frontiers in Earth Science

ORIGINAL RESEARCH
published: 25 September 2020
doi: 10.3389/feart.2020.542654

A Socio-Seismology Experiment in Haiti

Eric Calais[1,2]*, Dominique Boisson[3], Steeve Symithe[3], Claude Prépetit[4], Bétonus Pierre[4], Sophia Ulyse[4], Laennec Hurbon[5], Alain Gilles[5], Jean-Marie Théodat[6], Tony Monfret[2], Anne Deschamps[2], Françoise Courboulex[2], Jérôme Chèze[2], Fabrice Peix[2], Etienne Bertrand[2], Jean-Paul Ampuero[2], Bernard Mercier de Lépinay[2], Julien Balestra[2], Jean-Luc Berenguer[2], Remy Bossu[7,8], Laure Fallou[7] and Valérie Clouard[9]

[1] École Normale Supérieure, Université PSL, Paris, France, [2] Université Côte d'Azur, Centre National de la Recherche Scientifique, Institut de Recherche pour le Développement, Observatoire de la Côte d'Azur, Géoazur, France, [3] Faculté des Sciences, Laboratoire URGéo, Port-au-Prince, Haiti, [4] Bureau des Mines et de l'Énergie, Port-au-Prince, Haiti, [5] Faculté des Sciences Humaines et Sociales, Port-au-Prince, Haiti, [6] École Normale Supérieure, Port-au-Prince, Haiti, [7] European-Mediterranean Seismological Center, Arpajon, France, [8] Commissariat à l'Energie Atomique, Direction des Applications Militaires, Ile de France, Arpajon, France, [9] Observatoire Midi-Pyrénées, Laboratoire Géosciences Environnement Toulouse, Toulouse, France

OPEN ACCESS

Edited by:
Jenni Barclay, University of East Anglia, United Kingdom

Reviewed by:
Kiran Kumar Singh Thingbaijam, Institute of Seismological Research, India
Max Hope, Leeds Beckett University, United Kingdom

***Correspondence:**
Eric Calais
eric.calais@ens.fr

Specialty section:
This article was submitted to Geohazards and Georisks, a section of the journal Frontiers in Earth Science

Received: 13 March 2020
Accepted: 04 September 2020
Published: 25 September 2020

Citation:
Calais E, Boisson D, Symithe S, Prépetit C, Pierre B, Ulyse S, Hurbon L, Gilles A, Théodat J-M, Monfret T, Deschamps A, Courboulex F, Chèze Jô, Peix F, Bertrand E, Ampuero J-P, Mercier de Lépinay B, Balestra J, Berenguer J-L, Bossu R, Fallou L and Clouard V (2020) A Socio-Seismology Experiment in Haiti. Front. Earth Sci. 8:542654. doi: 10.3389/feart.2020.542654

Earthquake risk reduction approaches classically apply a top-down model where scientific information is processed to deliver risk mitigation measures and policies understandable by all, while shielding end-users from the initial, possibly complex, information. Alternative community-based models exist but are rarely applied at a large scale and rely on valuable, but non-scientific, observations and experiences of local populations. In spite of risk reduction efforts based on both approaches, changes in behaviour or policies to reduce earthquake risk are slow or even non-existent, in particular in developing countries. Here we report on the initial stage of a project that aims at testing, through a participatory seismology experiment in Haiti—a country struck by a devastating earthquake in January 2010—whether public or community involvement through the production and usage of seismic information can improve earthquake awareness and, perhaps, induce grassroots protection initiatives. This experiment is made possible by the recent launch of very low-cost, plug-and-play, *Raspberry Shake* seismological stations, the relative ease of access to the internet even in developing countries such as Haiti, and the familiarity of all with social networks as a way to disseminate information. Our early findings indicate that 1) the seismic data collected is of sufficient quality for real-time detection and characterization of the regional seismicity, 2) citizens are in demand of earthquake information and trust scientists, even though they appear to see earthquakes through the double lens of tectonics and magic/religion, 3) the motivation of seismic station hosts has allowed data to flow without interruption for more than a year, including through a major political crisis in the Fall of 2019 and the current COVID19 situation. At this early stage of the project, our observations indicate that citizen-seismology in a development context has potential to engage the public while collecting scientifically-relevant seismological information.

Keywords: earthquake, Haiti, seismic network, risk perception, citizen science

INTRODUCTION

Over the past 50 years, earthquakes have cost about US$ 800 billions, mostly in developed countries, and 1.3 million human lives, mostly in developing countries (Bilham, 2013; EM-DAT, 2020). Faced with these figures, which show no sign of inflection over time, the classic and rational approach to reduce earthquake risk is "top-down" (e.g., UNISDR, 2015). It consists in formulating a scientific discourse—an explanation of the natural phenomenon—then in translating it to the public and decision-makers while adapting the wording to these audiences in order to develop risk awareness and trigger protective measures. In a complementary way, community-based, "bottom-up" approaches are more and more common, but are rarely applied at a large scale. They rely on valuable, but non-scientific, observations and experiences of local populations (e.g., Fischer, 2000; Sim et al., 2017). One would like to believe that these approaches would lead, over time, to changes in behaviour, or even in policies, so that people and property are better protected against a threat that is often known and quantified. However, each major earthquake puts us face to face with the obvious: these changes are slow, or even non-existent. Why?

Disaster risk reduction studies have shown that it is difficult for stakeholders—individuals, their governing bodies, the private sector, etc.—to feel directly concerned by a threat that they do not perceive as immediate (e.g., UNISDR, 2014)—an attitude similar to the one we may have toward death (Théodat, 2013; Théodat et al., 2020). "*The philosopher is the one who learns to die*" says a Michel de Montaigne. Since earthquake disasters occur rarely, the time interval between them within a given territory, a time often longer than a human life, establishes a disconnect between stakeholders and the seismic threat that constantly surrounds them (Moon et al., 2019). The scientific discourse on the reality of the threat—while the Earth is calm!—is listened to passively, even though with sincerity and interest. This holds particularly true in areas where the culture of seismic risk is low—such as Haiti before the devastating earthquake that struck its capital region in 2010 (Bilham, 2010; Desroches, 2011).

Here we report on the initial stage of a participatory seismology project in Haiti (**Figure 1**) that aims at testing whether public involvement can improve earthquake awareness and grassroots protection initiatives. The project investigates under which conditions a community of citizen-seismologists, in a development context, can collect and share information about earthquakes while producing data that is useful for seismologists. Eventually, one could envision a symbiotic relationship between citizen and scientists where it is recognized that one needs the other to reach their goals. The expected project outcomes are the conditions under which such a relationship is reachable and sustainable.

In this paper, we describe the seismic instrumentation put in place and the results of a first survey aimed at collecting information on the perception of earthquakes and on the expectations of citizens in terms of earthquake information.

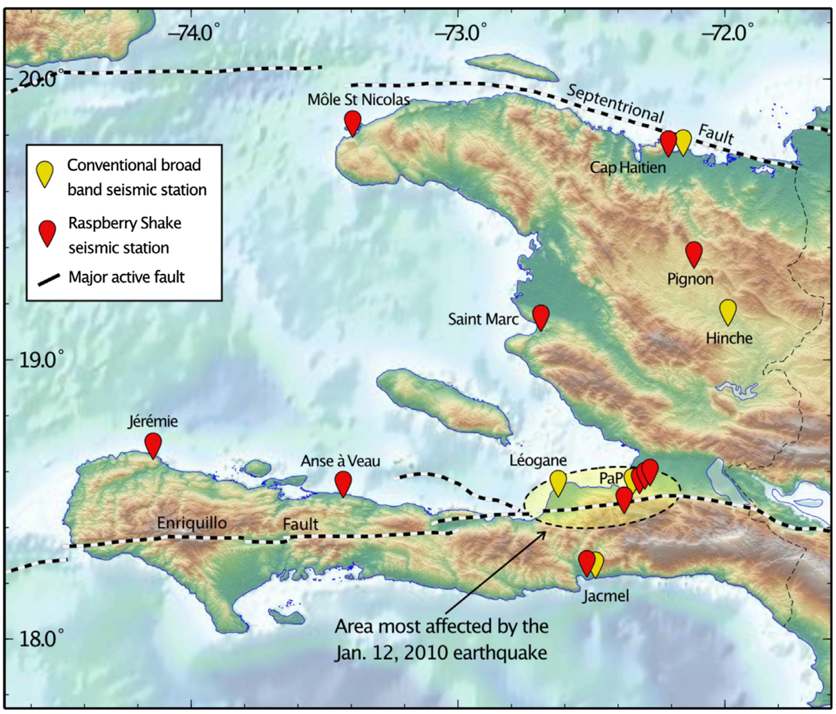

FIGURE 1 | Map of Haiti showing the main active faults (dashed lines), the area most affected by the M7.1, January 12, 2010, earthquake, the location of conventional broadband seismic stations, and the location of Raspberry Shake seismic stations installed to date in the framework of the project described here.

These first steps are key to ensure that 1) the seismic instruments provide data of sufficient quality to produce reliable seismological information, and 2) the information extracted from these data is adapted to the needs and demands of the general public.

CONTEXT

Any geoscientist engaged in research with developing countries knows their chronic difficulty, despite their heightened vulnerability, in maintaining observation networks of environmental variables for the benefit of protecting societies and citizens from natural threats. Complex technology networks are difficult to maintain there because they require sustained technical and financial capacity. This applies to seismic networks, which are expensive mechanical and electronic systems that rely on complex communication protocols. Without constant funding and maintenance, they tend to rapidly fail, so that the information that scientists can provide to the public or to decision-makers may become minimal or even inexistent. These failures, in turn, perpetuate the notion that these networks are, apparently, of little use.

The lack of earthquake information raises the risk of a misunderstanding of what science can do, and perhaps even a public denial of science, which may appear useless since it does not provide a concrete answer to questions as common as "when will the next earthquake take place?". On the other hand, the public is placed in a situation of passivity with regard to the scientific information. Its knowledge of earthquakes progresses little and the threat remains a theoretical possibility not integrated into daily life. Finally, this situation of under-information and/or information provided only by "official" national seismological institutes is conducive to the spread of rumours, false information, and even conspiracy theories. In the end, decision-making in the face of seismic risk may use the rational in a rather limited way. During the 2019 seismic sequence in Mayotte, for example, the lack of communication from the scientific community and the authorities, added to the local socio-cultural context, led citizens to consider false information and conspiracy theories as the only rational explanations in the face of unexplained seismic events and the silence of these authorities. By organizing themselves on the Facebook social network, citizens compiled information and developed their own expertize (Fallou and Bossu, 2019; Fallou et al., 2020).

In developing countries exposed to earthquakes, which are also the most vulnerable to that threat, relying on official institutions for information production and communication has limitations for financial reasons (the state and its donors have limited resources that they must direct to short-term objectives: elections, hunger, poverty, etc.), for reasons of continuity (very fast turn-over within institutions, little or no planning, lack of long-term vision, etc.), and for political reasons (earthquakes are too rare to affect anyone's election, protection is expensive, etc.). Relying only on the scientific community has limitations for financial reasons as well (maintaining networks is expensive and resources are scarce), but also because technical capacity in seismology may be limited, because the available scientific discourse is not suited to public expectations, or because national and international institutions may not be keen on listening about earthquakes when climate change, for instance, appears to be a much more pressing issue.

The situation described above is exacerbated in Haiti, a country affected on January 12, 2010, by one of largest seismic disasters known. In the late afternoon, a Mw7.0 earthquake struck the capital region of Port-au-Prince, killing more than 100,000 people,[1] leaving more than 1.5 million homeless, and destroying most governmental, technical, and educational infrastructure. The event caused an estimated $ 8 billion in damage, equivalent to about 120% of the country's Gross Domestic Product (Haiti Earthquake PDNA, 2010). No earthquake of such moderate magnitude had ever caused so many causalities and such extensive damage (Bilham, 2012). Before that dramatic event, the culture of seismic risk in Haiti was essentially inexistent, even though initiatives from the Civil Protection Agency were in place and scientific information on the hazard level was available (e.g., Manaker et al., 2008). The previous earthquake disaster had occurred 168 years earlier, in 1842, striking the northern part of the country and killing close to half of the population of Cape Haitian (Scherer, 1912).

Following the 2010 event, a national seismological network was set up, maintained by a governmental institution (Bureau of Mines and Energy, BME), which currently operates five broadband seismic stations (**Figure 1**; Bent et al., 2018). On October 7, 2018 an earthquake of magnitude 5.9 in the north-western part of the country killed 17 people and caused significant structural damage. None of the Haitian seismic stations was functional at the time. As a result, the national civil protection agency and the population had to rely on information from the U.S. Geological Survey, which only reports on events of magnitude greater than 4–4.5 in the region. This illustrates the difficulty of maintaining the operability of such a system and to provide quick and independent information to the public.

It is essential that seismologists monitor earthquakes with high-quality—though expensive—sensors located at carefully chosen sites where environmental noise is minimal, and try to ensure constant real-time data communication, for instance *via* satellite links. However, in the age of social media and participatory science, complementary ways to produce reliable and actionable earthquake information through the involvement of citizens and/or communities are emerging (e.g., Bossu et al., 2018a; Hicks et al., 2019) that warrant further investigation.

The concept of citizen-science has emerged in part as a consequence of the use of professional expertize in the fields of environmental science, and of the tension that arises between expertize and democratic governance (Fischer, 2000). Indeed, analyzing and finding solutions to most environmental issues—seismic hazard being one of them—require training or time that is beyond what most citizens can afford, while the

[1]Estimates vary between 225,000 (SNGRD, 2010), 137,000 (Daniell et al., 2013), 159,000 (Kolbe et al., 2010), and 46,000–8,500 (Schwattz et al., 2017), see also Corbet (2014).

technical expertize required is more and more often perceived by citizens as biased toward risky solutions designed to the advantage of the business and political elites. The participation of citizens in the production of scientific information and in its usage to influence policies is, in theory, a way to reconcile these two propositions, but there is no ideal model for applying this apparently straightforward concept.

For instance, Irvin (1995) argues that the public views on environmental risks is largely overlooked and describes a participatory, dialogical approach where citizens are given a prominent role in environmental risk management—though his argument addresses mostly the social aspects of this issue. Other workers, in particular from development and political economy perspectives, are more sceptical. For instance, Hickey and Mohann (2004) argue that, even though the collection of environmental data by citizens or communities may be of some superficial use, participation approaches in international development practices have not led to much transformative and sustainable progress for marginal peoples because "politics matter." Indeed, environmental issues are dynamically linked to socio-economic ones such as political decision making, poverty reduction, enhancing local democracy, social justice, gender inequalities, etc.

It is only recently that researchers from the broad field of "geosciences," defined here as "physics and chemistry of our planetary environment," have embraced the concept of participatory-, or citizen-science. They have been largely absent from the debate described above, as they also are largely absent from the scene of international development. In seismology, early efforts to bridge basic research with the broader public in a systemic way took place in the framework of education programs in primary and/or high schools (e.g., Cantore et al., 2003; Levy and Taber, 2005; Courboulex et al., 2012). These programs paved the way for the design of affordable and low-maintenance seismic instruments, as well as for the realization of the scientific value of the data they produce (e.g., Anthony et al., 2018; Calais et al., 2019; Schlupp et al., 2019). But the contextualization of such efforts in the broader scheme of risk perception and management, of socio-economic development, or of public policies is rarely accounted for in seismology-driven projects.

The experiment described here aims at using affordable and low-maintenance seismic instruments to go one step further by 1) involving seismologists in development science, taking advantage of the fact that they are—by design!—interested in long-term (>10 years) observations, as opposed to the short-term nature of most international development projects, and 2) using *Raspberry Shake* (RS) instruments as a sort of "alibi" to probe how citizens of a developing country perceive their seismological environment and how to best work with them in order to build a mutually-beneficial relationship between (seismological) science and society.

That community participation in data or knowledge production enhances risk perception—although it is a tenant of most citizen-science projects—is of course not granted. Enhancing risk perception continues to be at the core of international efforts to reduce environmental risks as increasing public understanding should develop a "culture of risk" (e.g., UNISDR, 2015) and stimulate individuals and communities to take appropriate protective actions (Twigg, 2004). However, this apparently simple logics must face the highly variable values and priorities of people and communities exposed to environmental hazards across cultures, socio-economic classes, genders, etc. (Löfstedt and Frewer, 1998).

For instance, there are evidence that higher-income countries tend to be more sensitive to risks arising from human actions (nuclear, pollution, etc.) while they also tend to underestimate the risks of natural hazards (Johnston et al., 2013; Yamori, 2013). In low-income countries, most poor and vulnerable people live in permanent risk and uncertainty—economic, political, social, etc.—and therefore struggle to determine a future. But if there is no future—ultimately no real world—then the very notion of risk disappears (Hurbon, 2014). In Bangladesh, a country particularly exposed to flooding, Jabeen and Johnston (2013) show that "people do not distinguish between hazards and other life stresses, but instead prepare for a range of possible negative events" and have developed a range of simple coping strategies that allow them to continue living in highly exposed areas.

Cultural influences also play an important role (Solberg et al., 2010) as risk perception is a matter of choice and interpretation of reality rather than open-page reading in a world of unambiguous codes (Théodat, 2010). In Haiti, the pervasive presence of vodoo likely affects risk perception, though in ways that have not yet been investigated (Hurbon, 2014). One may forecast the coexistence of an objective register—where the earthquake is a telluric reality—with a magical and religious one—where scientific reality is absent but that nevertheless provides other ways to cope with hazards and uncertainties.

Clearly, the factors that shape hazard perception are multiple—lack of awareness of infrequent high impact events, poverty, gender inequality, political and economic stresses, etc. The project described in this paper will attempt to better understand the multiplicity of those factors and the interactions between them, using low-cost seismic stations as a way to engage citizens in a dialog with scientists. As this early stage of the project, this paper aims at describing its motivations and setup, as well as the results of a first a baseline survey on earthquake and risk perception.

METHODOLOGY

Our objective is to test, through a participatory seismology experiment, whether citizen or community involvement through the production and usage of seismic information can improve earthquake awareness and, perhaps, induce grassroots protection initiatives. This experiment is made possible by 1) the recent launch of very low cost seismological stations with minimal maintenance (RS,[2]), 2) the relative ease of access to the internet, even in developing countries such as Haiti, 3) the

[2]https://raspberryshake.org.

possibility to distribute information through simple smartphone applications that anyone can handle, 4) the existence of social networks as a way to share and disseminate information. A similar initiative using RS instruments is on-going in Nepal, focused on schools (Subedi et al., 2020, submitted).

This project[3] is exploratory in nature as we are embarking on a direction that has not yet been systematically investigated. Indeed, if several hundreds of these very low-cost seismological stations exist in the world, there is not yet an integrated scientific study of their impact both on regional seismological knowledge or on the perception of seismology and seismic risk amongst their hosts. It is different from a classic community-based approach to risk reduction because it includes a significant scientific element through the usage of RS seismometers. Putting citizens at the core of a scientific project, while placing scientists in a position of support, is not a natural process. There is no guarantee that this strategy will gain support amongst the public, especially in a development context, but it is important to learn from it both on the standpoint of the usability of the RS instruments and of the perception of risk. Addressing such issues implies research at the boundary between seismology and social/behavioural sciences.

The seismology part of the project consists in installing RS stations in collaboration with citizens, collecting and processing the resulting data, and making information on earthquake locations and magnitudes available to the public in quasi-real time. The sociology part of this project was intended to capitalize on the availability of RS stations for a low price and of this quasi-real time information on earthquakes. We had envisioned to constitute two groups of individuals, one equipped with RS instruments and duly informed of their significance, the other group unequipped and uninformed. This would allow us to evaluate, over time, the impact of using the RS and receiving privileged information on the perception of earthquake and the associated risk. We identified two groups around Léogâne (very much affected in 2010) and Cap Haïtien (high risk but no recent earthquake), to be surveyed by master students from the Faculty of Social Sciences of Port-au-Prince. Unfortunately, the deplorable political and security situation in Haiti from September to December 2019, almost directly followed by the COVID19 sanitary crisis, did not allow students to travel to the provinces. We therefore decided to set up an alternative methodology in order to obtain a minimum of sociological data usable for our project. We put together, distributed, and analyzed an online questionnaire (in French and in Creole) in order to collect quantitative information on the perception of earthquakes and the citizens' information expectations. The form was built collaboratively by seismologists and sociologists—the first tangible interdisciplinary collaboration within the project.

Online surveys have indeed become increasingly prevalent in research inquiries, though they should comply with "good practices" in order to be efficient, useful, and ethical (e.g., Buchanan and Hvizdak, 2009; Alessi and Martin, 2010; McInroy, 2016). The online methodology we used considered the most likely platform to be available/easy to use for respondent (a simple Google form). We made sure that the questions would be understandable by the broadest audience by first testing them on a pilot sample of students from all disciplines. We optimized the content through a series of iterations on the list of questions and their specific wordings between the sociologists and seismologist of the project. In order to maximize response rates, we used the 10th anniversary of the January 12, in 2020, earthquake to disseminate information about the questionnaire as widely as possible. We did so by using the main national media as well as social platforms such as Facebook and WhatsApp, which are the two most widely used ones in Haiti. We made sure that the survey format was simple and usable on a simple smartphone, without photos or videos that would affect the respondents' bandwidth, and that it could be answered in less than 15 min. As the January 12, 2020, earthquake has been—and remains—traumatic for a number of Haitians, we introduced as a first question "*I do not wish to answer this questionnaire because I am still too affected by January 12, 2010*." Finally, the survey was designed to be entirely anonymous.

We are well aware that such an online survey necessarily samples the Haitian population in a biased manner, as it favours a social class that has easy access to the internet, is literate and urban, and is motivated enough to respond. Indeed, the literacy rate in Haiti is 53%, the unemployment rate 41%, and the percentage of the population below the poverty line (living with less than US$ 3/day) 51%. We tried to reduce the sampling bias by administering the questionnaire in the streets of Port-au-Prince during the week of January 12, 2010, targeting popular neighbourhoods.

FIRST RESULTS

Seismology

Interacting with citizens requires that we are able to use the information they produce to determine earthquake locations and magnitudes in near-real time on the Haitian territory. This is especially important when events are felt by the population. Since it was unrealistic to try and convince individuals to acquire a RS station and become part of a project that had not even started, we purchased 15 RS4D seismic stations that we installed at private homes across the country (**Figure 1**). The only required condition was access to electricity and internet, though we prioritized some locations in order to optimize the network geometry. Given that the objective of the project is to test a citizen seismological network, we did not make much efforts to ensure that the site noise conditions were optimal. The stations are placed on the ground floor of the house, often in the living room, in a place as far as possible from environmental noise disturbances (**Figure 2**). We deliberately did not provide training to the hosts, as we hope to observe if/how the presence of a RS stations may lead them to spontaneously requests more information earthquakes, preparedness, etc., and under what format.

So far, the hosts are volunteers known to the project participants. We aim at diversifying the host population in order to increase the number of stations, but also the number

[3]"Socio-Seismology of earthquake Risk in HAIti," acronym "S2RHAI."

FIGURE 2 | Example of a Raspberry Shake (RS) station installed in Jérémie (**Figure 1**) with its host on the right, M. Guild Mézile, a local farmer. The instrument is placed on the ground floor of his home, with good access to electricity—thanks to a local generator—and to the internet. Steeve Symithe is pointing at the RS station, with the internet modem on the floor just behind the host. This station has been up and running 75% of the time since it was installed on September 11, 2019. Written informed consent was obtained from the individuals for the publication of any potentially identifiable images or data included in this article.

of individuals with whom we can interact—or who can interact with each other *via* social media. In order to stimulate this interaction, we created a WhatsApp group dedicated to the hosts, as this media is one of the most prominently used in Haiti. The group, with currently 30 participants, is intended to share information produced by hosts and other citizens that can be verified and certified by scientists. We have observed that this generally quiet group becomes very active as soon as an earthquake is felt, with immediate requests for information. On the other hand, there is little activity in the absence of a felt earthquake. How to best use this down-time to keep hosts—and eventually the general public—engaged is a yet unsolved question, part of our upcoming research objectives.

We developed an automated system for rapid and automatic earthquake detection and location/magnitude determination. The system, called "Ayiti-séismes" is portable and meant to be transferred to Haiti. It is based on developments implemented at the Géoazur laboratory[4] to display regional earthquake information in the south-east of France. First, we developed a VPN software that we installed on each RS station in order to allow for real-time data recovery *via* the "seedlink" protocol. The data still also flows to the open-access OSOP server, the default procedure for RS stations worldwide, but our additional link ensures a better control of the data flow. Second, we implemented a server that aggregates data flows in real time from 11 RS stations, 3 broadband stations in Haiti, and 14 regional stations in the Dominican Republic, Jamaica, Cuba, Bahamas, and Puerto Rico whose data are publicly available. Third, we configured an automated near-real-time detection system based on the SEISCOMP3 software (Weber et al., 2007). Automatic detection can be quite complex with RS stations, whose noise level can vary significantly from one station to another as well as during the course of a day. We are continuing to investigate how to optimally parameterize this system in the context of Haiti.

Finally, we installed a web server for disseminating the information through a simple, interactive, map interface where earthquake locations and magnitudes are readily visible[5]. This interface also provides quantitative information to seismologists such as visualization of the seismic traces and statistics on the quality of detections. This server has been continuously operational since August 1, 2019. Each earthquake detected and automatically characterized first appears as "not yet confirmed." It is then checked and validated, or rejected, by a seismologist.

We used the August 1 to December 31, 2019, time interval for an initial assessment of the performance of Ayiti-séismes by comparing its location and magnitude (M) determinations with those of the Haitian seismological network (BME) and of the Loyola Polytechnic Seismological Observatory (OSPL) in the Dominican Republic (**Figure 3**). The latter is mainly focused on the south-eastern part of the island (Rodriguez et al., 2018). Within the "Haiti" region (17.04–1.41°N; 71.48–76.31°W), the

[4]http://sismoazur.oca.eu.

[5]http://ayiti.unice.fr/ayiti-seismes/.

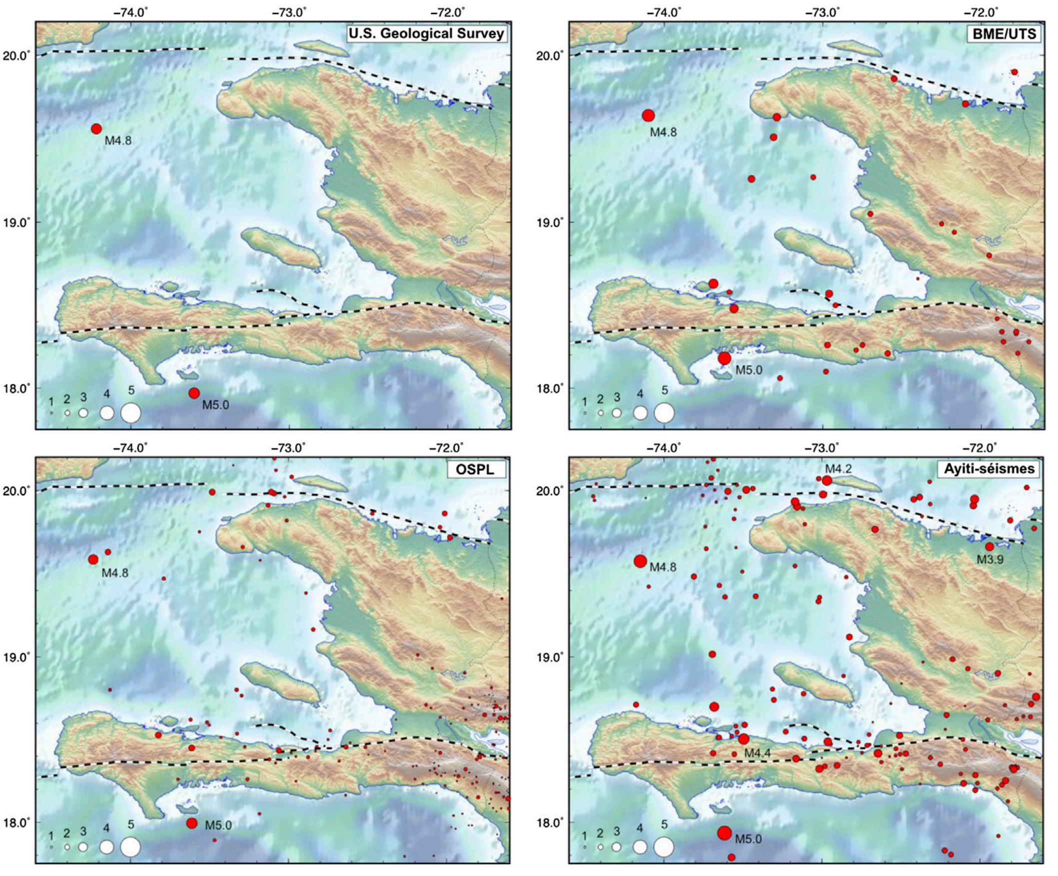

FIGURE 3 | Comparisons of earthquake locations for the August 1, 2019 to December 31, 2019 time interval. Top right: the U.S. Geological Survey uses a global distribution of seismic stations and, for the Haiti region, reports events with magnitude greater than 4–4.5. Top left: the Haiti Bureau of Mines and Energy uses its broadband stations (**Figure 1**) and several other regional stations. During the time interval considered here, their operations were severely affected by the political crisis in Haiti, which limited the number of events they could detect. Bottom-left: the Loyola Polytechnic Seismological Observatory (OSPL) in the Dominican Republic uses their own stations in the southern part of their country, which explains the larger number of detections in the south-eastern corner of the map. Bottom right: Ayiti-séismes uses Raspberry Shake and broadband stations in Haiti, as well as 20 other regional stations. Its magnitudes may be slightly overestimated, as discussed in the text.

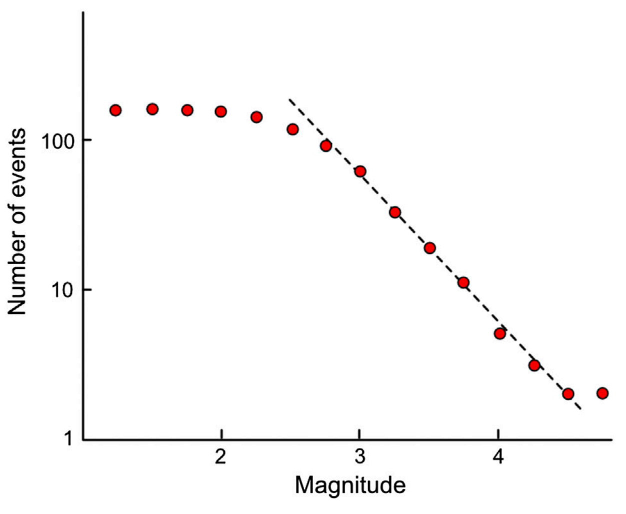

FIGURE 4 | Number of Ayiti-séismes determinations as a function of magnitude illustrating a completeness magnitude between 2.5 and 3 Mlv.

BME reported 33 events (2.2 < M < 4.8), OSPL 246 events (0.6 < M < 4.4), and Ayiti-séismes 146 events (1.5 < M < 5.0). Of the 33 BME events, 31 were detected by the OSPL and 29 by Ayiti-séismes. During the same time interval, the U.S. Geological Survey reported only two events (M4.8 and M5.0).

The difference between the OSPL and Ayiti-séismes catalogues concerns, 89% of the time, events of magnitude 0.5–2.25 that are located in the southernmost part of the Dominican Republic, where the OSPL seismological stations are concentrated. These earthquakes are currently undetectable by Ayiti-séismes. Event locations are consistent within 25 km between Ayiti-séismes and OSPL, but can differ from those of the BME by up to 90 km. As both Ayiti-séismes and BME use the IASPEI91 global seismic velocity model, whereas OSLPL uses a more suitable regional model (Rodriguez et al., 2018), we assume that the location differences with BME are the result of the smaller number of seismic stations they use. We also observed that the Ayiti-séismes magnitudes are systematically larger than those of OSPL. Resolving this issue requires discussions with network operators to ascertain the instrumental responses and attenuation equations they use.

In summary, the installation of RS stations in Haiti, coupled with permanent regional seismic stations and the implementation of an automated, quasi-real time, earthquake detection and characterization system provide rapid seismological information for any earthquake of magnitude greater than ~2.5 (**Figure 4**), down to events of magnitude 1.5–2.0 under certain conditions. The current limitations of this system are the small number of RS stations currently in operation and the discontinuous availability of broadband station data from the Haitian seismic network (**Figure 1**). Regarding the former issue, it is not trivial to find hosts who can provide continuous electricity and internet everywhere in Haiti. In addition, road conditions and insecurity prevented repairing internet access at some stations or installing instruments at locations where hosting had been established. Some of these difficulties are shared with conventional seismic networks, but in several cases of RS misfunction it only took an email to the host to reboot the RS and solve the issue—an advantage of using plug-and-play technology and involving hosts in station management.

Earthquake Awareness and Vulnerability

The on-line survey described above received a total of ~1,000 responses, most of them within a week of the questionnaire being announced. We gathered an additional ~200 responses from administering the questionnaire in the streets. Again, we acknowledge the bias introduced by the on-line sampling methodology, but as no previous similar survey has been performed in Haiti, to our knowledge, its results nevertheless provides important elements that will help us—and perhaps other similar projects elsewhere—better understand the perception of earthquake risk, at least within the section of the Haitian population sampled here. We summarize hereafter the preliminary findings of this survey.

A Trauma Still Present

Field investigators reported that a significant number of citizens contacted on the streets did not wish to answer the questionnaire. This is partly explained by a lack of time, but also by a desire not to plunge back into the past trauma. This is corroborated by the fact that 2% of the respondents answered the first question "I do not wish to answer this questionnaire because I am still too affected by January 12, 2010," thus interrupting their participation. One percent refused to answer for "other reasons." We can hypothesize that a larger number of people refused to answer the questionnaire altogether for that same reason, without even going through this first question. Despite the trauma still present, interest in the subject is noticeable among the respondents, with more than 90% answering that they are "interested in better understanding earthquakes." This interest was also reported by the field investigators who noted that the respondents were eager to speak about earthquakes. This is confirmed by the length of the write-ups in the open questions.

Lessons Learned From the January 12, 2010 Earthquake

Ninety one percent of the respondents experienced the January 12, 2010, earthquake. While 53% declared that they understood that it was an earthquake, a large percentage did not understand what was going on. Some thought of "the end of the world" (11%), "a divine punishment that had befallen us" (3%), or that "our contract with Earth had ended" (2%). This latter answer was meant for vodou believers, for whom there is an actual contract between mankind and nature, brokered by the vodou spirits (or "loas"). The profile of the respondents and the mode of survey may underestimate the importance of such religious beliefs.

When asked about the cause of earthquakes, 92% of the respondents chose "the movement of tectonic plates," 15% "American military experiments," 6% "oil drilling," and 5% "divine anger." The responses also point to alternative explanations that fall either in the mystical or conspiracy areas. Sometimes plate tectonics and an alternative explanation were answered together by the same respondent. There is therefore a certain level of ambivalence in the understanding of the seismic phenomenon.

Sixty five percent of the respondents believe that the likelihood of an earthquake similar to that of 2010 during their lifetime is "very high" (42%) or "high" (23%). Only 9% consider it "low" or "very low." This awareness is confirmed by the fact that earthquakes are perceived as one of the main risks in Haiti, together with insecurity and violence, political instability, health risks, and cyclones. The vast majority of the respondents answer that they know better than before the 2010 event the safety instructions to follow before, during and after an earthquake. This knowledge seems mainly disseminated by the scientific community and the media, not by political, educational or religious institutions. All in all, it appears that the January 12, 2010, earthquake significantly raised the awareness of seismic risk and understanding of earthquakes in Haiti.

A Need for Information

Consistent with the risk awareness improvement noted above, 93% of the respondents want more information about earthquakes. They prioritized customized, actionable information such as earthquake-resistant construction rules, what to do during an earthquake, or which areas are the most at risk. Such information can indeed be applied directly by individuals in order to implement protection measures for their own safety. It is unclear whether such information would actually be put to use by individuals, but this suggest that they may consider acting to reduce their own risk. When it comes to information after an earthquake, the most popular requests are in the categories of "where to get help," and "how to help." Information on the earthquake itself or the aftershocks are not the priority. Here again, the need for actionable information dominates over the need for scientific information.

When asked about the means they would use to find information in the case of an earthquake, the respondents show voluntarism, declaring that they would not only use traditional means [radio (54%), TV (59%), press (54%)] but also social networks (29% for Facebook and Twitter) and WhatsApp (40%), making themselves not only consumers but also producers of information.

Distrust Toward the Authorities

When asked which sources of information they trust most, the respondents rank "scientists" and "the Bureau of Mines and

Energy" at the top, with, respectively, 78 and 68% of "confidence" or "total confidence." The Government of Haiti only comes in 7th place, after civil protection, international organizations, relatives, and journalists, with 44% or distrust 29% of trust, the remainder being neutral. This is also expressed in numerous open comments that criticize the inaction of the authorities. This distrust in the government is a key element of the political situation in Haiti, caused in part by the weak reaction of the authorities after the 2010 earthquake and an unaccomplished reconstruction phase (Hurbon, 2014) but also, more recently, by a multi-billion dollars corruption scandal and heightened insecurity throughout the country. This permanent turmoil is currently leading to a feeling of chaos amongst the Haitian civil society.

In spite of this, from the respondents' point of view, the solutions to be provided must be national. Eighty percent would like more Haitian scientists to be trained—while only 22% think that more international experts are needed—and 71% want more "measuring devices" to be installed on the national territory. But the respondents also think that "earthquake prediction research" (16%), or "learning how to interpret the signs of nature" (27%) can contribute to understanding earthquakes.

The Place of Religion?

Religious institutions appear not to be trusted very much either. For example, only 6% of the respondents declare to trust or totally trust the vodou associations, with similar numbers for catholic or protestant churches. This result is however likely biased by the survey method, as mentioned above, which did not allow us to properly sample social groups that are more inclined to trust religious institutions. Directive or semi-directive interviews are needed to shed more light on the role of religion and faith in risk perception and understanding. Survey answers show, in a significant number of cases, answers that are dual: there is a scientific explanation, but also a divine one. Understanding how individuals may be able to juxtapose these two views without conflict is an interesting topic for future research.

This juxtaposition of faith and science also happens in places where magic or fiction can lead people to react in a way that can worsen vulnerability. For instance, during the cholera epidemic of late 2010, close to 50 vodou priests were killed by mobs on the accusation that they were using "black magic" to spread diseases.[6] That cholera had been brought to Haiti by Nepalese UN soldiers (Frerichs et al., 2012) was suspected, but not yet demonstrated at the time.

The Place of Women?

Women represent only 35% of the respondents. At this stage of our research, it is unclear why this number is so much lower than men. They were subjected to a higher risk of post-traumatic symptoms (Nemethy, 2010) which may have detracted them from answering the questionnaire. In particular, beyond the earthquake itself, one must account for the sexual trauma endured by a number of them in refugee camps. This should not be underestimated in our future research. In addition, interviews in the streets indicated that they often were less available than men, perhaps because of their role to ensure that daily family logistics is achieved in the Haitian society. A more detailed analysis of their responses to the questionnaire is needed to reveal differences in perception or needs for information. Interviews to come may be an opportunity to establish a more secure framework for collecting their views.

DISCUSSION AND CONCLUSION

As we initiated this project, it was not clear how easy or difficult it would be to find hosts for RS stations and to maintain their interest over many months, or possibly years. We were also unsure of the benefit of RS stations for earthquake locations and magnitude determination in a variety of noise environments. Although access to electricity and internet can be a serious issue in Haiti, we found a significant number of volunteers motivated to host a RS instrument, even though there is no financial support from our side. The seismological analysis of the RS data shows that more stations would be useful, and that redundancy is important: several RS in the same city, for instance, is not a waste as they may not all be operational at the same time. Also, during the difficult months of October and November 2019, when political instability and insecurity locked-up the country causing schools, universities, and most governmental institutions to close—hence official seismic data streams to stop—data from citizen seismometers were flowing at rate no different from the 6-month average. Citizen seismology can therefore be a viable means to alleviate such difficulties and provide continuity in seismological information even under duress.

As for the usefulness of RS stations to complement the existing—but hard to operate and maintain—broadband seismic network, the above analysis demonstrates that they bring valuable information for real-time detection and characterization of the regional seismicity. We also better understand their limitations in terms of sensitivity, as well as the limitation of having only one velocimetric component in high noise environment and with interrupted data flow. With an automatic detection system that is operational, portable to Haiti, and scalable to hundreds of stations (RS and other types), we can now start thinking of how to best interface that information with RS hosts, as well as with the general public, beyond a simple web interface with a seismicity map. Designing such a system will require joined efforts from seismologists and sociologists, informed by more in-depth surveys and interviews.

The online survey, in spite of the bias and limitations discussed above, indicates that the January 12, 2010 earthquake raised seismic risk awareness and the level of understanding of earthquakes amongst the population surveyed. Future directive and semi-directive interview are needed to explore this further, but one may hypothesize that this results from the numerous interventions of trusted scientific figures in the national media in

[6] https://www.bbc.com/news/world-latin-america-12073029; https://www.lemonde.fr/ameriques/article/2010/12/23/cholera-en-haiti-les-autorites-inquietes-de-lynchages-a-mort_1456914_3222.html.

the wake of the event. Indeed, the survey reveals an overall trust of scientists, an information that seismologists should use to further develop opportunities to convey basic earthquake information and seismic risk protection messages. However, the survey also reveals a first-order need for practical and actionable information—protection measures, where to seek help, etc.—whereas scientific information—magnitudes, aftershocks, etc.—is not favored by the respondents. This may be a bit disappointing to seismologists, but likely reflects the fact that what is learned by studying aftershocks or small unfelt earthquakes is too theoretical and remote from the priorities of most citizens. However, the appetite for information on earthquake protection measures is an indication that, if that information was properly packaged and distributed—it is available, but on the internet pages of government institutions—then it may have a better chance of having an impact.

The survey highlights the need for information through internet platforms and tools, which is to be expected in this current day and age. Seismological products (quasi real-time earthquake locations and magnitudes, information on protective measures, etc.) must obviously be disseminated that way, but more work is needed to understand the specific expectations of citizens and communities, in the Haitian context, so that information perceived as relevant is conveyed with an optimal chance of motivating grassroots risk reduction efforts.

The distrust toward the authorities and the government, understandable in the Haitian context, is an indication that government-only initiatives are likely to be insufficient for efficient disaster risk reduction. That respondents point at the inaction of the state is an indication that there may be a place for informed citizen action. In an economic and governance situation such as Haiti, imposing the "building back better" principle systematically and at a large scale is difficult. Increasing awareness through initiatives such as the one described here may create a public demand for more effective policies, and, perhaps more usefully, instigate grassroots initiatives to build better.

The survey highlights other interesting points that cannot be further discussed without directive or semi-directive surveys, such as the juxtaposition of faith and science. We anticipated that the earthquake would be seen through the double lens of tectonics and magic/religion. Our survey provides a hint of this, though its limited social sampling, as well as the methodology used here, likely underestimate this element. In Haiti, the weak state leaves a vacant space—as noted by survey respondents—which is heavily occupied by religious movements. In fact, any social reflection must take into account patterns of thought where rationality can vary significantly from one individual to another, from one group to another. How to insert earthquake science as yet another element, without conflicting or negating other representations of one's environment, remains an open question.

The gender ratio of respondents remains to be understood, especially in a society where women play a structuring role in most families. Interviews in the streets indicate that they often were less available than men, perhaps because of their role to ensure that daily family logistics is achieved. A more detailed analysis of their responses to the questionnaire is needed to reveal differences in perception or needs for information. Interviews to come may be an opportunity to establish a more secure framework for collecting their views.

Our preliminary observations indicate that citizen-seismology in a development context has potential to engage the public while collecting scientifically-relevant seismological information. However, the actual impact of the experiment on risk perception and, in turn, the stimulation of individuals and communities to take protective actions remains be determined. At this early stage of the project, and because of the recent political situation in Haiti, our interaction with target populations and communities have been limited so that measures of success or failure are not yet available. Many questions remain open—Will there be a sustained engagement of citizens in hosting RS stations? How much involvement from seismologists will be needed to develop and maintain interest? How to anchor the potential achievements of a citizen-seismology into long-term policy goals? How should the citizen-seismology model described here should evolve to better fulfill its objectives?

Finally, a citizen-based source of seismological data in Haiti also has the potential for being used in teaching programs. Educational seismic network experiences have shown that local seismic datasets improve the impact of teaching about earthquakes. They also increase the awareness of seismic risk among students who live in a seismically area, especially when events are detected close by, even though those events may not be felt (Courboulex et al., 2012). The ability to detect and report close-by events may have a similar impact on volunteer citizens.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the study containing human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The project concept was developed by EC, with input from all co-authors. The Ayiti-séismes system was developed by JC and FP. The daily verification and relocation of earthquakes has been performed by TM, AD, and FC. The educational aspects of the project are carried out by JB and J-LB. The survey analysis was carried out by LF and LH. The preparation of the manuscript and figures was done by EC. All authors discussed the results, and contributed to the final manuscript.

FUNDING

This research was funded through the CNRS-MITI/IRD program "Risques Naturels," the "Interreg Caraïbe" program of the European Union through the PREST project, and the URGéo "Jeune Equipe Associée de l'IRD" (JEAI) at the Haiti State University supported by the Institut de Recherche pour le Développement (IRD). EC acknowledges support from the Institut Universitaire de France.

ACKNOWLEDGMENTS

We deeply thank the individuals and organizations that are currently hosting RS stations in Haiti, they make a difference! We thank the master students from the Faculté des Sciences Humaines et Sociales of Port-au-Prince, Haiti, for carrying out the survey in the streets of Port-au-Prince. We thank Branden Christensen and the OSOP team for their efficient technical support. We are grateful to two reviewers for their comments that significantly helped improved the original version of the paper.

REFERENCES

Alessi, E. J., and Martin, J. I. (2010). Conducting an internet-based survey: benefits, pitfalls, and lessons learned. *Soc. Work Res.* 34, 122–128. doi:10.1093/swr/34.2.122

Anthony, R. E., Ringler, A. T., Wilson, D. C., and Wolin, E. (2018). Do low-cost seismographs perform well enough for your network? An overview of laboratory tests and field observations of the OSOP Raspberry Shake 4D. *Seismol. Res. Lett.* 90, 1–10. doi:10.1785/0220180251

Bent, A. L., Cassidy, J., Prépetit, C., Lamontagne, M., and Ulysse, S. (2018). Real-time seismic monitoring in Haiti and some applications. *Seismol. Res. Lett.* 89, 407–415. doi:10.1785/0220170176

Bilham, R. (2010). Lessons from the Haiti earthquake. *Nature* 463, 878–879. doi:10.1038/463878a

Bilham, R. (2013). Societal and observational problems in earthquake risk assessments and their delivery to those most at risk. *Tectonophysics* 584, 166–173. doi:10.1016/j.tecto.2012.03.023

Bossu, R., Roussel, F., Fallou, L., Landès, M., Steed, R., Mazet-Roux, G., et al. (2018a). LastQuake: from rapid information to global seismic risk reduction. *Int. J. Disaster Risk Reduct.* 28, 32–42. doi:10.1016/j.ijdrr.2018.02.024

Buchanan, E. A., and Hvizdak, E. E. (2009). Online survey tools: ethical and methodological concerns of human research ethics committees. *J. Empir. Res. Hum. Res. Ethics* 4, 37–48. doi:10.1525/jer.2009.4.2.37

Calais, E. (2017). *Science et conscience dans la Post-urgence du Séisme d'Haïti*. Paris, France: L'Harmattan, 98.

Calais, E., Boisson, D., Symithe, S., Momplaisir, R., Prepetit, C., Ulysse, S., et al. (2019). Can a Raspberry Shake seismic network complement a national seismic network? A case study in Haiti. Eos, 100. doi:10.1029/2019eo123345

Calais, E., Freed, A., Mattioli, G., Amelung, F., Jonsson, S., Jansma, P., et al. (2010). Transpressional rupture of an unmapped fault during the 2010 Haiti earthquake. *Nat. Geosci.* 3 (11), 794–799. doi:10.1038/ngeo992

Cantore, L., Bobbio, A., Di Martino, F., Petrilio, A., Simini, M., and Zollo, A. (2003). The EduSeis project in Italy: an educational tool for training and increasing awareness of seismic risk. *Seismol. Res. Lett.* 74, 596–602. doi:10.1785/gssrl.74.5.596

Corbet, A. (2014). "Invisibles omniprésents. Les morts du séisme, in Catastrophes et environnement, Haïti, séisme du 12 janvier 2010," in *Editions de l'EHESS*. Editors L. Hurbon, Collection « Cas de figure », 29–58. doi:10.4000/books.editionsehess.7320

Courboulex, F., Berenguer, J. L., Tocheport, A., Bouin, M. P., Calais, E., Esnault, Y., et al. (2012). SISMOS à l'Ecole: a worldwide network of realtime seismometers in schools. *Seismol. Res. Lett.* 83 (5), 870–873. doi:10.1785/0220110139

Daniell, J. E., Khazai, B., and Wenzel, F. (2013). Uncovering the 2010 Haiti earthquake death toll. *Nat. Hazards Earth Syst. Sci. Discuss.* 1, 1913–1942. doi:10.5194/nhessd-1-1913-2013

Desroches, R., Comerio, M., Eberhard, M., Mooney, W., and Rix, G. J. (2011). Overview of the 2010 Haiti earthquake. *Earthq. Spectra* 27 (1), S1–S21. doi:10.1193/1.3630129

EM-DAT, Centre for research on the epidemiology of disasters (CRED), School of Public Health, Université Catholique de Louvain, Belgium (2020). Available at: https://www.emdat.be (AccessedMarch 12, 2020).

Fallou, L., and Bossu, R. (2019). Taking into account the cultural context to improve scientific communication—lessons learned from earthquakes in Mayotte. EGU blogpost. Available at: https://blogs.egu.eu/divisions/sm/2019/03/08/taking-into-account-the-cultural-context-to-improve-scientific-communication-lessons-learned-from-earthquakes-in-mayotte/.

Fallou, L., Bossu, R., Landes, M., Roch, J., Roussel, F., Steed, R., et al. (2020). Citizen seismology without seismologists? Lessons learned from Mayotte leading to improved collaboration. *Front. Commun.* 5, 49. doi:10.3389/fcomm.2020.00049

Fischer, F. (2000). *Citizens, experts, and the environment: the politics of local knowledge*. Durham, NC: Duke University Press.

Frerichs, R. R., Keim, P. S., Barrais, R., and Piarroux, R. (2012). Nepalese origin of cholera epidemic in Haiti. *Clin. Microbiol. Infect.* 18 (6), E158–E163. doi:10.1111/j.1469-0691.2012.03841.x

Haiti Earthquake Post Disaster Needs Assessment (2010). Assessment of damage, losses, general and sectoral needs. Available at: http://siteresources.worldbank.org/INTLAC/Resources/PDNA_Haiti- 2010_Working_Document_EN.pdf.

Hickey, S., and Mohan, G. (2004). *Participation – from tyranny to transformation? Exploring new approaches to participation in development*. London, UK: Zed Books.

Hicks, A., Barclay, J., Chilvers, J., Armijos, M. T., Oven, K., Simmons, P., et al. (2019). Global mapping of citizen science projects for disaster risk reduction. *Front. Earth Sci.* 7 (165), 226. doi:10.3389/feart.2019.00226

L. Hurbon (2014). "Catastrophes et environnement, Haïti, séisme du 12 Janvier 2010, collective work under the direction of L. Hurbon," in *Editions de l'EHESS*, Collection « Cas de figure ».

Irwin, A. (1995). *Citizen science: a study of people, expertise and sustainable development*, London, UK: Psychology Press.

Jabeen, H., and Johnson, C. (2013). "Perceptions of climate variability and coping strategies in informal settlements in dhaka, Bangladesh," in *Cities at risk. Advances in natural and technological hazards research*. Editors H. Joffe, T. Rossetto, and J. Adams (Dordrecht, Netherlands: Springer), Vol. 33. doi:10.1007/978-94-007-6184-1_9

Johnston, D. M., Becker, J., McClure, J., Paton, D., McBride, S., Wright, K., et al. (2013). "Community understanding of, and preparedness for, earthquake and tsunami risk in Wellington, New Zealand," in *Cities at risk: Living with perils in the 21st century*. Editors H. Joffe, T. Rossetto, and J. Adams (Berlin, Germany: Springer Science & Business Media), 131–148.

Kolbe, A. R., Hutson, R. A., Shannon, H., Trzcinski, E., Miles, B., Levitz, N., et al. (2010). Mortality, crime and access to basic needs before and after the Haiti earthquake: a random survey of Port-au-Prince households. *Med. Confl. Surviv.* 26 (4), 281–297. doi:10.1080/13623699.2010.535279

Levy, G., and Taber, J. (2005). Shake up your community with the IRIS, seismographs in schools program. *Earth Sci.* 21 (2), 28–29.

Löfstedt, R., and Frewer, L. (1998). *The Earthscan reader in risk and modern society*. London, UK: Earthscan/James & James.

Manaker, D. M., Calais, E., Freed, A. M., Ali, S. T., Przybylski, P., Mattioli, G., et al. (2008). Interseismic plate coupling and strain partitioning in the northeastern Caribbean. *Geophys. J. Int.* 174, 889–903. doi:10.1111/j.1365-246x.2008.03819.x

McInroy, L. B. (2016). Pitfalls, potentials, and ethics of online survey research: LGBTQ and other marginalized and hard-to-access youths. *Soc. Work. Res.* 40, 83–94. doi:10.1093/swr/svw005

Moon, J., Hwang, H., and Chung, J. (2019). Factors affecting awareness of preparedness after moderate earthquakes: an analysis of the Pohang earthquake in Korea. *Disaster Prev. Manag.* 29 (3), 405–420. doi:10.1108/dpm-07-2019-0209

Nemethy, K. (2010). Mental illness and resilience following the Haiti earthquake: an initial assessment. MSc thesis. Paris (France): École des Hautes Études en Santé Publique, 33.

Rodriguez, R. Y., Havskov, J., Sørensen, M. B., and Santos, L. F. (2018). Seismotectonics of south-west Dominican Republic using recent data. *J. Seismol.* 22 (4), 883–896. doi:10.1007/s10950-018-9738-9

Scherer, J. (1912). Great earthquakes in the island of Haiti. *Bull. Seismol. Soc. Am.* 2 (3), 161–180.

Schlupp, A., Chavot, P., Grunberg, M., Bes-De-Berc, M., Jund, H., Ajak, F., et al. (2019). SeismoCitizen: a project combining seismology and human science approaches based on a deployment of a dense low-cost seismic network hosted by citizens. *Geophys. Res. Abstr.* 21.

Schwartz, T. T. (2017). *The great Haiti humanitarian aid swindle*. Scotts Valley, CA: CreateSpace Independent Publishing Platform, 508.

Sim, T., Dominelli, L., and Lau, J. (2017). A pathway to initiate bottom-up community-based disaster risk reduction within a top-down system: the case of China. *Int. J. SAFE* 7, 283–293. doi:10.2495/safe-v7-n3-283-293Google Scholar

SNGRD(Système national de gestion des risques et des désastres – National Risk and Disaster Management Agency) (2010). SNGRD Situation Report 16. Bulletin d'Information du Gouvernement Haïtien – 8 au 12 Mars 2010 (Information Bulletin of the Haitian Government spanning 8th–12th March).

Solberg, C., Rossetto, T., and Joffe, H. (2010). The social psychology of seismic hazard adjustment: re-evaluating the international literature. *Nat. Hazards Earth Syst. Sci.* 10, 1663–1677. doi:10.5194/nhess-10-1663-2010

Théodat, J. M. (2010). Haïti 2010: les leçons d'une catastrophe. *EchoGéo*, 1–5. doi:10.4000/echogeo.11682,Google Scholar

Théodat, J. M. (2013). Port-au-Prince en sept lieux. *Outre Terre* 35–36, 123–150.

Théodat, J. M., Simoens, P. J. M., Sobczak, F., and Cornut, P. (Forthcoming 2020). La perception du risque sismique à Canaan: Haïti 2019. *Revue Haïtienne d'Histoire et de Géographie*.

Twigg, J. (2004). *Disaster risk reduction: mitigation and preparedness in development and emergency programming*. London, UK: Overseas Development Institute (Humanitarian Practice Network, Good Practice Review #9).

UNISDR (United Nations International Strategy for Disaster Reduction) (2014). *Progress and challenges in disaster risk reduction: a contribution towards the development of policy indicators for the post- 2015 framework on disaster risk reduction. Summary and main findings*. Geneva, Switzerland.

UNISDR (United Nations International Strategy for Disaster Reduction) (2015). Sendai framework for disaster risk reduction 2015–2030. Available at: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030 (Accessed March 11, 2020).

Weber, B., Becker, J., Hanka, W., Heinloo, A., Hoffmann, M., Kraft, T., et al. (2007). SeisComP3-automatic and interactive real time data processing. *Geophys. Res. Abstr.* 9, 09219, 2007 ,General Assembly European Geosciences Union.

Yamori, K. (2013). "A historical overview of social representation of earthquake risk in Japan: fatalism, social reform, scientific control and collaborative risk management," in *Cities at risk: living with perils in the 21st century*. Editors H. Joffe, T. Rossetto, and J. Adams (Berlin, Germany: Springer Science & Business Media), 73–92

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.