Event Recap Report:
1/12/10 Haiti Earthquake

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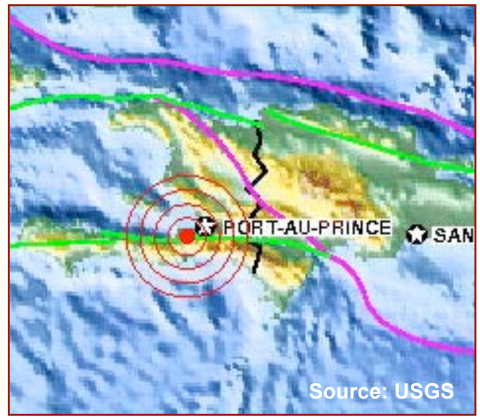
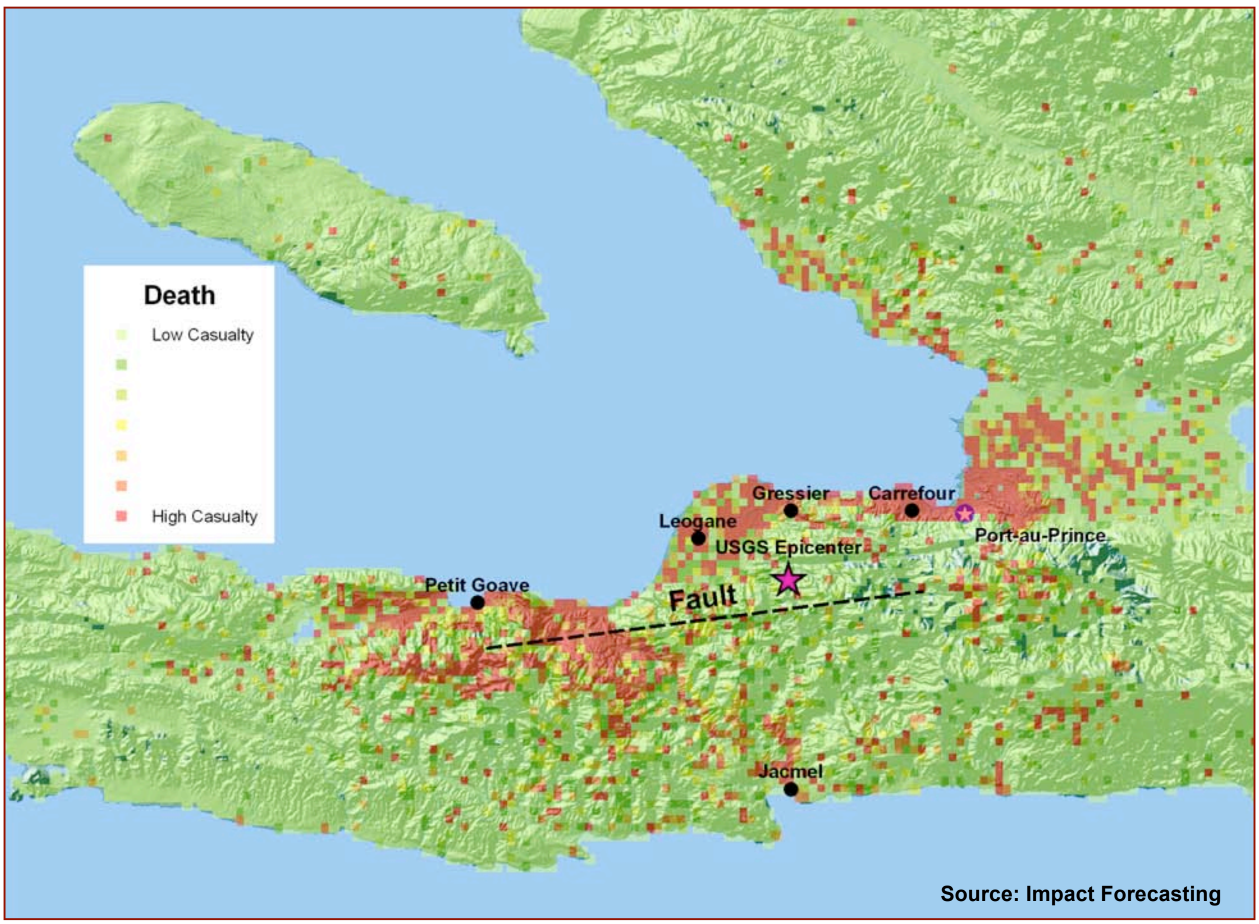
Introduction

A massive magnitude-7.0 earthquake struck Haiti on Tuesday, January 12th. The earthquake and over 40 aftershocks led to widespread catastrophic damage in the capital city of Port-au-Prince and in smaller towns surrounding the epicenter such as Jacmel, Carrefour, Léogâne, Petit-Goâve and Gressier. Fatality estimates from the United Nations, the International Red Cross and the Haitian government have settled around 200,000, though the final number may not be known for many months. At least three million people, nearly one-third of Haiti's entire population, were affected by the earthquake. According to some estimates, it may take upwards of ten years for earthquake-stricken areas of Haiti to be rebuilt. Based on data from the United States Geological Survey (USGS), this is the third deadliest earthquake to strike the globe since 1900 (See appendices A, B and C).



The figure below is a simulated distribution of casualties from the Impact Forecasting catastrophe model.



Seismological Recap

Tectonic Settings of Hispaniola

The island of Hispaniola (comprised of Haiti and Dominican Republic) lies at the eastern part of the Gonave microplate bounded by two mega plates: the North American Plate (NAP) to the north, and the Caribbean Plate (CP) to the south. The boundary between these large plates is geologically very complex as shown in Figure 1.

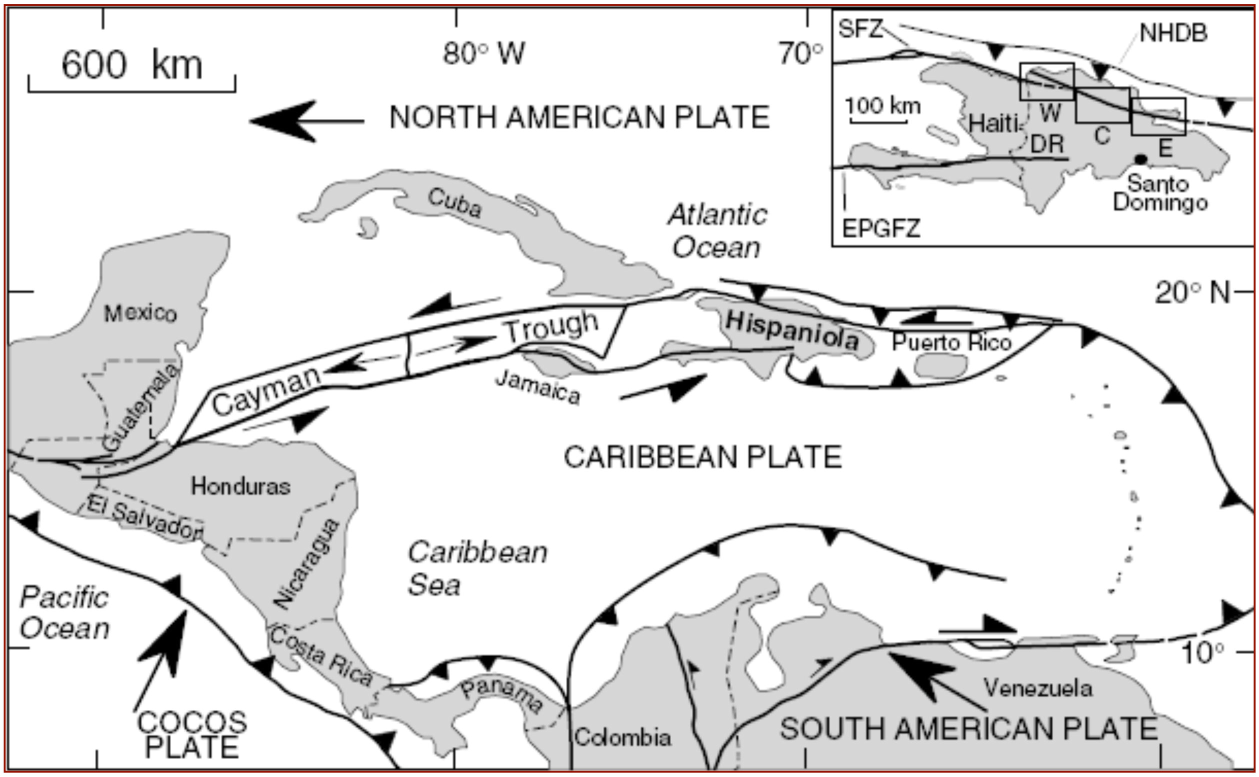


Figure 1. Map showing tectonic setting of the Caribbean region (and Hispaniola, inset). Large arrows show motion relative to a fixed Caribbean plate. Smaller half arrows show relative motion across major strike-slip faults. Inset shows enlargement of Hispaniola. SFZ, Septentrional fault zone; NHDB, North Hispaniola Deformed Belt; EPGFZ, Enriquillo-Plantain Garden fault zone; DR, Dominican Republic. Rectangles show Western (W), central (C), and eastern (E) portions of Cibao Valley. (Credit: Prentice et al., 2003, JGR; Tuttle et al, BSSA 2003)

There are two parallel zones of strike-slip faults (i.e. either sides of the fault move past each other) bounding Hispaniola (Figures 1 and 2). The northern zone, called the Septentrional Fault (SFZ), extends along the northern coast of Haiti to southern Cuba and continues to the Oriente Fault in Jamaica and along the Cayman trough to Central America. The Enriquillo Fault is the second major left-lateral strike-slip fault in Hispaniola. It continues to the west with the Plantain Garden Fault in Jamaica and is known as the Enriquillo-Plantain Garden Fault Zone (EPGFZ). The Enriquillo Fault ends abruptly in south-central Hispaniola (Figure 2). The two zones merge near the Mid-Cayman spreading center in the Cayman Islands.

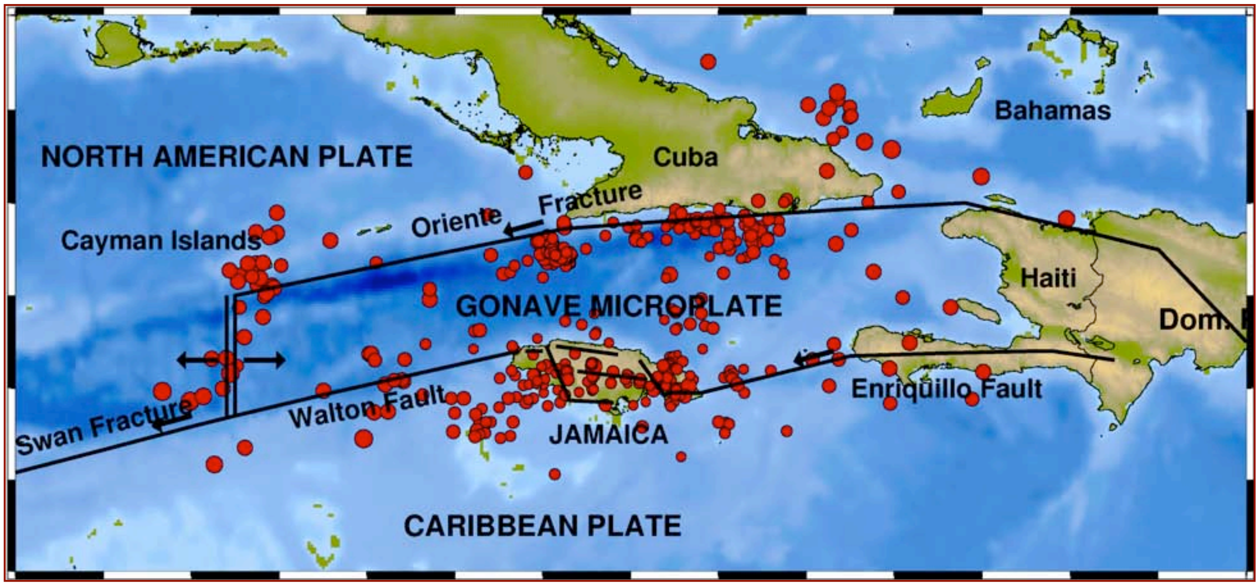


Figure 2. Location of the two major strike-slip faults bounding the Gonave microplate. Red dots are locations of earthquakes within and around the Gonave microplate. (Credit: http://www.mona.uwi.edu/earthquake/jaequake.htm)

The January 12, 2010 Magnitude-7.0 Haiti Earthquake

The magnitude-7.0 earthquake from January 12th, 2010 is the largest earthquake to occur on the EPGFZ over the last 250 years. This crustal earthquake occurred at a very shallow depth (approximately six to eight miles (10 to 13 kilometers) on a 70-degree north-dipping strike-slip fault about two miles (three kilometers) from the Enriquillo Fault and 15 miles (24 kilometers) from the highly populated city of Port-au-Prince. The fault has been recognized for many years as a potential hazard to cities in that region and is well exposed in Haiti. The fault is marked by a 120-mile (200-kilometer) long narrow valley situated in an east-west orientation passing south of Port-au-Prince. There are similarities between this fault and the San Andreas Fault in California in structure and character, as both are strike-slip faults. However, the EPGFZ and San Andreas Fault systems are part of different plate boundaries and not directly linked. The focal mechanism of the January 12th earthquake in Haiti, as reported by USGS, is consistent with the geology of the fault (left-lateral strike-slip).

Analysis of aftershock distribution shows propagation of rupture predominantly to the west from the main shock with the rupture length estimated at approximately 30 miles (50 kilometers) (Figure 3a). The red colors in Figure 3b show the increase in potential of near-future earthquakes, including aftershocks, as a result of the magnitude-7.0 January 12th earthquake. The potential of earthquakes occurring in that area is measured by what is called Coulomb stress. The larger the Coulomb stress, the greater the chance of a possible earthquake occurrence.

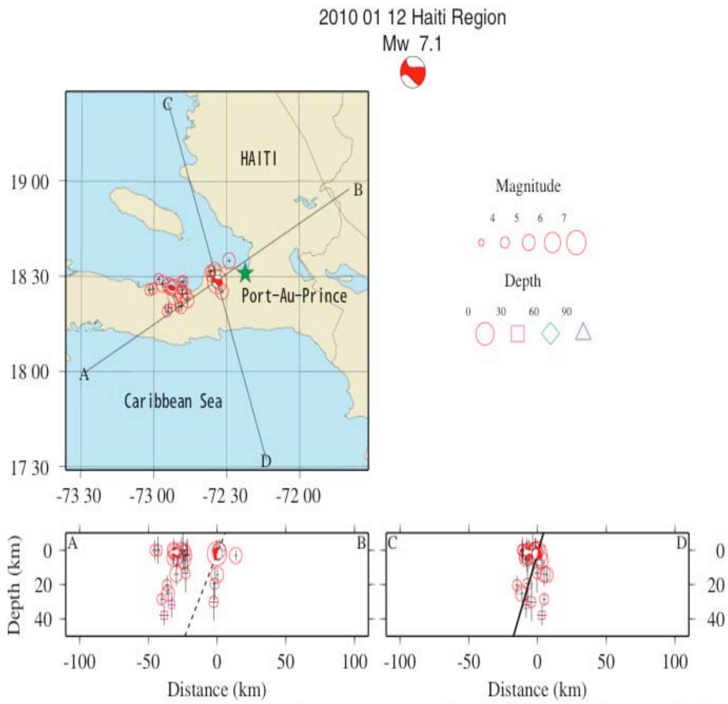


Figure 3(a). Aftershock distribution and two vertical cross sections along A-B and C-D lines, which are perpendicular to strikes of the two nodal planes, are shown. Two nodal planes are shown by lines in cross sections. The nodal plane corresponding to the fault plane is shown by thick solid line in the C-D cross section. (Credit: Nobuo Hurukawa, http://iisee.kenken.go.jp/special/20100112haiti.htm)

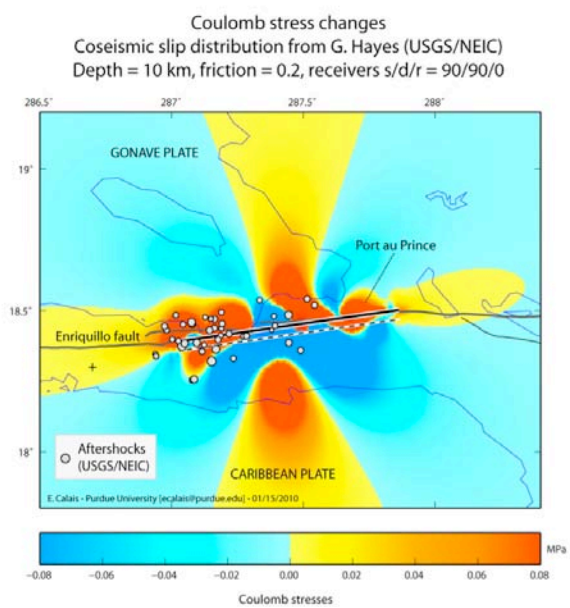


Figure 3(b). Changes in Coulomb failure stresses caused by the magnitude-7.0 earthquake on January 12th, 2010. Red areas have been brought closer to rupture. Note that the aftershocks concentrate at the western end of the rupture, in an area where the model predicts an increase in Coulomb failure stress. (Credit: Eric Calais; http://web.ics.purdue.edu/~ecalais/haiti/)

No tsunami was caused by this earthquake, as the Enriquillo Fault extends down the length of the southern peninsula of Haiti and does not go offshore until it reaches the western tip of the peninsula (Figure 2). For this reason, the ruptured part of the fault only affected land areas. In addition to the severe ground shaking, another source of hazard came from triggered landslides, as many poorly constructed residential houses were built on the steep mountain slopes that form the southern part of Port-au-Prince and the city of Pétionville.

Haiti Population Exposure and Peak Ground Acceleration (PGA) during the January 12th earthquake

Haiti has an extremely high population density, particularly in the cities of Port-au-Prince, Jacmel, Carrefour, Léogâne, Petit-Goâve and Gressier. According to exposure data from the USGS, an estimated 2.5 million people felt Extreme or Violent shaking from the magnitude-7.0 earthquake (X and IX on the Modified Mercalli Intensity Scale). (See figures 4 and 5).

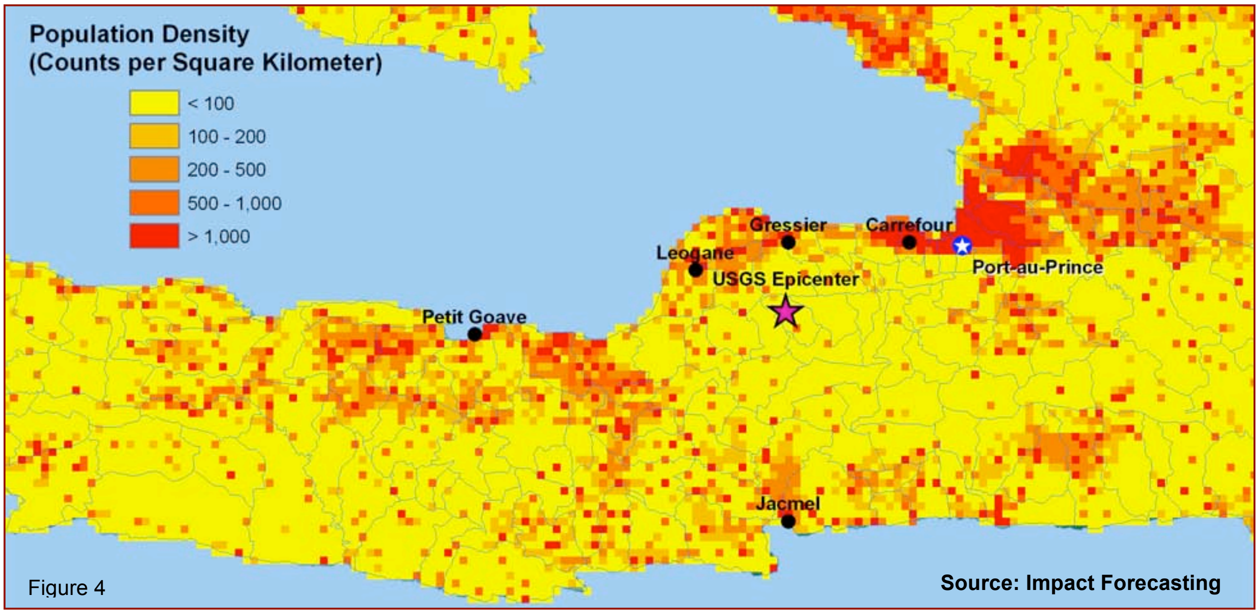


Figure 4

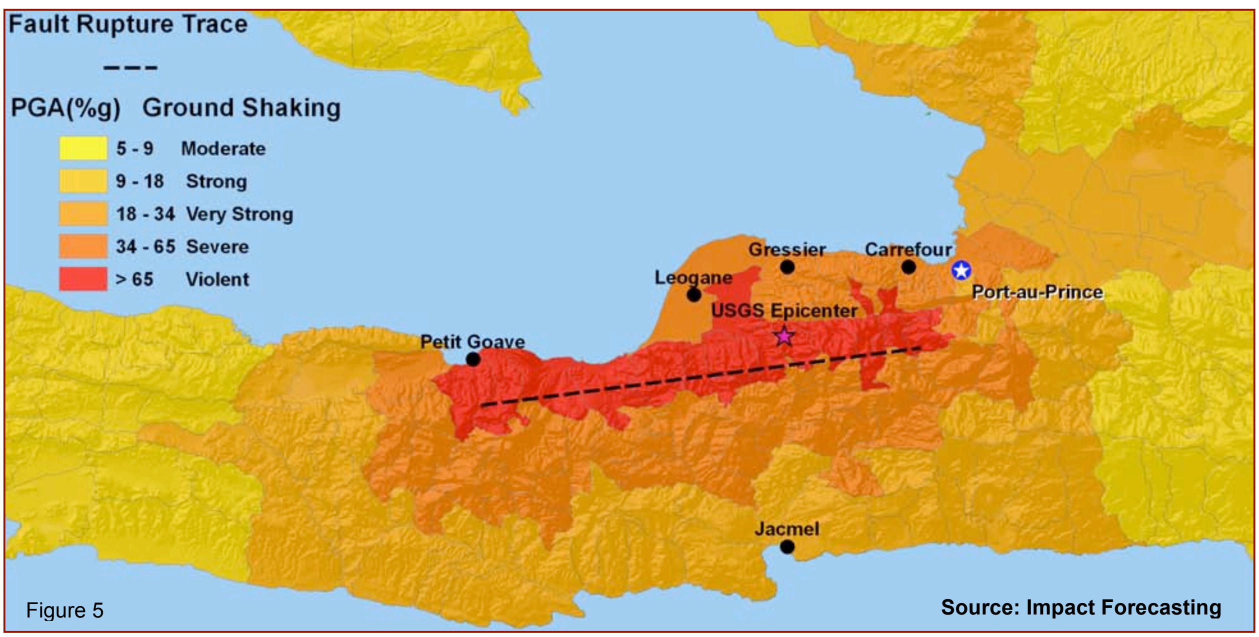


Figure 5

Historical Seismicity and Future Seismic Potential

Global Positioning System (GPS) studies have shown that the Caribbean Plate (CP) is moving east-northeastward at a rate of 0.59 to 0.91 inches (15 to 23 millimeters) per year relative to the North American Plate (NAP), implying oblique convergence between the two large plates (Figure 6). The plate motion is partitioned into strike-slip motions and convergence. Both the Septentrional Fault Zone (SFZ) and the Enriquillo-Plantain Garden Fault Zone (EPGFZ) accommodate strike-slip motion. The NAP moves southward under the CP across the offshore North Hispaniola Deformed Belt (NHDB) in Figure 1 (inset). Convergence is responsible for the uplift of the Hispaniola Island at approximately 9,842 feet (3,000 meters).

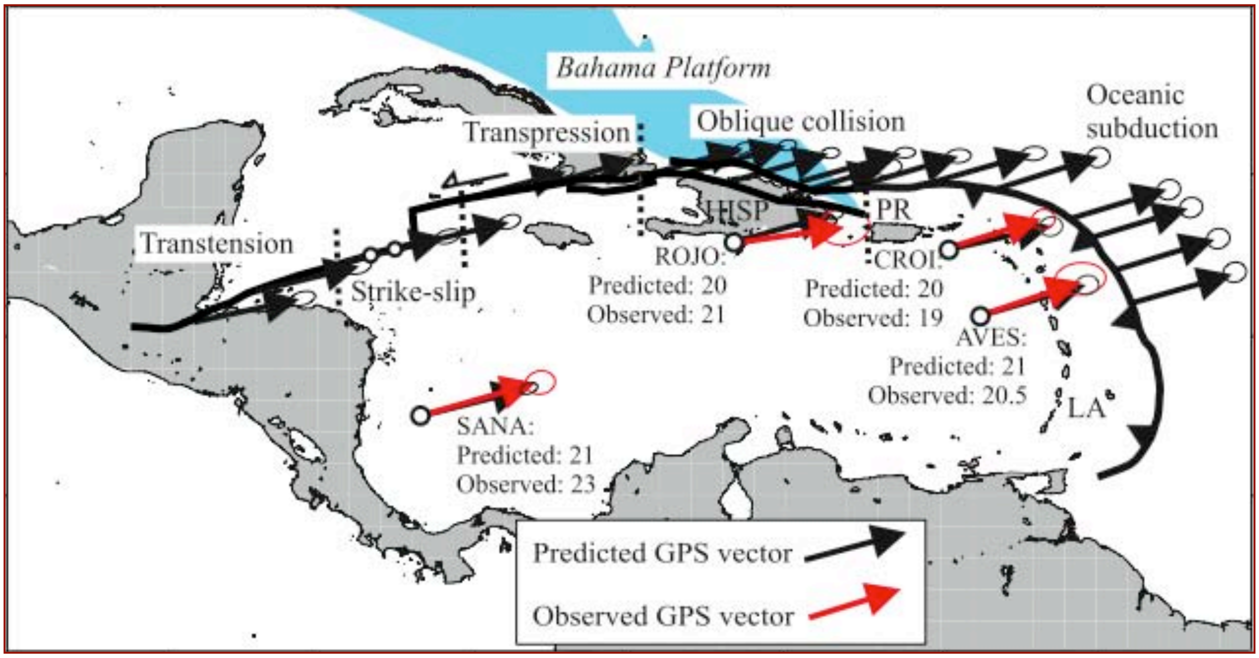


Figure 6 Caribbean-North American plate velocities (prediction and observed using GPS). (Credit: Mann, EOS, 2004).

There are ample scientific studies of the SFZ, while there are only limited studies of the EPGFZ. GPS and trenching studies across the SFZ estimate a slip rate of 0.24 to 0.47 inches (six to 12 millimeters) per year based on offsets of Holocene (a geologically recent period) stream terraces risers. These studies also found evidence for a penultimate event circa A.D. 1200 in the central Cibao Valley (Figure 1, inset) of the Dominican Republic. A slip rate of 0.24 to 0.47 inches (six to 12 millimeters) per year combined with an elapsed time of 800 years since the penultimate event on the SFZ suggests that enough strain energy has accumulated since A.D. 1200 to generate an earthquake greater than magnitude-7.0 (e.g. Manaker, 2008, GJI). There has not been any previous fault trenching along the EPGFZ, meaning that scientists do not have a comparable paleoseismic estimate of earthquake repeat times along this fault (Mann, 2004, The University of Texas, at Austin). However, the slip rate from GPS data on the EPGFZ, although less well constrained, is on the order of approximately 0.28 inches (seven millimeters) per year.

Hispaniola and Puerto Rico have experienced at least eleven large (magnitude-7.0 or greater) earthquakes over the past 250 years, mostly distributed over the subduction zone between the Caribbean and North American plates and on the two major strike-slip fault systems (SFZ and EPGFZ) within the Gonave Microplate (Figures 2 and 7). These events show evidence for time-space progression on the strike-slip SFZ (1842, 1887) and EPGFZ (1751b in Figure 7, 1770) faults and along the subduction contact (1787, 1943, 1946, 1953 and 2003). This suggests possible triggering relationships amongst earthquakes within each fault system. For example, the alternate timing of events on the EPGFZ (18th century) and SFZ (19th century) faults suggests activity on one may temporarily suppress activity on the other.

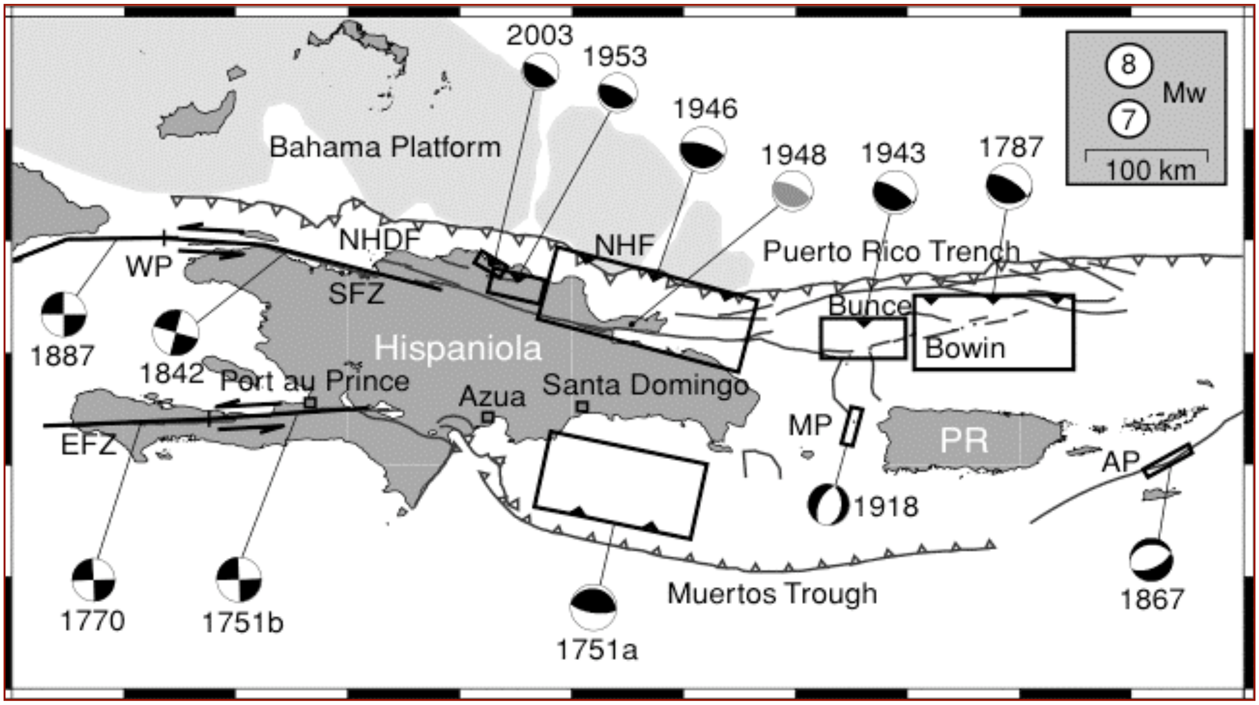


Figure 7. Map showing the focal mechanism and surface projection of estimated rupture planes/geometry for large (magnitude > 7.0) historic and recent magnitude-6.5 earthquake in the region since 1751. NHDF, North Hispaniola Deformation Front; NHF, North Hispaniola Fault; WP, Windward Passage; EFZ , Enriquillo Fault Zone; Septentrional Fault Zone; MP, Mona Passage; PR, Puerto Rico. (Credit: Ali et al. GJI, 2008)

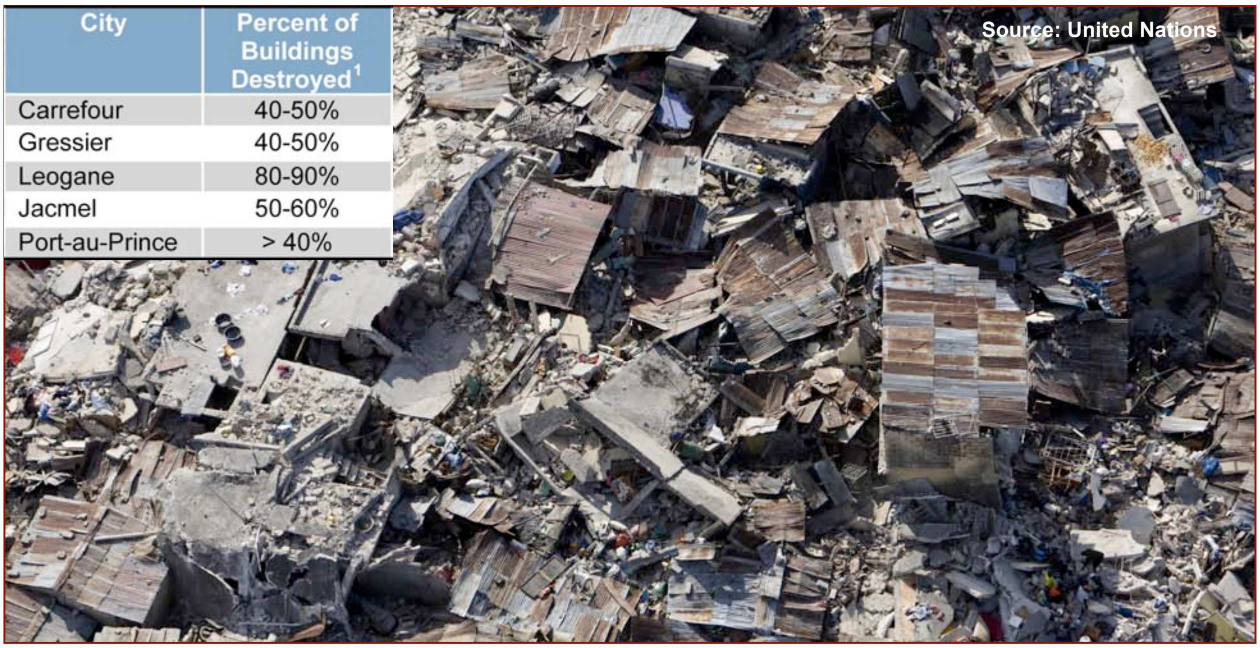
The 1751b (magnitude-7.5) earthquake, a major event following the 1751a (magnitude-8.0) event, occurred on the EPGFZ and is to have ruptured 93 miles (150 kilometers). The magnitude-7.0 earthquake in 1770 on this same fault is believed to have occurred in Haiti west of the 1751b earthquake and also similar in rupture length. With its last major event in 1751, the EPGFZ in Haiti was predicted to be capable of a magnitude-7.2 event today (Manaker and others, 2008). The EPGFZ has not been investigated in detail with paleoseismological methods and the penultimate event (or a recurrence time) for that fault is not known.

The SFZ running offshore Haiti (with its latest largest event in 1842) is capable of a magnitude-6.9 event today. Paleoseismological studies indicate that a recurrence time of 1,100 to 1,250 years is necessary to produce an event of similar magnitude as the magnitude-8.0 earthquake from 1842. Part of the SFZ in the Cibao Valley of the Dominican Republic is capable of magnitude events of 7.5 to 7.7. With 770 to 960 years since the last major ground-rupturing earthquake and at least an 800- to 1,200-year maximum repeat time between major earthquakes, the SFZ represents a source of high seismic potential for the Dominican Republic.

Property Effects

Reports indicate that widespread substantial damage occurred throughout Port-au-Prince. According to a report from the United Nations, at least 50% of all homes and buildings in the city were destroyed and that another 25% were damaged beyond repair. Nearly every sector of the country sustained damage. Well-built governmental buildings also sustained heavy damage, including the National Palace, the National Assembly, Parliament, the Finance Ministry, the Ministry of Public Works, the Ministry of Communication and Culture, the Palace of Justice, the Tax Office and a main prison. Numerous foreign embassies were severely damaged or destroyed as well. Other notable destroyed buildings included the five-story headquarters of the United Nations Stabilization Mission in Haiti (MINUSTAH) at the Christopher Hotel, the Hotel Montana, the offices of the World Bank and Citibank, three Doctors Without Borders medical facilities, eight hospitals, the Caribbean Market, Castel Haiti, the Port-au-Prince Central Cathedral, the Superior Normal School, the National School of Administration and the Aimé Césaire Institute.

City	Percent of Buildings Destroyed[1]
Carrefour	40-50%
Gressier	40-50%
Leogane	80-90%
Jacmel	50-60%
Port-au-Prince	> 40%



Source: United Nations

Outside Port-au-Prince

Towns to the west and south of Port-au-Prince such as Jacmel, Carrefour, Léogâne, Petit-Goâve, and Gressier also sustained extensive and catastrophic damage. Due to severe damage to roads in and out of Port-au-Prince, detailed assessments have not been taken by relief groups. Initial reports indicate that around 90% of the buildings in Léogâne (population 134,000) were destroyed along with 50% and 80% of the buildings in the towns of Carrefour (population 442,000) and Gressier (population 25,000). In Petit-Goâve, major damage was reported, and 2,000 of the town's 12,000 population sustained injuries. In Pétionville, a wealthy suburb of Port-au-Prince, damage was less widespread, though a hospital and a low number of homes and buildings still collapsed.

Foreign effects

In the neighboring country of the Dominican Republic, buildings shook in the capital of Santo Domingo, but no major damage was reported. In both Cuba and Jamaica, the earthquake caused ground shaking, though there have not been any reports of structural damage.

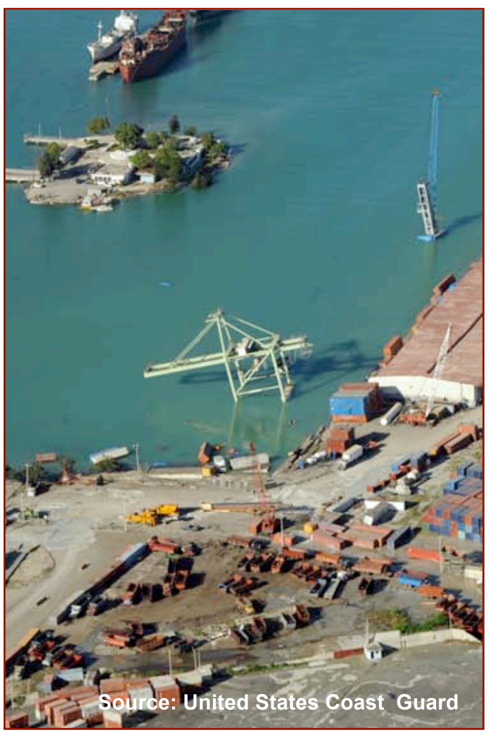
Utility Effects

Source: United Nations

Significant damage to communications occurred, hampering relief efforts. Haitian government officials, foreign relief workers and local residents struggled to make or receive any phone calls for the first 48 to 72 hours as both main cell phone towers and numerous power poles and power lines were downed. According to Haiti's largest cellular server, Digicel, service was extremely limited but operational by January 14th. However, due to the high volume of calls they were receiving, most calls could not get through. Additional utility damage included destruction of underground water and sewage pipes, leading to contamination fears in drinking water.

The damage led to numerous radio stations losing the ability to report news and information throughout Port-au-Prince and the surrounding communities. The Committee to Protect Journalists reported that the offices of Radio-Tele Ginen had been destroyed, while radio stations Melodie FM, Radio Caraibes, Signal FM and Radio Metropole suffered only minor damage and were still functioning. However, due to the widespread death and injuries, Haitian journalism as a whole was affected as many employees were simply unable to work.

Infrastructure Effects


Source: United States Coast Guard

The earthquake brought widespread damage to the transportation infrastructures including the airport, seaport and roads. At the Toussaint L'Ouverture International Airport, the main control tower was seriously damaged and was unable to be used. The main runway sustained cracks but was able to be fully utilized. Air traffic control was unable to navigate incoming or outgoing aircraft for the first 48 hours after the main tremor. The United States Air Force delegated special combat controllers to create a makeshift control tower on the ground to begin directing private and commercial aircraft that were transporting aid and victims.

The Port-au-Prince Seaport sustained significant damage. According to officials, damage consisted of the collapse of cranes (see picture) and containers into the water, structural damage to the pier and an oil spill after an underwater pipeline broke. The damage was enough to render the facility unusable for immediate rescue operations. Foreign engineers and aid workers worked quickly to fix the port to enable large ships to arrive and deliver countless medical supplies and food, allowing the port to reopen after ten days. The Killick Seaport, located near the town of Carrefour, sustained minor damage, but the port was too small to handle large international ships. The Gonaïves Seaport, located to the north of Port-au-Prince, did not suffer damage and remained operational through the period.

Highway and road damage was also widespread, but the majority of the road problems came from the tremendous amounts of debris and bodies blocking any potential passage.

Insurance Market Effects and Insured Loss Estimates

While there is not yet a clear indication as to what the insured losses may be, a minimal amount of insurance in the region have kept the loss expectations low. Haiti's main catastrophe insurer, the Caribbean Catastrophe Risk Insurance Facility (a regional fund administered by Caribbean governments), announced that it will provide approximately US$8 million, though only little recovery from private insurers is expected. However, economic losses are likely to be at least in the low single-digit billions of dollars (USD). Actual numbers may not be known for months as damage assessments are expected to linger for the foreseeable future. In addition, there are likely to be losses from foreign nationals in the Accident and Health lines.

Source: United Nations

Fire Following Earthquake

While there are likely multiple occurrences of fire ignition throughout Port-au-Prince and the surrounding regions, there is no evidence of widespread conflagration. This is further evidenced by a review of MODIS satellite fire ignition data for the week following the main shock (see Appendix D).

Background on Haiti

Economic conditions

Haiti is the poorest country in the Western Hemisphere, as nearly 80% of the population lives below the poverty level. Widespread corruption within the government normally involves humanitarian aid being pocketed by authoritative officials. According to recent estimated statistics, Haiti's 2008 Gross Domestic Product (GDP) was US$11.59 billion after sustaining a 2.3% growth from 2007. When breaking down the GDP by sector, 52% comes from services, 28% from agriculture and 20% from industry. At least two-thirds of all Haitians depend on the agriculture sector (primarily small-scale subsistence farming) and remain vulnerable to damage from frequent natural disasters, exacerbated by the country's widespread deforestation. Statistics indicate that 3.6 million people are part of the work force, even though more than two-thirds of these people do not have formal jobs. On average, most Haitians live on a US$2 dollar-per-day income. The Haitian government offices rarely releases any economic data, therefore foreign countries normally have to rely on estimates from the United States Agency for International Development (USAID).

Construction
As is the case with many nations throughout the Caribbean, there are little to no building codes in Haiti. Due to such widespread poverty, most contractors are not able to afford large amounts of concrete (much of which is imported from the United States). Due to this reasoning, it is possible that many contractors tend to cut corners by adding sand into the cement mix, leading to a structurally weaker building. Also, the high cost of steel normally leads to contractors not using reinforcing steel bars with the concrete or using the bars incorrectly. In addition, few homes have wood framing, mainly due to the extremely limited supply of lumber due to mass deforestation.

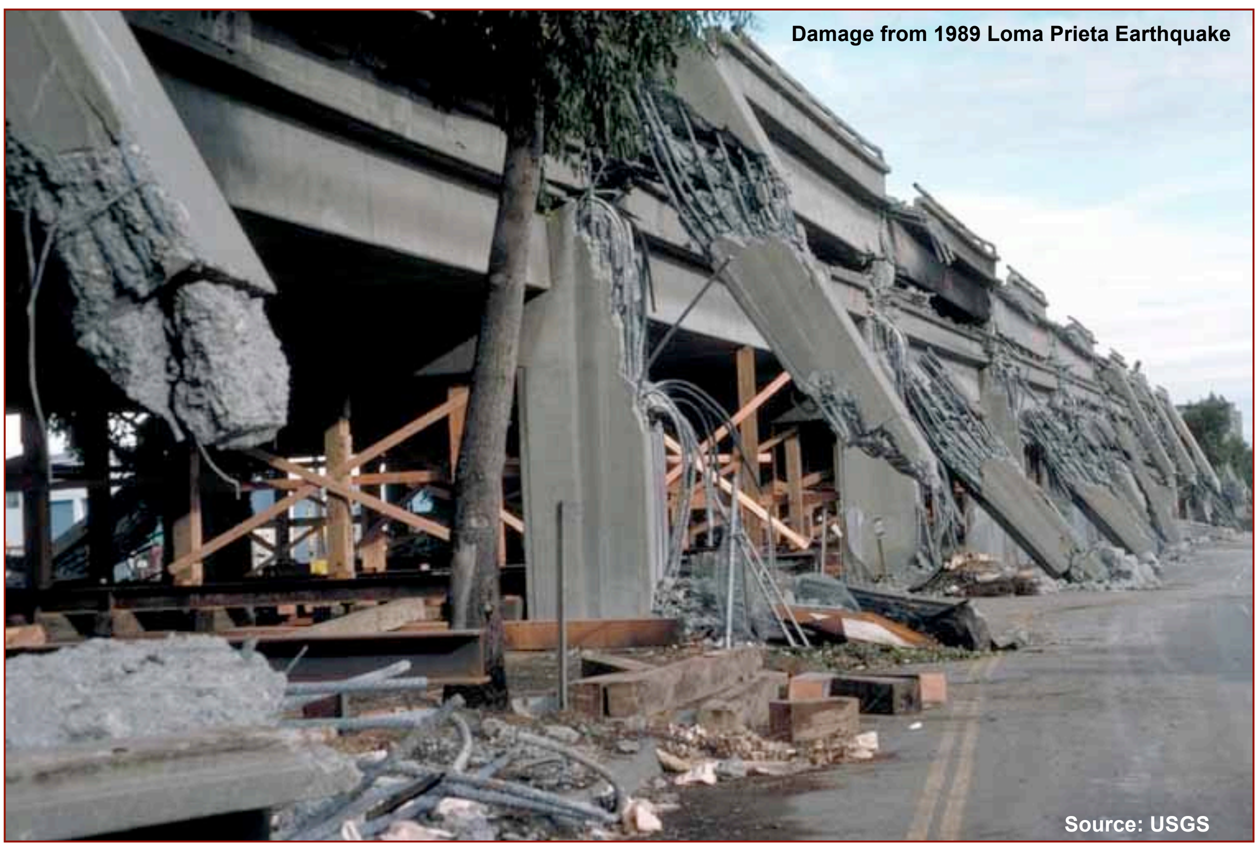
After the January 12th earthquake, engineers reviewed photos of some of the collapsed multi-story structures and noted that most had slender columns supporting heavy concrete slabs. These photos also confirmed that the amount of steel reinforcement in many cases was minimal, if it was present at all. This type of construction is consistent with areas that are not earthquake-prone, where the structure is expected to carry only vertical loads such as those due to the weight of the building material. However, earthquakes shake structures both horizontally and vertically along with torsion. With slim columns and little reinforcement, the columns in Haiti's structures crumbled as they lacked the shear and bending strength. Engineers indicated that higher-strength columns would have been needed to resist the earthquake forces, but they also would have needed to be properly connected to the beams or floor slabs with additional steel bars running from the columns into the beams to provide continuous transfer of the forces from one structural element to another.

Historical Perspective

Comparing the similar 1989 magnitude-7.1 Loma Prieta earthquake to the magnitude-7.0 Haiti earthquake:

On October 17th, 1989, a magnitude-7.1 earthquake struck the San Francisco Bay Area in California. The Loma Prieta earthquake was a shallow strike-slip event on the San Andreas Fault, very similar in size and rupture properties as the Haiti earthquake that ruptured a portion of the Enriquillo-Plantain Garden fault system. The earthquake left 63 people dead, 3,757 people injured and 51,000 housing units and 2,600 businesses damaged or destroyed. The tremor caused severe damage throughout the San Francisco Bay Area, most notably on unstable soil in San Francisco and Oakland as well as other communities located in Alameda, San Mateo, Santa Clara, San Benito, Santa Cruz and Monterey counties. Major property damage in San Francisco's Marina District (60 miles (97 kilometers) from the epicenter) resulted from liquefaction of soil used to create waterfront land. Other effects included sand volcanoes, landslides and ground ruptures. The earthquake caused around US$10 billion (2009 USD) in property damage and became one of the most expensive natural disasters in U.S. history at the time. It was the largest earthquake to occur on the San Andreas Fault since the historic 1906 San Francisco earthquake.

When comparing the causes for the damage during the 1989 Loma Prieta and the 2010 Haiti quakes, the differences are rather stark. The majority of the Loma Prieta structural damage occurred due to soft soils that amplified ground shaking to damaging levels and caused liquefaction of sandy artificial fills. Seismologists and engineers noted that the strong shaking was amplified by a factor of two by soft soils that caused damage at up to 60 miles (100 kilometers) from the epicenter. As with all California earthquakes, instrumental recordings of the ground shaking were used to improve the existing building codes and, in this particular case, how to better design for site amplification effects from soft soils. The limited number of casualties caused by the event is testimony to the continuous improvement of building codes with every major earthquake. In contrast and as previously mentioned with the Haiti earthquake, the majority of the damage resulted from poor construction and the total lack of building code requirements.



Damage from 1989 Loma Prieta Earthquake

Source: USGS

Appendix

Appendix A

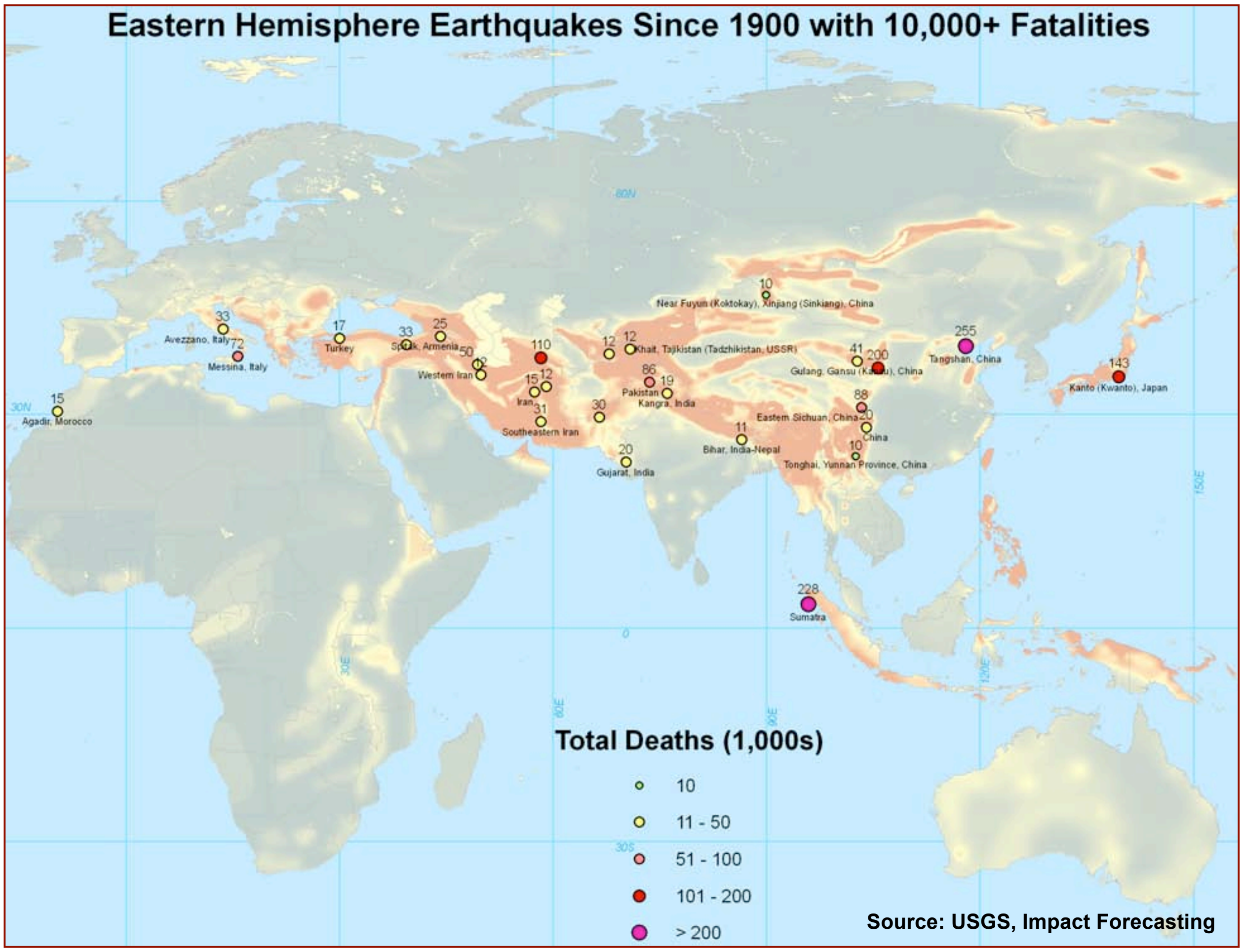
Table including the largest recorded earthquakes since 1900[1]

Earthquakes with 10,000 or more Deaths (since 1900)				
#	Date	Name/Location	Deaths	Magnitude
1	July 27, 1976	Tangshan, China	255,000	7.5
2	December 26, 2004	Sumatra, Indonesia	227,898	9.1
3	**January 12, 2010**	**Haiti**	**200,000**	**7.0**
4	December 16, 1920	Haiyuan, Ningxia (Ning-hsia), China	200,000	7.8
5	September 1, 1923	Kanto (Kwanto), Japan	142,800	7.9
6	October 5, 1948	Ashgabat (Ashkhabad), Turkmenistan (Turkmeniya, USSR)	110,000	7.3
7	May 12, 2008	Eastern Sichuan, China	87,587	7.9
8	October 8, 2005	Pakistan	86,000	7.6
9	December 28, 1908	Messina, Italy	72,000	7.2
10	May 31, 1970	Chimbote, Peru	70,000	7.9
11	June 20, 1990	Western Iran	40,000 to 50,000	7.4
12	May 22, 1927	Gulang, Gansu (Kansu), China	40,900	7.6
13	December 26, 1939	Erzincan, Turkey	32,700	7.8
14	January 13, 1915	Avezzano, Italy	32,610	7.0
15	December 26, 2003	Southeastern Iran	31,000	6.6
16	May 30, 1935	Quetta, Pakistan (Baluchistan, India)	30,000	7.6
17	January 25, 1939	Chillan, Chile	28,000	7.8
18	December 7, 1988	Spitak, Armenia	25,000	6.8
19	February 4, 1976	Guatemala	23,000	7.5
20	January 26, 2001	Gujarat, India	20,085	7.6
21	May 10, 1974	China	20,000	6.8
22	April 4, 1905	Kangra, India	19,000	7.5
23	August 17, 1999	Turkey	17,118	7.6
24	September 16, 1978	Iran	15,000	7.8
25	February 29, 1960	Agadir, Morocco	12,000 to 15,000	5.7
26	September 1, 1962	Bu'in Zahra, Qazvin, Iran	12,225	7.1
27	July 10, 1949	Khait, Tajikistan (Tadzhikistan, USSR)	12,000	7.5
28	October 21, 1907	Qaratog (Karatag), Tajikistan (Turkestan, Russia)	12,000	8.0
29	January 15, 1934	Bihar, India-Nepal	10,700	8.1
30	January 4, 1970	Tonghai, Yunnan Province, China	10,000	7.5
31	August 10, 1931	Near Fuyun (Koktokay), Xinjiang (Sinkiang), China	10,000	8.0
32	August 31, 1968	Dasht-e Bayaz, Iran	7,000 to 12,000	7.3

[1] **Source: USGS**

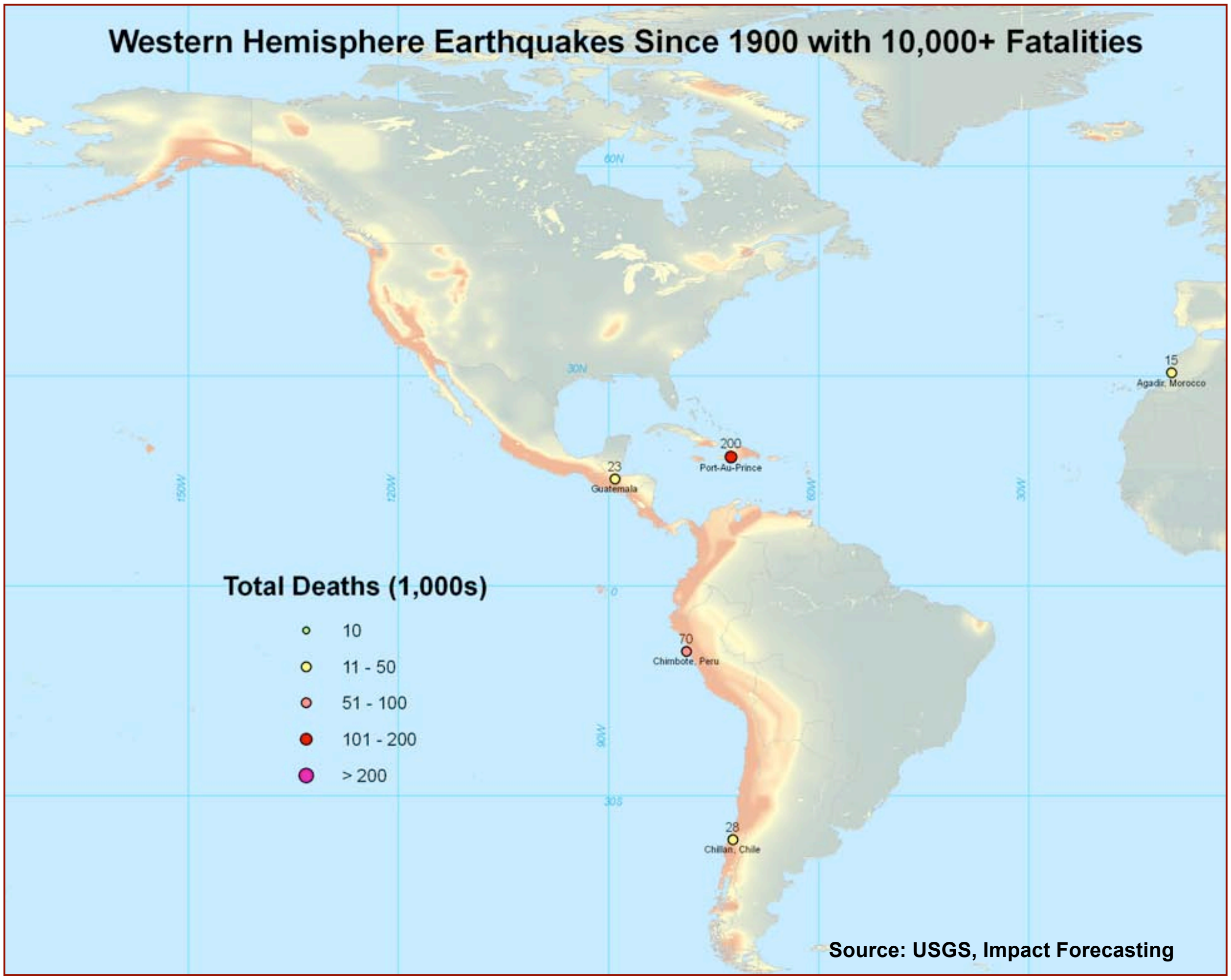
Appendix B

The map below plots the largest recorded earthquakes by fatality in the Eastern Hemisphere since 1900



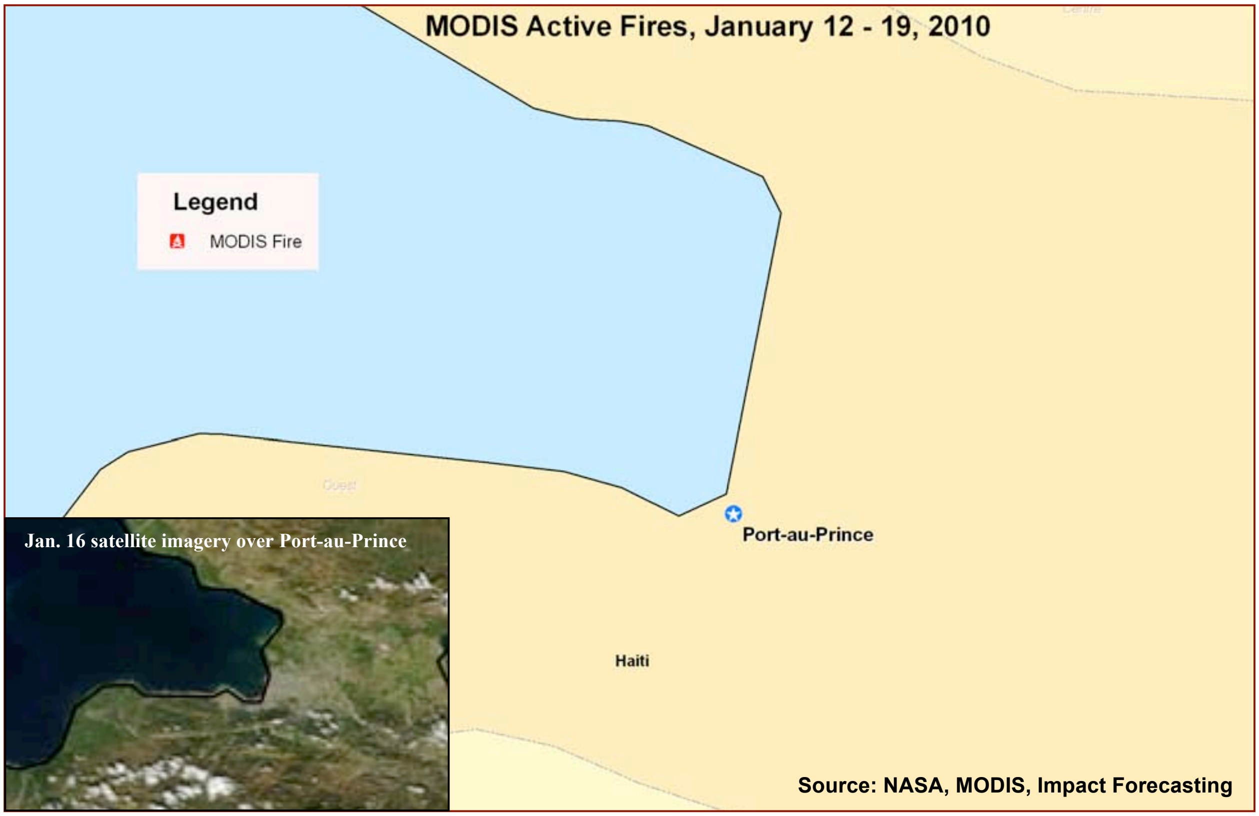
Appendix C

The map below plots the largest recorded earthquakes by fatality in the Western Hemisphere since 1900.



Appendix D

The map below indicates MODIS not recording any significant fires following the main earthquake and subsequent aftershocks between January 12th and the 19th. The inset graphic is a zoomed-in satellite image focused specifically over Port-au-Prince to indicate only isolated cumulus clouds and no smoke clouds.



Event Recap Reports use publicly available data from the internet and other sources. Aon Benfield summarizes this publicly available information for the convenience of clients and Aon Benfield employees.

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