Monitoring Haiti's Quakes with Raspberry Shake

A network of "personal seismometers" is intended to complement Haiti's national seismic network to engage and inform residents about earthquake hazards and preparation.

A woman displays a Raspberry Shake seismometer. Poor-quality construction, typical of many neighborhoods in Haiti, is visible in the background. A pilot project to create a network of these personal seismometers across Haiti aims not only to provide earthquake data but also to involve citizens in earthquake awareness and hazard mitigation efforts. Credit: E. Calais

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On 12 January 2010, a devastating earthquake put Haiti on the map for many of us who were unaware of the recurrent difficulties that the country has endured over the past decades. The earthquake claimed more than 200,000 lives, and the damage amounted to about $11 billion, close to 100% of the country's gross domestic product.

Before the earthquake, Haiti had no seismic network, no in-country seismologist, no active fault map, no seismic hazard map, no microzonation (https://earthquake.usgs.gov/learn/glossary/?term=microzonation), and no building code (https://eos.org/features/the-wicked-problem-of-earthquake-hazard-in-developing-countries). The national seismic network that has emerged since then currently consists of 10 broadband stations (Figure 1) [*Bent et al.* (https://doi.org/10.1785/0220170176), 2018], operated and maintained by Haiti's Bureau of Mines and Energy (BME). Although this network was a significant step in the right direction, it has not proved to be a panacea.

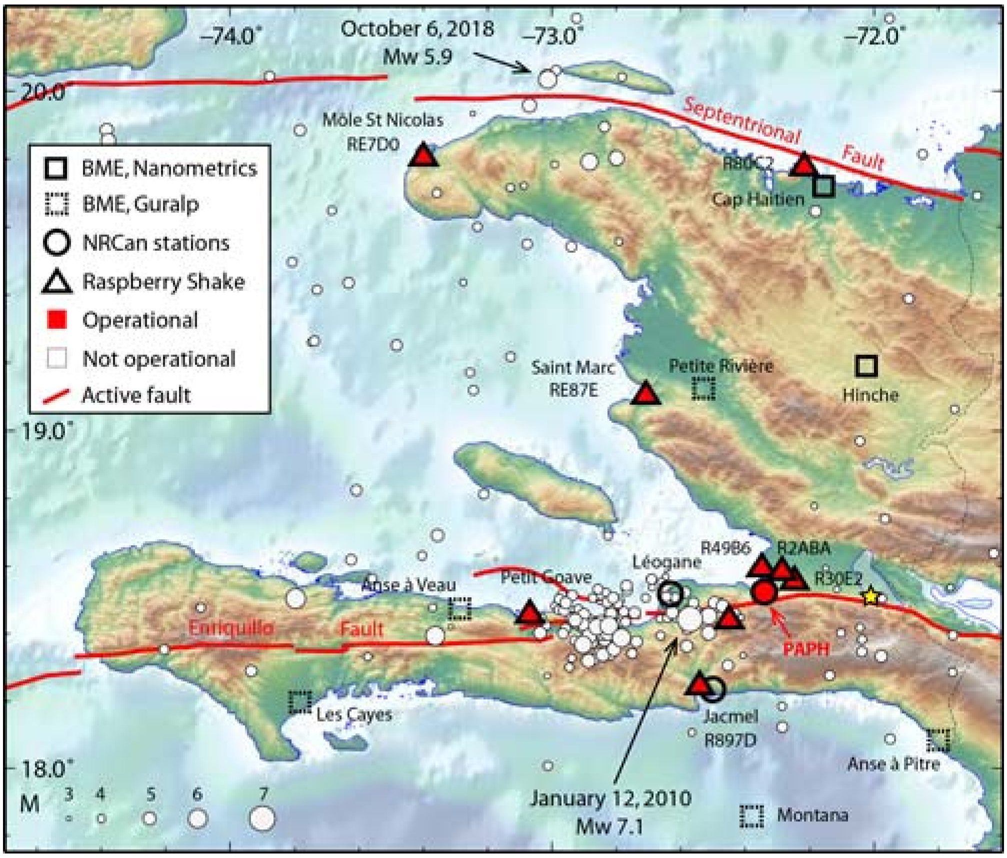

Fig. 1. Seismic stations in Haiti (symbols) and seismic activity as reported by the U.S. Geological Survey (white circles) from August 1946 to 14 January 2019. Natural Resources Canada (NRCan) broadband station PAPH (red circle), based in Port-au-Prince, is usually operational. The nine Raspberry Shake stations shown on this map (with their code names) were installed in January 2019 and were operational as of 15 February. The yellow star east of Port-au-Prince indicates the location of the *M*3.1 earthquake shown in Figure 3. Stations RE7D0, RE87E, and R2ABA, which use Wi-Fi to connect to the Internet, are not observing the radio frequency interference noted

by some RS hosts elsewhere who also use Wi-Fi to connect to the Internet. BME is Haiti's Bureau of Mines and Energy, which operates seismic instruments from two manufacturing companies.

On 6 October 2018, a magnitude 5.9 earthquake struck northwestern Haiti, causing 17 fatalities and significant damage in the larger cities of the epicentral area. Only one seismic station was operating at the time, a situation that has persisted for several years now. In spite of its continued efforts, it is difficult for the BME to overcome the chronic lack of resources—financial and human—necessary to maintain such a high-technology system.

This is where Raspberry Shake (http://www.raspberryshake.org/) (RS) comes into play [*Anthony et al.* *(https://doi.org/10.1785/0220180251)*, 2018]. This organization, founded using a Kickstarter campaign in 2016, provides affordable "personal seismometers" powered by small Raspberry Pi computers. The low cost of an RS station and the ease of installation and maintenance make it possible to imagine a situation in which perhaps as many as 100 citizens, businesses, or schools throughout Haiti would host an RS station.

To do more than just imagine, we began a pilot project last January, purchasing and deploying nine one-component vertical velocimeters (RS1D) throughout Haiti (Figure 1), four of them additionally equipped with 3-D accelerometers (RS4D). Except for one station located at the BME, all RS hosts are private homes or hotels. We selected these hosts from people whom we knew had quasi-continuous Internet access and electricity, the latter being a major issue in Haiti. This initiative is similar to the Quake Catcher Network (http://quakecatcher.net/index.php/) [*Cochran et al.* *(https://doi.org/10.1785/gssrl.80.1.26)*, 2009], although the latter uses only accelerometers.

Overcoming Limited Resources

As a result of resource limitations, seismologists in Haiti are able to provide only limited information to the public or to decision-makers when earthquakes are felt. This reinforces the ill-founded perception that seismic monitoring is of little value, and it keeps the population in the dark about seismic hazard. As a result, citizens and businesses do little to protect themselves from future large events. The lack of reliable information also provides ground for fake seismonews, including the notion that earthquake prediction has already been around for years so that earthquake monitoring is irrelevant.

Members of the public ask questions, want to be informed, and want to know how to prepare for earthquakes.

Interestingly, however, the public demands reliable information about earthquakes and tsunamis (https://eos.org/project-updates/nations-work-together-to-size-up-caribbean-tsunami-hazards) and their associated risks. They ask questions, want to be informed, and want to know how to prepare. Some would even like to be able to help improve earthquake knowledge in Haiti.

A citizen's network of small, affordable seismic stations could be a starting place for providing this information. Even though RS instruments would most likely be concentrated in major cities, their redundancy would alleviate inevitable maintenance issues at any single station. Such a network would improve the ability of the Haiti seismic network to detect small-magnitude earthquakes on a continuous basis, resulting in a better understanding of earthquake distribution and fault behavior. In addition, installing seismometers in people's homes may be a way to initiate a conversation with the population to promote a culture of earthquake safety.

Setting Up the Network

Raspberry Shake setup at station R897D in Jacmel (see Figure 1) uses an RS1D instrument located on the first floor of a public notary's office, under "made-on-the-spot" wooden protection. The RS station is connected to secure power and to the Internet through an Ethernet cable to the router visible on the windowsill. From left to right are Berthony (technician from the Haiti Bureau of Mines and Energy); Mrs. Beaulieu, who hosts the station; and authors Eric Calais and

Steeve Symithe. Credit: E. Calais

We set about creating our RS network by simply laying an RS instrument on the floor of the quietest first-story room we could find at each location. We connected them to power and Internet utilities, in six cases directly to the router via an Ethernet cable and in three cases via Wi-Fi. We made it clear to the hosts that the RS stations would use very little power and Internet bandwidth but that they should contact us if they suspected any issue. We also told them that they were free to disconnect the RS in case of a problem.

Several hosts asked whether their RS could serve to predict earthquakes or whether they would sound an alarm if seismic waves were coming. We made it very clear that this was not the case and explained that we were mostly interested in the smaller earthquakes: the ones they never feel but that occur every day.

"What? There are earthquakes every day in Haiti?" was a common reaction. Yes, indeed, we told our hosts, and knowing where and how big the small quakes are tells us a lot about the future large ones. Many hosts asked how they could see the information. We showed them how to view the helicorder (which records data from the seismometer) from their smartphone or computer on their local network, but often, they were not impressed with the displays. Helicorder output is indeed difficult to read because most squiggles are not earthquakes. Clearly, we need to do more work on how to provide relevant and useful information to RS station hosts.

First Observations

Three weeks after the installation of the first RS, we could already make a few observations that will be useful for the next phase of our project and, we hope, for other similar projects elsewhere.

We have detected many events that occurred less than 100 kilometers from this first RS station. The first one (Figure 2), recorded on 13 January 2019, was later located by the seismological network of the Dominican Republic, which quoted its magnitude as 3.1. We also recorded a sequence of four events in northwestern Haiti the day after we installed another station; these events were not reported by any regional seismic network. Regional events show up very well too, for example, the *M*5.3 earthquake that struck the Dominican Republic on 4 February 2019. Even the *P* wave and *S* wave arrivals of teleseismic (distant) events are recorded, including an *M*5.6 earthquake that occurred in Colombia on 26 January 2019.

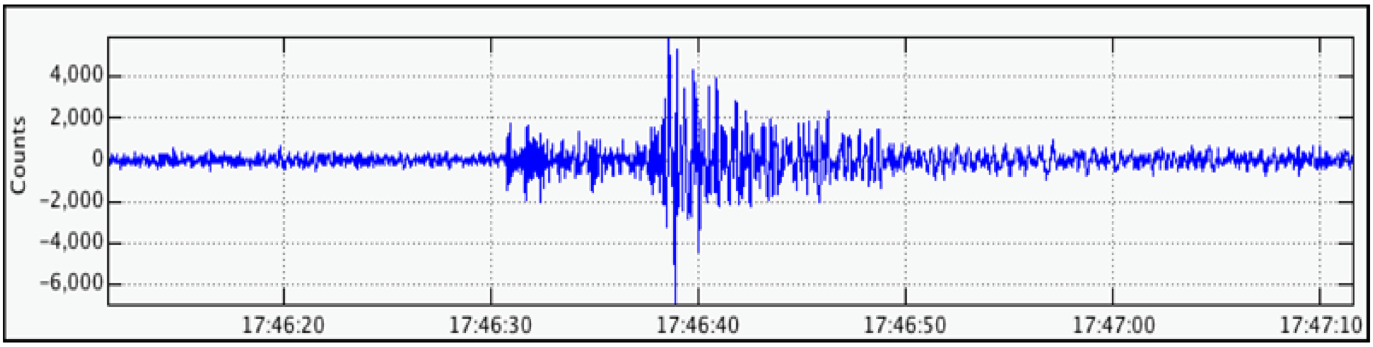

Fig. 2. Station R30E2, located in downtown Pétion-Ville, produced Haiti's first Raspberry Shake station recording of a local earthquake on 13 January 2019. This event was not reported by Haiti's national seismic network, but it was later reported by the Dominican Republic seismic network as an *M*3.1 event (yellow star in Figure 1) along the Enriquillo–Presqu'île du Sud fault close to the border between Haiti and the Dominican Republic.

Noise levels are, of course, very different from station to station, unless tight seismological prescriptions are enforced. However, that is not the point of using low-cost RS stations at individual homes, businesses, or schools. Our hope is that the redundancy of RS stations within a small footprint—a city—will suffice to ensure the availability of enough reliable data. This remains to be investigated in a quantitative manner as more stations come online.

We noticed that reliability and continuity of service are an issue, even though we tried our best to place the RS instruments at locations with continuous power and reliable Internet. One RS station host wanted to negotiate communication costs and, after a few days, apparently disconnected his station. Another station, located in a power-secure part of Port-au-Prince that had not previously needed power backup, is now experiencing regular blackouts. This underscores the importance of observation redundancy, with many stations at short distances from each other, because one never knows which one will have an issue and stop operating when an interesting earthquake shows up.

A Work in Progress

We were positively impressed by the response of civil society members and the private sector to this initiative. However, to gain the support of civil society, it is clear that we need to provide RS hosts with personalized information, such as "your RS instrument detected an earthquake of magnitude 2.5 located 50 kilometers away, in the area of…." A smartphone application would be a great way to provide this information in quasi-real time and keep station hosts engaged. It could also serve to broadcast information on earthquake preparedness and hence use the (fortunately long!) time intervals between large earthquakes to educate and promote earthquake safety (https://eos.org/features/lessons-from-mexicos-earthquake-early-warning-system).

Our goal now is to push forward and engage the civil society and the private sectors to be a bigger part of this project.

With the lessons learned during this pilot experiment, our goal now is to push forward and engage the civil society (https://eos.org/articles/crowdsourced-seismology) and the private sectors—at least those entities that can afford continuous power and Internet—to be a bigger part of this project. Expanding the project would provide more RS stations and thus redundancy and continuity of service. It would also engage RS hosts in a project that puts them at the center of the information chain. RS hosts will become information providers to scientists rather than passive listeners to scarce and unintelligible information.

It is our hope that as RS hosts and others become more aware of the earthquake issue, they will share information they will be privy to. We hope that they will become advocates for seismic monitoring, but more important, we hope that they will act to reduce seismic risk for themselves and their community.

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