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From a Seismological Network to a Socio- Seismological One: A Citizen Science Experiment in Haïti to Reduce Seismic Risk

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Appendices are at the end of the article.

Les annexes se situent à la fin de l'article.

From a seismological network to a socio-seismological one: a citizen science experiment in Haïti to reduce seismic risk

Analysis of a "small box" that can do a lot

Abstract

On January 12, 2010, Haiti was hit by one of the largest seismic disasters known to date. At the time, the culture and perception of seismic risk was low among the population and— because of the lack of seismic sensors in Haiti —so was seismological knowledge.

In a citizen seismology approach, the S2RHAï project used low-cost seismic sensors (Raspberry Shake) to (1) complement the national seismic network and (2) to improve risk perception, preparedness, and scientific knowledge of the population. Through these objectives, we introduce a paradigm shift in which seismic networks are not only composed of sensors, but also of citizens who gather around these tools and the information they produce.

We present here the results of a qualitative survey of 15 Raspberry Shake (RS) seismometer hosts in Haiti. Semi-structured interviews were conducted to learn about users' experience to assess their motivations, difficulties, and expectations in this citizen seismology process. We found that RS hosts

expressed pride and interest in being part of the RS network and actively contributing to risk reduction in their community. Some of them reported a form of empowerment in that they could compensate for the deficiency of the state, which they generally distrust. However, the RS hosts also expressed the need for more technical and scientific support from scientists. Also, few of them engaged in mediation activities or discussions with their community members, partly because they feared that this would awaken the trauma caused by the earthquake of 12 January, 2010. This allowed us to list concrete actions to (1) improve the seismic information system, (2) better integrate the volunteers into the network, (3) enrich the collaboration between citizens and seismologists, and (4) accompany them in their role as ambassadors to their community. We conclude that understanding the motivations, obstacles, and expectations of volunteers is essential to increase the chances of sustainability of this citizen seismology project.

Keywords:

Haiti, Raspberry Shake Seismological Network, citizen science, seismology, risk awareness, empowerment

From a seismological network to a socio-seismological one: a citizen science experiment in Haïti to reduce seismic risk

Analysis of a "small box" that can do a lot

Introduction

Haiti shares the island of Hispaniola with the Dominican Republic, at the boundary between the Caribbean and North American tectonic plates (Figure 1). The island is crossed by seismically active geological faults, which regularly cause major earthquakes (Scherer 1912). On January 12, 2010, an event of magnitude 7.0 devastated the metropolitan area of Port-au-Prince, the country's capital city, as well as the communes of Carrefour and Léogane to the west, and Jacmel further south. It caused the deaths of tens of thousands of people and injured hundreds of thousands more (Schwartz, Pierre, and Calpas 2011). The trauma for all those who witnessed the disaster and lived through the terrible following hours, was real and tremendous (Cénat et al. 2017). Many had to move to one of the refugee camps that swarmed the territory. Ten years later, despite the massive presence of numerous aid mechanisms, notably under the aegis of the United Nations (UN) and many nongovernmental organizations (national and international NGOs), traces of the earthquake can still be seen in the landscape. Haiti has not recovered from the 100% GDP loss caused by the earthquake (Haiti Earthquake PDNA 2010). To the contrary, economic, political, and security instability have increased since. In 2012, 58% of the population was living below the poverty line (World Bank 2019) while the country was sinking into a serious socioeconomic crisis marked by scandals (such as that of the PetroCaribe funds) and violence. The president of the republic was even assassinated in his official residence in July 2021, and gangs control access to oil terminals, bringing the country to its knees.

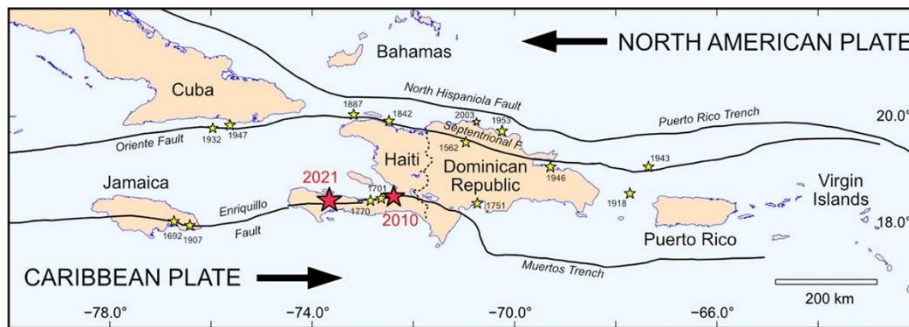


Figure 1: Location map. Haiti and the Dominican Republic share the island of Hispaniola. The black lines indicate the major seismic faults, which accommodate the movement between the North American (north) and Caribbean (south) plates whose relative displacement (2 cm/year) is shown by the black arrows. The most important historical earthquakes in terms of damage are indicated by yellow stars. The red stars indicate the epicenters of the earthquakes of January 12, 2010 and August 14, 2021.

The major disaster of 2010 highlighted a lack of preparedness to face earthquakes in Haiti, on the parts of citizens and scientists alike (Calais 2019). Indeed, seismic risk culture and perception were very low among the population, governance bodies, and their international partners. Moreover, knowledge of local seismicity was also very limited, especially because of the absence of seismic sensors on the national territory, which made seismologists almost blind as to the capacity of geological faults to generate major earthquakes, even though many of those faults were known.

Such a situation is well known to seismologists in developing countries who often face obstacles that are both institutional and scientific (e.g., Bent et al. 2018; Subedi et al. 2020). Indeed, relying on institutions in these contexts has its limits for financial reasons (the State and its donors have limited resources that go primarily to short-term objectives such as food security, poverty, governance, etc.), for continuity issues (the turnover in personnel within institutions is very rapid, there is little to no planning, little or no long-term vision, etc.), and for political reasons (for the electoral candidates, the earthquake is not considered to bring back votes, protecting oneself is expensive, etc.). But relying only on the scientific community also has its limits, again for financial reasons (maintaining the

networks generates significant costs), technical capacity (there are very few trained seismologists in Haiti, for instance), because the scientific discourse is poorly adapted to public expectations, and because of a lack of interest in earthquakes and the associated risks from national and international institutions, especially at times when climate change has taken center stage. However, faced with these difficulties, it remains essential to strengthen seismological networks to collect more scientific data, but also to use social networks to make that information available and effective to the population with the aim of raising awareness and reducing seismic risk. As a whole, the issue is to design a model that will make such a system operational, appropriated by all, and sustainable; and to do all of this with limited State resources or capacities—while strengthening local capacities—and with the help of social networks.

In this context, a multidisciplinary research team combining seismology and social sciences has been deployed in Haiti between 2019 and 2021 within a project named S2RHAI. The aim of S2RHAI was to test the feasibility of an approach in which seismic observations are carried out by distributing small (10x10x5 cm), low-cost and low-maintenance Raspberry Shake (RS) seismometers (Figure 2) to non-scientific volunteers throughout the country: 7 Haitians and 3 foreigners.



Figure 2: Photo of a Raspberry Shake (RS) seismometer installed at a host located in Port-au-Prince. The RS is lying on the floor in a corner of their living room, behind a piece of furniture that hosts a TV and various electronics. The mobile phone gives the scale. The connection to the electricity (black cable) and the internet router (blue cable) can be seen.

Volunteers' recruitment criteria are more detailed in the Appendix 1 on methodology, but included 1) internet and electricity access and 2) homogeneous geographical distribution for earthquake location purposes. Figure 3 shows a map of the RS station hosts: Several are located in the Port-au-Prince area; others are in Jacmel, in Anse-à-Veau, in Saint Louis du Sud, and in Jérémie, which are not far from the Presqu'île du Sud fault, and other RS stations are in Môle St Nicolas and in Cap Haïtien, which are not far from the Septentrional fault.

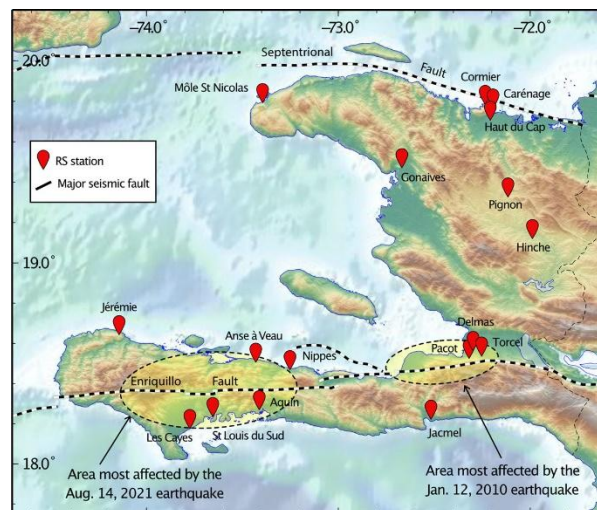


Figure 3 : Map of the location of Raspberry Shake stations in Haiti at the time of the interviews (*red*) and subsequently installed (*yellow*), as of October 24, 2021. Regions affected by the 2010 and 2021 earthquakes are indicated approximately by yellow ellipses.

The results of the data produced by the RS are accessible via a website (<https://ayiti.unice.fr/sismo-ayiti/>), which is equipped with an automatic earthquake detection system. Automatic detections are

then verified and validated by a seismologist. In order to facilitate communication and information sharing, a WhatsApp group has been created with RS hosts and scientists.

Two years after the installation of these RS stations, we can now question the impact of their presence on the hosts. Have they increased the hosts' awareness and knowledge of risk? To what extent do the hosts feel integrated in this new socio-seismological network? Did the RS have an impact on the hosts' community? Are hosts on their way to becoming "ambassadors," spreading earthquake knowledge more widely around them? Finally, our research reflects on doing citizen science in places where the government is unable or unwilling to monitor environmental threats.

Although citizen science is growing, there are not many citizen seismology projects based on low-cost stations (in California, see Cochran et al. 2019; Clayton et al. 2011), and they are usually distributed only in a specific place, like in schools (Subedi et al. 2020), and not to a large sample of different citizens. Our approach increases the reflection on this method and its social significance, especially in a country where access to science and knowledge is complicated (low level of education, deficient state, very disturbed economic context, etc.). Our particular interest is in the fact that seismometers were installed to obtain seismological information as much as to understand the populations that host or live around these tools. The dialogue with the hosts is the basis of the investigation, not an outcome. It seeks to see if it is possible, and under what conditions, for the hosting citizen to be proactively involved beyond just accepting that a seismologist put a device in his home, thus promoting and measuring citizen involvement. We can then speak of co-construction of the project, and of the evolution of the project along with them, as has been imagined several times by researchers and adapted according to projects and research fields (Hernández et al. 2022). Our whole team was keenly aware of the social construction of the research and also of the social analysis of its functioning and of the results (Calais et al. 2020).

Methodology

To address these questions, we conducted semi-structured interviews with 10 hosts in order to learn from their experience and to assess their motivations, difficulties, and expectations (see Appendix 1). The interview consisted of about 40 questions, which were organized around four themes. The first questions asked about the host's profile: who they were, their past experiences, and their previous knowledge of seismology. The second section looked at their experience with the RS they had been hosting: how and why they hosted one and their interest in the device, from maintenance to data collection, including accessing their RS information or the project website. The third part asked about the community dimension of this participation: Were the RSs introduced to visitors or family, for example, or could a sense of belonging to a "scientific community" be identified? Finally, the fourth part was an open space for comments and suggestions from the hosts, with the goal of finding concrete ways of improving their experience.

These interviews, made by phone then transcribed, were analyzed by researchers from different disciplines in order to identify the salient elements we present here. Because of the small number of interviews, the coding method was inadequate. We adopted a very qualitative method revealing people's explicit and implicit discourses by sharing and discussing all transcripts. The cross-disciplinary perspectives of the team's researchers led to a consensus on the major themes expressed by the interviewees.

In this paper, we note the enthusiasm of the hosts and their motivation to host the RSs and to continue with the project. The article will conclude with a discussion of the future of the project, as shaped by this citizen science experience. It shows how the participatory aspect of our approach is really motivating, individually and collectively, especially in the specific context of Haiti, between failed-state and magical world.

A strong enthusiasm for participating in a collective citizen science project

Contributing in the long term and through science, to the development of their country

Research on citizen science shows that its success relies heavily on the motivation of participants (Nov et al. 2011) and on a project's ability to support participants' information needs (Bossu et al. 2018). The interviews reveal that the enthusiasm for participating in the S2RHAI project is fueled by a strong desire to help "develop" the country. The idea conveyed by the hosts is that science and the data it produces can help Haiti advance and ensure its sustainable development. All the hosts still have the traumatic earthquake of 2010 in mind, and they understand the importance of limiting the risk in order to avoid another disaster. The seismic data collected by the RSs are therefore not only perceived in their purely scientific dimension, but also in their practical, risk-management dimension. The data produced by the RSs are considered valuable information to be taken care of and archived. For example, a host in Pignon told us: *"I know that everyone needs data but that it is extremely difficult to access and collect it in Haiti. So, when I heard about the RS... and since I have a home with electricity and internet, I offered to host one [...] Having the knowledge available is important. For me it helps the world."*ⁱ

This risk management for the development of the country includes three main aspects. Firstly, the hosts hope that this RS-based system will make it possible to improve awareness of the risk, to know that it is present, to measure it, and perhaps even to control it. Awareness and knowledge of the risk appear to be *sine qua non* conditions to allow the future to be envisaged, even if it is initially painful. *"I understood from Eric"ⁱⁱ the more of these devices there are, especially in the most remote areas, the more we will be able to detect and record these seismic movements with precision. So that's what it's*

all about. [...] I think that's what we, Haitians, need to do it right now so that it can, how should I say, move forward. So that it can progress." (Host in Jérémie).

They also hope that this will lead to better construction practices, to make buildings stronger and therefore more durable, as one host in Jérémie said: *"And then, based on what we have understood or based on the movements of the ground, based on the orientation of these movements, we could deduce other construction techniques. And then ask the municipalities to impose these conditions on the builders."* While it was not present specifically in the questionnaire, the mention of construction in the interviews is frequent, and as one hostess in Jacmel points out, is linked to the trauma of 2010: *"We have to be more careful, for example, in construction. For example, I take that into account in construction because I was traumatized enough as it is."* She goes on to explain that, as an investor, she understands the need to document risks to be able to lay out scenarios for them and, in fine, to better control for them.

Finally, some hosts also hope that the data collected by the RSs will eventually make it possible to predict earthquakes, or at least to issue an early warning to the population, and thus reduce the risk. In this respect, the words of a hostess in Pacot are particularly revealing of this desire for prediction: *"All the people in Haiti want is to have advance notice of an earthquake. If it's not possible according to Prépetitⁱⁱⁱ to get an advance notice of an earthquake, for me it's still the beginning of an advance notice mechanism. Which you couldn't do at the moment. [...] If with the Raspberry Shake and the network we can follow the general trends, maybe we can see in advance big earthquakes, small earthquakes in an area that concerns me."* Indeed, if earthquake prediction is not scientifically feasible today, it is possible—under certain conditions and thanks to precise detection devices and a highly reliable communication system—to detect an earthquake in its early phase and warn populations further away from the epicenter a few seconds before they feel the shaking (Allen R. 2019; Bossu et al. 2021). This so-called "earthquake early warning" service is operational in Japan, Mexico, and California for instance. It requires technological means that are however far from being

available in Haiti. This desire to predict earthquakes is also accompanied by the hope of being able to prevent tsunamis, as pointed out by a host in Anse-à-Veau: "*This is information [data on an earthquake] that comes after the fact. [...] We expect it [the RS] to facilitate responsiveness. The town of Anse-à-Veau is located in a coastal area, and if there is a real concern, it is with regard to underwater earthquakes. In case of a tsunami for example, the device could allow the evacuation of the population between the first tremors felt and the first waves. Its usefulness is not to be demonstrated. It is even essential.*" In any case, in order for the project to really help the development of the country, many volunteers stress the need for it to be sustainable. A host at Môle Saint Nicolas, for example, expresses his desire for the project to last and "*for all generations to be touched by the issue.*"

A collective interest that takes precedence over individual interest

Citizen science takes on its full meaning here. We can indeed assume that all these reasons for participating in the project, and the satisfaction expressed in the exercise, strengthen the inclusion of citizens. The participants not only make up for the lack of involvement of the State, but they participate both as individuals and as part of a national community serving their country and their future. However, in general in Haiti, historical, socio-cultural, economic, and political factors make individualism very strong. A person's network of relatives is a bonus, in a large part because it is through them that one survives on a daily basis: It provides an environment of mutual aid, particularly in the face of the shortcomings of the State, helping with the purchase of products, with loans between families, with childcare, etc. (Corbet 2012). The S2RHAI network, which connects citizens scattered throughout the country, conversely allows for the existence of a larger community by including them in a scientific endeavor as citizens and orienting them toward a common goal.

This investment in the project, which takes on a collective, even political, color, reveals in both overt and covert ways a real pride in project participation. *"I am very happy to host the system because it is the only one in the area. At least when there is something going on, it allows us to know what is going on. [...] For me it was a citizen's duty and I thought it was perfectly normal to do so,"* said a hostess in Jacmel, for example.

As can be read in the original quotes (see Appendix 2 with quotes and translations), this pride is expressed recurrently; some affirm the pleasure they experience from participating in an innovative project, some appreciate being considered a local authority figure through the possession of a seismometer, and others express a sense of honor in working for science in general and the country in particular. It is one of the most positive elements of the project: One could indeed have thought that people would lose interest or would disinvest, or at the very least that they would not express specific feelings about their cooperation. Especially since there was no strong earthquake, and a fortiori no destructive earthquake, between the installation of the RSs and our survey, their "watch" could have seemed of little use. Overall, by seizing scientific data to address the failures of the state and to take control of their future and that of the community, the volunteers demonstrate a form of empowerment common to many citizen science projects (Bonney et al. 2016; Kinchy 2017). Individuals seize the opportunity to fully exercise their power as citizens through concrete action and for the collective good. And as one host in Anse-à-Veau rightly notes, "information is power": As for seismology, it does not (yet) have the power to predict an earthquake. But, for citizens, it is the power to participate and to be included in something bigger than any single individual's capacity.

Making up for the failure of the State

Although this was not formulated explicitly, a certain distrust of the State is apparent from the interviews. This is recurrent in Haiti, where the State does not ensure its regalian prerogatives such as security, education, infrastructure, etc. (Wargny 2008). The Haitian state has put in place some disaster risk-management mechanisms (cyclones, floods, earthquakes) thanks to support from the international community, and certain local figures, such as engineer Claude Prépetit, the current Director General of the Bureau des Mines et de l'Energie (BME), have made their mark in this landscape. But this is quite recent and, so far, occurs with little participation from the local population, who therefore remain spectators and, above all, under-informed. This lack of inclusion of citizens in Haiti in the various institutional arrangements is characteristic and has already been investigated in numerous studies (Lundhal 1983; Trouillot 1990; Trouillot 2003). Hosting an RS and providing useful information therefore embodies real citizen involvement for the hosts and helps to overcome the failings of the State, which has not been able to set up an operational seismological network, for instance. RS host volunteers are therefore no longer just beneficiaries of science, but full-fledged actors who help produce knowledge about Haiti, in Haiti.

In this scientific approach, the national dimension, despite the absence of the State, is important. The S2RHAI team is composed of Haitian and French scientists, many of whom were in contact with the hosts when they were "recruited" or when the RS was set up at their place. We can assume that the actual involvement of local researchers reinforces the fact that this is a project that does not just come from the outside, but is part of a dynamic of collaboration and co-construction with Haitians.

However, the presence of French researchers in the team can be perceived from different, sometimes contradictory angles. For example, it may suggest that Haitian researchers cannot support this scientific project alone (in terms of skills and technical and financial resources). It could even be interpreted as a form of "scientific interference," a recurring theme in local populist discourse, which in particular criticizes the foreign policy of the great powers vis-à-vis Haiti as well as the omnipresence of international NGOs in the country (Katz 2014; Schuller 2016). Haiti is indeed characterized by a very

strong foreign presence, in particular via a large number of solidarity projects through NGOs, some of them established in the country for a long time and with no intention to leave. However, even though many of them were designed to fulfill the needs of Haitians, relatively little was done with or by the Haitians. That said, the presence of foreign researchers can also be perceived as positive, as the image of the international, renowned researcher also carries some cachet, and the hosts were enthusiastic about participating in a project of international scope. Our future surveys will clarify RS hosts' perception of the research team composition.

A still-incomplete integration into the network

Much more than a sense of usefulness to country, the comments of the hosts reflect a sense of belonging to the seismic network, of legitimacy, and of commitment under various forms. While some claim to have acquired knowledge about seismology, others point to the limitations of this effort and refer to scientists as the "holders of knowledge," while at the same time placing themselves outside of the community we are trying to build. The words of a host at Môle Saint Nicolas is emblematic of this attenuation of his own knowledge: *"I am used to watching [on the website] those [earthquakes] that occur in the Dominican Republic as well. [...] I see these things but I don't record more. You know, my knowledge is limited in this area."*

This variable belonging to the seismic citizen network can also be observed in the interlocutors chosen during the exchanges. If, when an earthquake is felt, hosts can compare amongst them what they felt or measured, the vast majority of requests on the WhatsApp group mentioned above are directed towards the "knowledgeable," that is, the scientists. We thus note a limit in our attempt to reduce the asymmetry of the power/knowledge duo, which should encourages us to better reflect on the social meaning of our research (Bojovic et al. 2021). The voice of the latter is authoritative, closes

a debate on the magnitude of an earthquake, or even silences rumors about hypothetical earthquakes in a given region. For example, on July 23, 2021, a rumor of an earthquake that had caused significant damage, with a photo to back it up, spread through the WhatsApp group. It was important to find out whether this was true. Even if there are other ways to disprove the news, the answers of the scientists and their “proofs” (notably by referring to the project website) sounded the end of the discussion; it was not an earthquake but the sad and natural failing of an aged ceiling in a high school. The public view of scientific authority is reflected both in the direction of the questions (toward scientists) and in the acceptance of the responses of the “knowers.” However, in the S2RHAI project and in the interviews, the figure of the “knower” is not at all disembodied: The names of Éric Calais, Steeve Symithe, or engineer Prépétit come up frequently during the interviews. They are repeatedly cited as sources or reference authorities to justify statements or technical practices related to the use of RS. Interaction with scientists is a strength here, as the success of citizen science initiatives can hardly do without discussions between citizens and scientists (Fallou et al. 2019).

Overall, the interviews indicate that the presence of the researchers is considered a guarantee of trust. As the S2RHAI project's approach is based on exchanges and reciprocal listening between seismologists and RS hosts, even though the researcher remains the referent, the experience tends to position the RSs as tools that make it possible to become aware of everyone's knowledge—cognitive knowledge, validated by science; but also knowledge-being, validated by society and all a person's cultural influences; and knowledge-doing, validated by work—each as legitimate as the other (Héber-Suffrin 1993). The project approach tries to find the balance between situated knowledge (Haraway 1988) and socially relevant knowledge, the one that interests the citizens (Lemos et al. 2018).

On the whole, the hosts show a feeling of belonging to this social-seismological network under construction, although they do not necessarily consider themselves on the same level as other participants, and they establish mental hierarchies based on their perception of each other's knowledge. While some are satisfied with their level of involvement and do not wish to become more

involved, all have made requests to improve not only the project but also the network as a whole and its sustainability. These requests are intended to enable them to go further in their knowledge of scientific facts and in their usefulness to society as a whole. They also embody the need for balance in the relationship between the experts recognized as such (the "knowers") and those who are recipients of the system (the hosts).

Another interesting point is that, two years after the beginning of the project, volunteers took advantage of the interviews to talk about the concrete difficulties they encountered and to outline possible improvements. We identified various requests that RS hosts felt were necessary to better understand the system and to play their role as fully as possible. We list hosts' requests for support and their suggestions for the project improvements in Appendix 3. They specifically asked for support of three kinds: technical, scientific, and educational. These requests are considered in the continuation of the project, with technical assistance of course, but also better training and scientific discussion, greater consideration of pedagogy (including school students), and further education on RS and earthquakes, in order to better understand and disseminate the project.

Conclusion: Understanding citizens' needs to reinforce their integration in the socio-seismological network and to empower their citizenship

What are the next steps for the project after these analyses? Funding from the French National Research Agency (ANR) will make it possible to continue the project and to extend it on a larger scale, with more RS stations installed in the country across a broader socio-economic sample of the population. It will provide more assistance to the hosts, improve the communication network, and better support hosts in their role as ambassadors. Indeed, they are privileged relays to pass on

information to their communities, which for the moment are not benefiting from the potential outcomes of the project. The idea is to maintain individual links between hosts and scientists while improving the collective dynamic—being part of a common project, of a research group, but also of a community.

In addition to these improvements derived from the interviews with the hosts, local institutions, in particular schools, will be included in the next step of the project, which will add a dimension of citizen science and education for young Haitians. Having the RSs in schools should be accompanied by training for teachers and pedagogical presentations to ensure the sustainability of the project (see Subedi et al. 2020, in Nepal, for instance). Institutions other than the current project collaborators will also be considered, as long as they wish to participate in public information, always with the aim of greater participation and better dissemination of knowledge.

During the discussions within the S2RHAI multidisciplinary team, another request emerged: Scientists need to better understand the socio-cultural, economic, and political context of the hosts in order to better assess local acceptance of the RSs and their data, to better adapt their scientific discourse and communicate more effectively. As of now, although the project aims at a co-construction with the hosts, the dialog still remains asymmetrical, as demonstrated in the interviews that highlight the authority attributed to scientists. Some researchers are open to questioning or even changing their communication methods after gaining a grassroots perspective from RS host interactions. Our future research will also investigate how scientists accept, or not, the so-called "non-expert" knowledge and the socio-cultural constraints of the environment where their research is applied. It will demonstrate how cognitive knowledge is associated with knowledge-being in our citizen science approach. Finally, the desire for knowledge of the local socio-cultural environment also stems, for scientists, from their need to be more useful to the citizens of Haiti, that is, to know them better in order to help them better.

Although the interviews already provide an initial response to this request, there remains an aspect that has not yet been explored: the magical world. The methodological framework was not ideal (a telephone interview with strangers), especially since the hosts mostly come from an educated part of the population, more reluctant to evoke or refer to the invisible world, and more interested in learning about science. Yet, the world of the "outside" is very present in Haiti where, whatever the religious practices, the vodou belief in acting spirits is very strong (Hurbon 2014). Called "lwas," these spirits are versatile and difficult to control, and their actions are complicated to interpret (even for Vodou masters: male *hougans*, female *mambos*). The earthquake, the RSs, the deaths, are all subject to interpretation between causes and consequences: The presence of the RSs, for example, could cause earthquakes, but the latter could also be the result of the anger of a spirit. Dreams are a medium of information, whether premonitory (warning of danger) or explanatory (making the dead, the spirits, or the forces involved in the disaster speak). This intangible world is important for the hosts as well as for those around them, for whom earthquakes are perceived from the angle of culture and risk rather than from a purely scientific perspective.

Accounting for this and accompanying the scientists in their understanding of the local culture is therefore a request, out of interest for the country, and out of necessity for optimizing the project. This will make it possible to consider not only the origin of the risk, but also the beliefs about its origin: The interviews evoke a multi-causality of a disaster, and remind us above all that these are diverse, cumulative, and can occur at any time. The unpredictability of the disaster is erased by the permanence of the risks and dangers hanging over Haiti. The earthquake, which can be major in its scope, is one disaster among many others of all kinds: floods, cyclones, political and economic crisis, insecurity, etc. In Haiti, there is therefore no society of risk, but risks (Hurbon 2014). These accumulate in daily lives, where the various ordeals that everyone may encounter are intertwined. This accumulation of risks is so deeply rooted in Haitian reality that it gives rise to day-to-day adaptation processes: The "do it yourself," or tinkering, of daily life allows individuals to be highly

reactive in the face of a disaster, whatever it may be, and to integrate impromptu events into ever-changing parameters of existence (Corbet 2014; Schuller and Morales, 2012). These individual and collective coping mechanisms evolve with the events that the population encounters, making them apparently "resilient," a term we use with caution because there is no normality to which people would return after a trauma, instability being the norm.

Among the environmental risks, tsunamis are quite frequently cited, even though the associated risk is quite low: There was a tsunami associated with the 1842 earthquake in Cap Haitien, and a micro-tsunami in the area of Leogane (related to a landslide) after January 12, 2010. This high level of evocation of the impressive phenomenon of the tsunami, especially in a coastal country, may be a consequence of the large information campaigns sponsored by UNESCO in the region.

Finally, better information on Haitian beliefs would allow for a better understanding of the fears and traumas of the hosts as well as of the Haitian population, and thus adapt the seismological information to raise awareness of natural risks without rejecting scientific knowledge or increasing fears. Indeed, it will be necessary to avoid bringing back memories that are too difficult for people for whom earthquakes are deadly realities, who have already experienced them, and who may hold that trauma in their bodies—all of this within a society that makes constant reference to them. For example, the rubble of the 2010 earthquake is still present in the urban landscape, people experience nightmares as a result of trauma, and allusions to the missing are omnipresent (Corbet 2014).

To answer some of these questions, the continuation of our project will include more Haitian institutions, will diversify places and types of hosts to better understand and adapt to the local culture, and will be more inclusive—while helping the State and its institutions improve their technical capacities. All of the project's actors, especially those from outside the country, are aware that even if the Haitian state is often described as "failed" (Verlin 2014), it must nevertheless be included in

international and national projects so as to strengthen its capacities and to avoid any suspicion of intrusion or interference in Haiti.

Our analysis focuses on the first steps in establishing a seismic network in an economically, socially, and politically challenging environment, in collaboration with citizens who are part of it. Setting up and consolidating such a network, in the broadest sense, will take time, and the issues must be considered over time to ensure the sustainability of this endeavor. The continuation of the project will be based on the first encouraging and instructive feedback presented above. Some conclusions are not surprising, such as the influence of local culture and the demand for a more interactive approach, but were very resolutely affirmed, and the citizen dimension appeared with force. The project is certainly small in scale, but we heard positive echoes that show real pride and commitment, from the hosts as well as from the researchers. This emerging network between citizens and scientists must be strengthened, for example by more attractive communication tools, and deployed more broadly, with an increase in the number of RSs, particularly in schools. It will also be a matter of individualizing the relationships with hosts, with consideration given to motivating individual investment while continuing to promote and develop a nascent collective dynamic.

Finally, the citizens' comments gave us a lot of information that allows us to better adapt the continuation of the project. It can succeed only with the cooperation of all, and this requires mutual listening and learning. A reciprocal curiosity is required to allow for a dialogue around an object (here, seismology embodied by the RSs) and to develop scientific questions geared toward all relevant aspects of seismic shaking, from the measurement of the ground vibrations to the psychological traumas of the population. We conclude that, in a citizen seismology project, understanding the motivations, obstacles, and expectations of the volunteers is essential to increase the chances of project sustainability.

In short, our collaborative project, which places the citizen at the center of the process, recognizes from its methodological approach that the echoes between the geological faults and the cultural dimension are elements that, through their crossed views, will allow us to be more effective, more accountable, more committed, and in short, better “citizens.” In a context in which the very notion of citizenship is being eroded as the capacities of the Haitian State, particularly the regalian ones, are disintegrating (Duval 2021), this is an even more crucial issue. If the 2018 seismic crisis in Mayotte demonstrated how citizen science can compensate for the lack of formal scientific information (Fallou et al. 2020), perhaps the case of Haiti shows how citizen science can compensate for a lack of state will and resources.

Supplemental files list:

Appendix 1: Presentation of S2RHAI and methodology.

Appendix 2: Original quotes.

Appendix 3: Hosts’ requests for support and suggestions for the project improvements.

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Figure Captions

Figure 1 Location Tectonic Plates. Haiti and the Dominican Republic share the island of Hispaniola. The black lines indicate the major seismic faults, which accommodate the movement between the North American (north) and Caribbean (south) plates whose relative displacement (2 cm/year) is shown by the black arrows. The most important historical earthquakes in terms of damage are indicated by yellow stars. The red stars indicate the epicenters of the earthquakes of January 12, 2010 and August 14, 2021.

Figure 2 Photo of a Raspberry Shake (RS) seismometer installed at a host located in Port-au-Prince. The RS is lying on the floor in a corner of their living room, behind a piece of furniture that hosts a TV

and various electronics. The mobile phone gives the scale. The connection to the electricity (black cable) and the internet router (blue cable) can be seen.

Figure 3 Map of the location of Raspberry Shake stations in Haiti at the time of the interviews (*red*) and subsequently installed (*yellow*), as of October 24, 2021. Regions affected by the 2010 and 2021 earthquakes are indicated approximately by yellow ellipses.

ⁱ Each quote has been translated by authors. Original quotes are provided in Appendix 2.

ⁱⁱ Eric Calais, seismologist, coordinator of the S2RHAI project, who installed the RS at this host.

ⁱⁱⁱ Claude Prépétit, a Haitian geological engineer, partner of the S2RHAI project.

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*From a seismological network to a socio-seismological one: a citizen science experiment in Haïti
to reduce seismic risk.*

Analysis of a "small box" that can do a lot.

Corbet A. , Fallou L. , Calixte N., Hurbon L., Calais E.

Appendix 1:

Presentation of S2RHAI and Methodology

Studying a paradigm shift under the S2RHAI project

The knowledge of local seismicity in Haiti was very low. The Bureau des Mines et de l'Énergie (BME), a national institution under the supervision of the Ministry of Public Works, had performed geodetic measurements in collaboration with American scientists, and put forward the hypothesis, as early as in 2008, that the faults located in the southern part of the

country were capable of an earthquake of magnitude 7 (Manaker et al., 2008). But this information, confined to scientific circles, was not translated to national and international decision-makers. As a result, even though the Civil Protection Directorate had initiated modest information campaigns on seismic risk, scientific knowledge remained weak and - aggravating factors - national technical and scientific capacities were largely insufficient for an effective advocacy on these issues to the general public and to the government.

The technical and financial assistance that followed the 2010 earthquake initiated the strengthening of the BME, with the creation of a "Technical Seismology Unit" in charge of setting up, maintaining and operating a network of high-end seismometers (so-called "broadband seismometers") on the national territory. Unfortunately, none of them were functional on October 6, 2018 during a magnitude 5.9 earthquake in the northwestern part of the country that claimed 12 lives. As a consequence, neither the Civil Protection Directorate nor the general public could be kept informed of what was happening, nor of the sequence of aftershocks that followed. It is indeed very difficult, in a country where financial and technical resources are as limited as in Haiti, to maintain in the long term a complex scientific apparatus, deployed throughout the entire country, and which requires sophisticated technology including expensive satellite communication means.

In this context, a multidisciplinary research team combining seismology and social sciences has been deployed in Haiti between 2019 and 2021 within a project named S2RHAI. Funded by the Mission à l'Interdisciplinarité du Centre National de la Recherche Scientifique (CNRS/MITI) and the Institut de Recherche pour le Développement (IRD), this project mobilized about 15 French researchers and engineers and 10 Haitian researchers and engineers. The S2RHAI project takes the original approach of considering that seismic networks are not only composed of technology, but also of people who gather around these tools and the information they provide, in line with the theory of the network actor (Akrich, M., Callon, M., Latour, B., 2006). The aim of S2RHAI is to test the feasibility of an approach where seismic observations are carried out by distributing small (10x10x5 cm), low-cost and low-maintenance Raspberry Shake seismometers (RS: see figure 2 in the main article) to non-scientific volunteers throughout the country. This would allow seismologists to detect small, unfelt, earthquakes that occur by the dozen every day and are of prime importance to better understand the likelihood of much larger events. Then, in turn, a dialog may emerge between RS station hosts and scientists, in such a way that one could explore the perceptions and information needs of the hosts, while they could interact with scientists in a non-hierarchical way.

In addition to their small size, RS seismometers have the advantage of being quite inexpensive (between 500 and 900 USD) compared to traditional seismometers (10,000 USD minimum). The installation and operation of RS only requires connection to the electricity and the internet to send their data, with low power and bandwidth usage. They can therefore be deployed in private homes or institutions that have this basic logistics at disposal. Thanks to these RS, S2RHAI applies a citizen seismology approach with a double objective: on the one hand, to complete the national seismic network and increase scientific knowledge on earthquakes, and on the other hand, to improve the perception of risk, the level of preparation and relevant information for the population. To achieve this, the volunteers

should eventually play an "ambassador" role that has been observed and studied in other citizen science projects (Dardier et al., 2021). They would disseminate their new knowledge to their community, act as mediators and opinion leaders (Katz and Lazarsfeld 1955), and increase the impact of the approach beyond the limited cohort of volunteers. That low-cost, low-maintenance RS seismometers are now available make it possible to (1) involve citizens in the collection of scientifically relevant data, and (2) create a link between the seismologists who process the data and the citizens who contribute to its production. And it is precisely this link that introduces a paradigm shift: the seismic network is no longer composed solely of complex instruments whose handling is reserved to experts, but also includes individuals, experts or not, who keep them operational, take an interest in them, and are nourished by the information they provide.

In order to distribute RSs across the country, we applied four main criteria related to the seismological and social requirements of the project:

- (1) Logistics: the hosts had to be able to provide a stable internet connection and electricity - commodities that can be hard to find in Haiti;
- (2) Location: in order to be effective, a seismic network must cover a large area with the most homogeneous station distribution as possible, so the hosts should be spread throughout the country (see figure 3 in the main article);
- (3) Acceptance: the hosts had to agree to install, on their premises, a tool that they neither knew nor fully understood, without financial compensation; we did not know at first how this would be perceived by the hosts;
- (4) Motivation: we had to find hosts with a minimal interest in the scientific or risk reduction objectives, so that they would not abandon the project early on.

It was initially decided to use personal acquaintances of Haitian project partners to try and disseminate a first batch of RSs throughout the country. This obviously introduced a methodological bias since these volunteers are not representative of the Haitian population as a whole, but rather come from a high social background. Nevertheless, this made it possible to start S2RHA1 with 7 Haitians and 3 foreigners (American and French) who have been living in Haiti for several decades, with no intention of leaving. Some of them are engineers or people with an interest in seismology. Others, with no particular scientific background, are interested in earthquakes as a result of personal seismic experiences, notably the 2010 earthquake, or because they are involved in local development programs. The volunteers are between 26 and 71 years old and 3 of them are women. The RSs were hand-delivered, with general explanations of the project, their operation and maintenance, which involved a direct relationship between the scientists and the 'hosts'. Once installed, powered and connected to the internet, the RS stations require little maintenance or intervention by seismologists.

The results of the data produced by the RS are accessible via a website (<https://ayiti.unice.fr/sismo-ayiti/>) that also presents the project. The website is equipped

with an automatic earthquake detection system (<https://ayiti.unice.fr/ayiti-seismes>) which allows everyone, especially the hosts and the project's seismologists, to observe the seismicity of the Haitian territory in real time. Finally, in order to facilitate communication and information sharing between hosts and scientists, a WhatsApp group has been created. WhatsApp is indeed a key media in the informational, communicational, and collaborative practices in Haiti.

Methodology: interviews

To address these questions, we conducted semi-structured interviews with 10 hosts (8 individuals and 2 institutional representatives (BME and the Maritime and Navigation Service of Haiti (SEMANAH)), in order to learn from their experience and to assess their motivations, difficulties, and expectations. Due to security issues in Haiti and to the COVID19 pandemic context, the interviews were conducted by phone over WhatsApp. A member of the project team was systematically associated with a student from the URBATER Master's degree of the Faculty of Sciences of the State University of Haiti, who was previously trained in interview modalities and who often led the exchanges. In addition to the fact that this provided them with practical training in interviewing, the use of Creole by the students, as well as the fact that they mastered the intonations or implicit formulations of the people being interviewed, allowed for a more trusting and qualitative relationship in the exchange. The interviews were conducted in French, Creole, or English, depending on the preference of the respondents. However, the use of the telephone and the fact that most of the interviewers were visually unknown to the hosts could have added distance and unbalanced the relationship between interviewer and respondent. Despite this, most of the interviews resulted in quality exchanges, with respondents sometimes asking questions of the interviewers, or detailing anecdotes. Having hosted RSs for 1-2 years, they had enough perspective to share their experience. It should be noted that between the beginning of the project and the interviews, while many low-intensity earthquakes were detected by the network (Calais et al. 2020), no destructive or strongly felt earthquake had occurred in Haiti. The destructive earthquake of 14 August 2021 occurred several months after the interviews were completed and is therefore not taken into account in this study. It will be the subject of further research.

The interview consisted of about 40 questions, which were organized around four themes. The first questions asked about the host's profile: who they were, their past experiences, and their previous knowledge of seismology. The second section looked at their experience with the RS they had been hosting: how and why they hosted one and their interest in the device, from maintenance to data collection, including accessing their RS information or the *ayiti-seismes* website. The third part asked about the community dimension of this participation: were the RSs introduced to visitors or family, for example, or could a sense of belonging to a "scientific community" be identified? Finally, the fourth part opened to comments and suggestions of the hosts, with the goal of finding concrete ways of improving their experience. The two institutional hosts, with a specific profile because they were more aware of the seismological issues and the details of the project's approach, had questions more directed towards their uses and scientific readings of the RS data, and towards interactions

with the public. The interview grid was developed following the analysis of the results of a quantitative survey on the perception and knowledge of seismic risk in Haiti (Calais et al. 2020). Due to the small number of interviewees, the multitude of languages used, and the analyses from multiple disciplines and researcher backgrounds, it was decided not to do any coding. This leaves more room for the flexibility of discourses and cultural interpretations.

Finally, the interviews show little criticism of the citizen-science approach in general. It is certainly related to the selection of the hosts, who are fairly well educated and open to the scientific approach. Perhaps they also did not dare to criticize an intervention coming from abroad, or to criticize the lack of measures in their own country? We predict that some criticism will emerge during time and extension of the project.

Acknowledgments

We would like to thank all the Haitians who welcomed us and participated in our research, and in particular the hosts of the RS, as well as all the researchers who worked on the S2RHAI project.

Ethical approach

The SR hosts were contacted personally, which made it possible to provide a lot of oral information, both during the installation of the SRs and at the beginning of the telephone interviews. Written documents are complicated in Haiti for reasons of comprehension (being able to read, and understanding what is in the document) and the act of signing can be frightening for people. We are working on a more formal ethical approach with the extension of the project. However, it was reported orally, on several occasions, that:

- Host can contact the researchers at any time, whose contact details they have or via the WhatsApp group. They can ask all the questions they want and withdraw from the project at any time.
- All individual data is anonymized.
- All activities of the researchers, such as articles that relate to the project, are shared with them on the WhatsApp group.

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Competing Interests

No competing interests.

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Appendix 2:

Original quotes

Original quotes extracted from the interviews made with RS hosts. The original quote is first and the english translation, made by the authors, is below in italics.

*

« Je sais que tout le monde a besoin de données mais que c'est extrêmement difficile d'y avoir accès et de les récolter en Haïti. Donc quand j'ai entendu parler du RS... et étant donné que j'ai un domicile avec de l'électricité et internet, j'ai proposé d'en héberger un [...] Avoir la connaissance à disposition c'est important. Pour moi ça aide le monde. »

> I know that everyone needs data but that it is extremely difficult to access and collect it in Haiti. So, when I heard about the RS... and since I have a home with electricity and internet, I offered to host one [...] Having the knowledge available is important. For me it helps the world.

*

« J'ai pu comprendre selon les dires d'Éric que plus il y aura de ces dispositifs, surtout dans les zones les plus reculées, plus on sera à même de détecter, de relever ces mouvements sismiques avec précision. Donc c'est de ça qu'il s'agit. [...] Je pense que c'est ce qu'on doit, nous autres haïtiens, faire à l'instant pour que ça puisse, comment dire, avancer. Pour que ça puisse progresser. »

> I understood from Ericⁱⁱⁱ the more of these devices there are, especially in the most remote areas, the more we will be able to detect and record these seismic movements with precision. So that's what it's all about. [...] I think that's what we, Haitians, need to do it right now so that it can, how should I say, move forward. So that it can progress.

*

« Et ensuite par rapport à ce qu'on aura compris ou par rapport aux mouvements du sol, par rapport à l'orientation de ces mouvements, on pourrait déduire d'autres techniques de construction. Et ensuite demander aux mairies d'imposer ces conditions aux constructeurs. »

> And then, based on what we have understood or based on the movements of the ground, based on the orientation of these movements, we could deduce other construction techniques. And then ask the municipalities to impose these conditions on the builders.

*

« Il faut faire plus attention par exemple dans les constructions, par exemple moi je tiens compte de ça dans les constructions parce que j'ai été assez traumatisée comme ça. »

> We have to be more careful, for example, in constructions. For example, I take that into account in constructions because I was traumatized enough as it is.

*

« Tout ce que les gens en Haïti veulent c'est d'avoir un préavis de séisme. Si ce n'est pas possible selon Prepetitⁱⁱⁱ d'avoir un préavis de séisme, pour moi c'est quand même le début d'un mécanisme de préavis. Que vous ne pourriez pas faire pour le moment. [...] Si avec le Raspberry Shake et le réseau on peut suivre les tendances générales, peut-être on peut voir à l'avance de grands séismes, de petits séismes dans une zone qui me concerne. »

> All the people in Haiti want is to have advance notice of an earthquake. If it's not possible according to Prepetitⁱⁱⁱ to get an advance notice of an earthquake, for me it's still the beginning of an advance notice mechanism. Which you couldn't do at the moment. [...] If with the Raspberry Shake and the network we can follow the general trends, maybe we can see in advance big earthquakes, small earthquakes in an area that concerns me.

*

« C'est une info [les données sur une secousse] qui vient quand même après coup... Mais ça reste utile face au risque de tsunami notamment. [...] On s'attend à ce qu'il [le RS] facilite la réactivité. La ville de l'Anse-à-Veau est située sur une zone côtière, s'il y a un vrai souci c'est par rapport aux séismes sous-marins. En cas de tsunami par exemple, l'appareil pourrait

permettre d'évacuer la population entre les premières secousses ressenties et les premières vagues. Son utilité n'est pas à démontrer. Elle est même capitale. »

> This is information [data on a shaking] that comes however after the fact. [...] We expect it [the RS] to facilitate responsiveness... But it remains useful in the face of tsunami hazard, in particular. The town of Anse-à-Veau is located in a coastal area, and if there is a real concern, it is with regard to underwater earthquakes. In case of a tsunami for example, the device could allow the evacuation of the population between the first tremors felt and the first waves. Its usefulness is not to be demonstrated. It is even essential.

*

« pour que toutes les générations soient touchées par la question. »

> for all generations to be touched by the issue.

*

« Je suis bien contente d'héberger le système parce que c'est le seul qu'il y a dans la zone. Au moins quand il y a quelque chose ça permet qu'on sache ce qui se passe. [...] Pour moi c'était un devoir de citoyen et puis je trouvais que c'était tout à fait normal de le faire. »

> I am very happy to host the system because it is the only one in the area. At least when there something happens, it allows us to know what is going on. [...] For me it was a citizen's duty and I thought it was perfectly normal to do so.

*

« J'ai l'habitude de visionner [sur le site internet] ceux [les séismes] qui se produisent en République Dominicaine également. [...] Je vois ces choses mais je n'enregistre pas plus. Vous savez, mes connaissances sont limitées dans le domaine. »

> I am used to watching [on the Website] those [earthquakes] that occur in the Dominican Republic as well. [...] I see these things but I don't record more. You know, my knowledge is limited in this area.

*

« Bien sûr, il y a Internet qui est parfois instable. Souvent, je suis confronté aussi à des difficultés avec le courant. J'ai un système avec des panneaux solaires, mais il ne fait pas toujours beau temps. »

> Of course, the Internet is sometimes unstable. Often, I am also confronted with difficulties with the electricity. I have a system with solar panels, but the weather is not always good.

*

« Mais il y a toujours des petits problèmes techniques, n'est-ce pas ? Il y a un problème avec le wifi et mon adresse IP... et la localisation quand je redémarre le truc. [...] Je dois juste le rebrancher en fait, mais ça crée des trous dans les données quand je dois faire ça. »

> *But there are always small technical problems, right? There's a problem with the wifi and my IP address... and the location when I restart the thing. [...] I just have to plug it back in actually, but it creates holes in the data when I have to do that.*

*

« Des « petites pièces » aussi. Une *incentive* pas forcément pour le propriétaire pourrait tout au moins encourager le technicien à qui revient la charge d'avoir l'appareil à l'œil tous les jours.»

> *"Small cash" as well. A financial incentive, not necessarily to the owner, could at least encourage the technician who has to keep an eye on the appliance every day.*

*

« Maintenant le seul petit problème que j'ai c'est parce que des fois j'essaie de voir ce qui se passe. Surtout si j'entends les gens dire « ah ça a secoué ! » Donc j'essaie de voir si l'appareil a enregistré. J'ai essayé à plusieurs reprises mais ça ne marche pas. On m'avait montré quoi faire. Je l'ai fait une fois ça marchait et après ça n'a plus marché. [...] Mais c'est un petit peu frustrant. J'aurais bien aimé pouvoir mieux savoir ce que c'est et pouvoir mieux l'utiliser. »

> *Now the only small problem I have is that sometimes I try to see what is going on. Especially if I hear people say 'ah that shook!' So, I'm trying to see if the device has recorded. I've tried a few times but it doesn't work. I was shown what to do. I did it once and then it didn't work anymore. [...] But it's a bit frustrating. I would have liked to have known better what it is and to be able to use it better.*

*

« Je ne maîtrise pas tout. Mais j'ai fini par apprendre ; une fois, il y avait un écart entre la valeur d'une magnitude sur Ayiti Séismes et sur d'autres plateformes comme l'USGS. Ça a donné lieu à des échanges intéressants sur le groupe. Les explications des scientifiques étaient très éclairantes. [...] J'ai compris surtout que les Raspberry fonctionnait en réseau. En cas de difficulté, je peux toujours recourir à quelqu'un qui en sait plus d'ailleurs. Le groupe WhatsApp, qui fédère une vraie communauté d'experts, est là pour ça. »

> *I don't master everything. But I ended up learning; once there was a discrepancy between the value of a magnitude on Ayiti Séismes and on other platforms like the USGS. This led to some interesting exchanges on the group. The scientists' explanations were very enlightening. [...] I especially understood that the Raspberries worked in a network. If I have problems, I can always turn to someone who knows more about it. The WhatsApp group, which federates a real community of experts, is there for that.*

*

« Il ne faut pas en faire une psychose, par exemple dans la mentalité haïtienne, ça fait peur. Mon épouse est haïtienne, par exemple, et je ne lui disais pas quand j'allais sur le site [internet], je lui disais pas « oh tiens il y a encore eu un tremblement de terre cette nuit, tu l'as pas senti mais c'est normal, il était tout petit ! » ; j'évitais de lui dire car elle a des traumatismes psychos, elle était à Port Au Prince en 2010. Moi j'étais à distance, mais elle a été traumatisée. »

> *You mustn't turn it into a psychosis, for example in the Haitian mentality, it's scary. My wife is Haitian, for example, and I didn't tell her when I went on the website, I didn't say to her 'oh, there was another earthquake last night, you didn't feel it but that's normal, it was very small'; I avoided telling her because she has psychological traumas, she was in Port au Prince in 2010. I was away, but she was traumatized.*

*

« L'appareil rassure les gens qui sont avisés. »

> *The device reassures people who are aware.*

*

« Vous savez, les gens qui ne sont pas avisés, quand vous leur expliquez quelque chose, ils prennent tout à l'envers. La dernière fois que j'en avais parlé à une personne, je lui ai dit que nous avons un petit appareil. Entre Haïti et la République Dominicaine, je crois qu'il y en a 8, 5 pour Haïti et 3 pour la République Dominicaine. Je lui expliquais comment l'appareil peut enregistrer le passage d'un tremblement de terre, sa profondeur etc. La personne a tellement mal pris la chose et elle a dit : « Anh vous installez un appareil ici pour produire des tremblements de terre !!! » [Rire]. Et il continue pour dire que le *blan* n'arrête pas de nous chercher querelles ! Ils viennent avec leur truc pour reproduire ce qui s'était passé à Port-au-Prince ici ! »

> *You know, people who are not wise, when you explain something to them, they take everything backwards. The last time I talked to someone about it, I told them we have a small device. Between Haiti and the Dominican Republic, I think there are eight, five for Haiti and three for the Dominican Republic. I explained to him how the device can record the passage of an earthquake, its depth, etc. The person took it so badly that he said, 'Anh you are installing a device here to produce earthquakes!' [Laughter]. And he goes on to say that the *blan*ⁱⁱⁱⁱ keeps picking a fight with us! They come with their thing to reproduce what happened in Port-au-Prince here!*

*

« Toutes les personnes, surtout haïtiens, à qui on disait c'est une boîte qui enregistre les tremblements de terre, disaient « c'est une boîte qui FAIT les tremblements de terre ? ». Il fallait expliquer le truc « non ça enregistre les mouvements », mais forcément quand on parle tremblement de terre y'a toujours un petit a priori, un mauvais souvenir qui remonte. Mais globalement, j'avais ce premier sentiment « drôle », dans le sens bizarre, déconcertant, pour la plupart des gens qui venaient... On sentait un petit truc. [...] Je n'ai pas eu de personnes qui

le regardaient comme un truc mystique. Après, Haïti est un pays magique, y'a forcément des gens qui pensent à ça. »

> *All the people, especially Haitians, who were told that it's a box that records earthquakes, said 'it's a box that MAKES earthquakes'. We had to explain the thing 'no, it records movements', but inevitably when we talk about earthquakes there is always a little apriori, a bad memory that comes up. But overall, I had this first 'funny' feeling, in the sense that it was strange, disconcerting, for most of the people who came... We felt a little something. [...] I didn't have people who looked at it as a mystical thing. After all, Haiti is a magical country, there are bound to be people who think that.*

*

« *Bwat ki pou anrejistre tranblemantè yo.* » [haïtian creole]

> The little box that records earthquakes.

*

« Je suis devenue un petit peu comme un complice dans la zone. « Ah ! Madame gen yon aparèy lakay li kap detekte ond » vous voyez c'est un petit peu comme ça. » [french and haïtian creole]

> *I have become a bit of an accomplice in the area. 'Ah ! Madame gen yon aparèy lakay li kap detekte ond [There's a device in her house that detects the waves]' you see it's a little bit like that.*

*

« Les gens savent que je dispose d'informations sûres. Quelqu'un avait annoncé, une fois, sur Facebook, qu'une secousse venait d'être ressentie à Anse-à-Veau. Le réflexe pour les personnes qui n'avaient rien senti, c'était de m'appeler afin que je puisse vérifier et trancher éventuellement trancher sur la question. »

> *People know that I have reliable information. Someone had once announced on Facebook that a shake had been felt in Anse-à-Veau. The reflex for people who had not felt anything was to call me so that I could verify and eventually decide on the issue.*

*

From a seismological network to a socio-seismological one: a citizen science experiment in Haïti to reduce seismic risk.

Analysis of a "small box" that can do a lot.

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Appendix 3:

Hosts' requests for support and suggestions for the project improvements

Technical support

Two years after the beginning of the project, volunteers took advantage of the interviews to outline possible improvements. One of the first difficulties mentioned by the hosts is the sometimes-discontinuous access to electricity and Internet, even though they were chosen precisely because they had these commodities available. The multiplicity of power supply systems (State electricity, solar power, generator) is however not always sufficient, as the host in Anse-à-Veau points out: *"Of course, the Internet is sometimes unstable. Often, I am also confronted with difficulties with the electricity. I have a system with solar panels, but the weather is not always good"*. Furthermore, some difficulties may also come from the interface with the RS: *"But there are always small technical problems, right? There's a problem with the wifi and my IP address... and the location when I restart the thing. [...] I just have to plug it back in actually, but it creates holes in the data when I have to do that."* (Host in Pignon). This concern for the power supply and internet connection reveals a willingness to do well, a commitment to the project and the network.

Faced with these difficulties, some hosts mention the question of financial support to ensure the operation of their RS and therefore the continuity of its data stream. For example, one host mentioned that a small solar *inverter* connected to the RS would be welcome (Host in Anse-à-Veau). *"Small cash" as well. A financial incentive, not necessarily to the owner, could at least encourage the technician who has to keep an eye on the appliance every day.*" (Host in Cap-Haitien). This request was not recurrent in the interviews, even though many stressed that few Haitians would be financially able to provide electricity and internet access, which could pose a problem for the democratization of the project in the future. On the other hand, others point out the recurring aspect of the demand for financial rewards in Haiti, a practice that is widespread in contact with NGOs.

Beyond the support for the production of data, RS hosts also express the need for support in the visualization of these data. Indeed, despite the implementation of a dedicated website, few of them master its functionalities. For example, a hostess in Jacmel said: *"Now the only small problem I have is that sometimes I try to see what is going on. Especially if I hear people say 'ah that shook!' So, I'm trying to see if the tool has recorded. I've tried a few times but it doesn't work. I was shown what to do. I did it once and then it didn't work anymore. [...] But it's a bit frustrating. I would have liked to have known better what it is and to be able to use it"*

better". This support, which the S2RHA1 team has started addressing, could take the form of tutorials or training sessions or material to better access its data, or an improvement of the interface and the digital tool better adapted to the uses and needs of volunteers. Automating the detection of a data outage, in order to warn the hosts of the problem and enable them to remedy it – a simple reset of the receiver by unplugging it from power then plugging it back in – could also help refine the technical support seismologist can provide, with limited burden on the hosts.

Scientific support

Enthusiastic and happy to participate in a scientific project, the hosts would like more in-depth explanations. Although the visual interpretation of the graphs which represent the RS data (Figure 1 Location Tectonic Plates. Haiti and the Dominican Republic share the island of Hispaniola. The black lines indicate the major seismic faults, which accommodate the movement between the North American (north) and Caribbean (south) plates whose relative displacement (2 cm/year) is shown by the black arrows. The most important historical earthquakes in terms of damage are indicated by yellow stars. The red stars indicate the epicenters of the earthquakes of January 12, 2010 and August 14, 2021.

) is generally mastered by the hosts, they would like to better understand the general geological and seismological context that legitimizes the study. Their attraction for answers from scientists was revealed by the interviews: to understand how the collection of multiple data on the territory can be useful for the future, to understand how the combination of several actors can lead to a better understanding of geological phenomena, and to understand why measuring the risk can help better understand it.

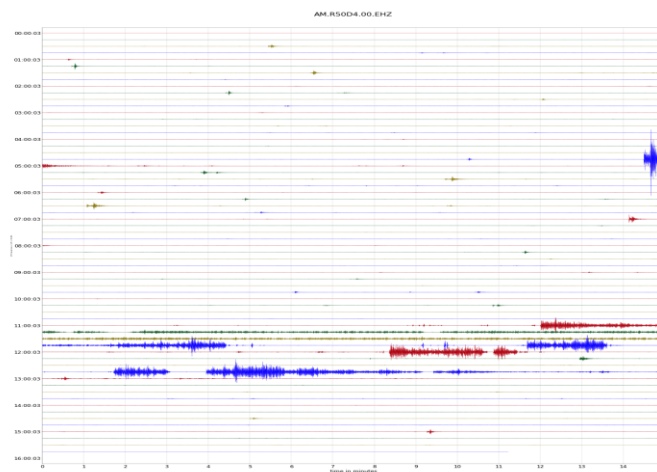


Figure 4: Example of a seismological recording, available to all on the ayiti-earthquakes platform, here for station R50D4 located in St Louis du Sud. The record is dated October 24, 2021 and lasts 16 hours. It can be read like a page in a book: it starts at the top left, each line corresponding to 15 minutes of recording, the time

scrolling from left to right. There are many small earthquakes, including a larger one just before 05:00; these are aftershocks of the 7.2 magnitude earthquake of August 14, 2021. The oscillations between 11:00 and 13:00 are mainly the result of anthropogenic noise caused by cars, trucks, or people driving near the sensor. Copyright: The authors.

The hosts who were most familiar with the scientific interpretation (especially those who had undergone scientific training during their education), and who best understood the project's process, were also those who saw the greatest practical utility in the project. One example, mentioned earlier, is that of the host of a RS in his seafront hotel who was able to interpret the RS data to reassure his entourage and decide not to evacuate the establishment, which could have been affected by a tsunami had the earthquake been much larger. Conversely, other hosts, less familiar with scientific practice, are less involved in the project and are simply content to host a RS in their homes. It can be argued that the more volunteers understand scientifically the usefulness of RSs, the more they will make concrete usage of them.

Both on the technical and scientific aspects, the WhatsApp group seems to have received rather positive feedback, at least for those who speak French and can benefit from the exchanges. The group acts as a support platform in case of technical problems or to verify information in case of an earthquake - or rumors of an earthquake. A host in Jérémie explains how it is a medium that allows him to learn: *"I don't master everything. But I ended up learning; once there was a discrepancy between the value of a magnitude on Ayiti Seismic and on other platforms like the USGS. This led to some interesting exchanges on the panel. The scientists' explanations were very enlightening. [...] I especially understood that the Raspberries worked in a network. If I have problems, I can always turn to someone who knows more about it. The WhatsApp group, which federates a real community of experts, is there for that"*. These considerations lead us to ask the question of information channels. Indeed, in Haiti this messaging platform has become an essential tool not only for interpersonal communication but also and especially for sharing information on a daily basis. For example, warnings of traffic jams or demonstrations circulate constantly through this medium via groups with various interests and pedigrees. It was therefore essential to be present on that platform. We clearly need to further study the possibilities offered by other channels (radio, newspapers or social networks) to broaden the distribution of information and increase interactions with the general public.

Moving ahead also requires understanding and account for the multiple explanations on the origin of earthquakes (and disasters in general). These origins are perceived as diverse, as expressed by several hosts. Even those with the most knowledge of seismology combine their perceptions of the event - its cause, its repercussion - with divine explanations (often in reference to voodoo), but also conspiracy explanations, relaying rumors of nuclear tests for example. If the voices of the "scientists" are often the accepted ones, through the acceptance of the status of authority of the "knower", this does not prevent them from coexisting with other registers. The latter can be mobilized differently, depending on the interlocutors, more apt to follow a particular discourse. As the panel of hosts represents an educated part of the Haitian population, one might therefore think that they rely largely on scientific data to make their decisions. Yet, we saw in the interviews that, for some of them, they are no more

important than other, equally legitimate, channels of understanding the world – religion, for instance (e.g., Abbott and White, 2019).

Pedagogical support

This brings us to the following point: if the involvement of the hosts shows their interest, many of them need support to better present the RS and play their role of "ambassador", i.e. of information relay within their communities. Some of them did not know how to describe the "object" to their relatives, and even less to a wider public (when the RS was in a passing place). Scientific explanations, for those who had mastered them, could appear jargon, and attempts to popularize them needed to be steered in order to be understandable. Aware of the deep trauma caused by the 2010 earthquake, some hosts were afraid to wake it up in their interlocutors' memory. For example, a host at Môle Saint Nicolas tells us how he avoids talking about it to his wife: *"You mustn't turn it into a psychosis, for example in the Haitian mentality, it's scary. My wife is Haitian, for example, and I didn't tell her when I went on the website, I didn't say to her 'oh, there was another earthquake last night, you didn't feel it but that's normal, it was very small'; I avoided telling her because she has psychological traumas, she was in Port au Prince in 2010. I was further, but she was traumatized"*. Another host noted, however, that the perception of the RS varies according to the audience: *"The device reassures people who are aware"*.

The hosts fear that the misinterpretation that could be made of their words could fuel fears, suspicions and ultimately spread false information. A host in Jérémie tells us how people can easily think that it is an instrument to create earthquakes. *"You know, people who are not wise, when you explain something to them, they take everything backwards. The last time I talked to someone about it, I told them we have a small device. Between Haiti and the Dominican Republic, I think there are eight, five for Haiti and three for the Dominican Republic. I explained to him how the device can record the passage of an earthquake, its depth, etc. The person took it so badly that he said, 'I'm not going to tell you how to do it. The person took it so badly and said: 'Anh you are installing a device here to produce earthquakes!' [Laughter]. And he goes on to say that the blanⁱⁱⁱ keeps picking a fight with us! They come with their thing to reproduce what happened in Port-au-Prince here!"* This fear of interpretation also feeds on vodou and magical beliefs, as a host at Môle Saint Nicolas half-heartedly recalls: *"All the people, especially Haitians, who were told that it's a box that records earthquakes, said 'it's a box that MAKES earthquakes'. We had to explain the thing 'no, it records movements', but inevitably when we talk about earthquakes there is always a little apriori, a bad memory that comes up. But overall, I had this first 'funny' feeling, in the sense that it was strange, disconcerting, for most of the people who came... We felt a little something. [...] I didn't have people who looked at it as a mystical thing. After all, Haiti is a magical country, there are bound to be people who think that."*

The RS, by its very presence, is not a purely technical object, for it is filled with meanings: those that the people who interact with it project onto it (Simondon 1958). It can remind of the traumas associated with past or potential earthquakes, although its purpose is precisely

to limit the risk of devastation from a future earthquake and should therefore reassure. Faced with this paradox, hosts find themselves helpless. However, when it concerns their relatives or audiences they know and understand, they adapt more easily to the questions and curiosity raised by these "small boxes". They can answer their friends' questions, train their relatives or children in the settings of the RS, or give a less technical name that explains what the device does: "*Le sismographe*" [the seismograph], in French. And in Creole, *'Bwat ki pou anrejistre tranblemantè yo'*. Sometimes also *sismographe* in Creole, but there is more popularization in Creole." (French host at Môle Saint Nicolas).

Some of the hosts have even become reference persons in seismology in their environment. A hostess in Jacmel told us: "*I have become a bit of an accomplice in the area. 'Ah! Madame gen yon aparèy lakay li kap detekte ond [There's a device in her house that detects the waves]' you see it's a little bit like that*". In Anse-à-Veau, a host was also contacted to verify information: "*People know that I have reliable information. Someone had once announced on Facebook that a shake had been felt in Anse-à-Veau. The reflex for people who had not felt anything was to call me so that I could verify and eventually decide on the issue.*" In all these situations, the RS gives a power of authority and knowledge, and places the citizen-seismologist as an actor both as a receiver of a device, and as a transmitter of information and knowledge.

The S2RHAI project was, in part, intended to test the dissemination of knowledge and risk awareness from hosts to their community, under the assumption that they could be ambassadors. While this seems to have worked for some of the hosts mentioned above, it is not the case for the majority of them. Pedagogy and popularization are indeed skills that must be acquired and it is therefore necessary to equip the hosts on these subjects. Many suggested that the scientific team should create small posters or flyers that could be handed out if a visitor was intrigued by RS, or that could be posted in busy places. They would answer passers-by's questions in a quick and educational way - even informing them of the presence of the RS and the project, as the tool is discreet, small and sometimes placed in areas that are not very visible. They also suggested developing tools more adapted to the Haitian context – for instance avoiding maps that many people do not understand, or using communication channels such as radio or social networks – and establishing partnerships with schools to reach a larger part of the population through school education. If the seismic information app LastQuake, which provides earthquake information globally, has already been translated in Creole, much more is still to be done to make the information accessible and usable by the RS and the broader population.

Better communication and inclusion of the hosts via the documents described above, as well as direct - and if possible face-to-face - links between scientists and citizens, will help maintain enthusiasm and pride in participating in the project, but also foster reciprocal learning for all. The restitution of the work in progress is finally a means of animating the team of hosts: the concretization in articles makes it possible to maintain the link and to reinforce the mutual enthusiasm for the realization of the project.