disasters*, Vol. 32 No. 4, pp. 537-560.

Zane, D.F., Bayleyegn, T.M., Hellsten, J., Beal, R., Beasley, C., Haywood, T., Wiltz-Beckham, D. and Wolkin, A.F. (2011), "Tracking deaths related to Hurricane Ike, Texas, 2008", *Disaster Medicine and Public Health Preparedness*, Vol. 5 No. 1, pp. 23-28.

Further reading

Emanuel, K. (2005), "Increasing destructiveness of tropical cyclones over the past 30 years", *Nature*, Vol. 436 No. 7051, pp. 686-688.

Corresponding author

Dr Michalis Diakakis can be contacted at: diakakism@geol.uoa.gr