Can a Raspberry Shake Seismic Network Complement a National Seismic Network? A case study in Haiti

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Complex networks of high-tech sensors are tough to operate and maintain in developing countries – but new low-costs, low-maintenance instruments may help. Because they are "connected objects" they also provide new opportunities to engage the civil society in citizen-science. Here we describe a seismological instrumentation experiment in Haiti with sensors that cost less than 500$ and can be installed at individuals, businesses, and schools. We seek to test how such instruments can (1) complement the national seismic network for regional earthquake location and magnitude determination, and (2) open a new communication gateway between seismologists and the civil society.

The devastating January 12, 2010, earthquake put Haiti on the map for many of us unaware of the recurrent difficulties endured by this country and its population over the past decades (Hurbon, et al., 2014). Adding to this, the 2010 earthquake cost more than 200,000 lives and about 11 billion dollars, close to 100% of the country's GDP (World Bank, 2010; Desroches et al., 2011). Science-wise, the pre-earthquake scene was daunting: no seismic network, no in–country seismologist, no active fault map, no seismic hazard map, no microzonation, no building code (Calais, 2017). Economics-wise, the earthquake was a major setback from which Haiti is far from having recovered today.

In 2010, soon after the earthquake, Natural Resources Canada (NRCan) installed three broadband seismic stations with real time transmission in the epicentral area (Bent et al., 2018), to be maintained by the Bureau of Mines and Energy, the Haitian governmental organization in charge of seismic monitoring. Only one (PAPH) of these stations is currently operating. Since then, the Haitian Ministry of Environment has obtained funding for 4 additional broadband stations, with real time transmission, which are now all installed and operated by the Bureau of Mines and Energy (Figure **1**). On October 6, 2018, a magnitude 5.9 earthquake struck northwestern Haiti, causing significant damage in the larger cities of

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the epicentral area, with 17 fatalities. Station PAPH was the only one operating. The director of the civil protection agency could only obtain information from the Catts Pressoir School, which has been hosting a Guralp CMG3 sensor since 2008 for pedagogical purposes.

The lesson here is that the continued efforts of the Bureau of Mines and Energy to operate the Haiti national seismic network were not sufficient to overcome the chronic lack of resources – financial and human – necessary to maintain such a high-technology system. This issue is of course not specific to Haiti and, outside of the private sector, is shared by most developing countries. As a result, seismologists in Haiti are only able to provide limited information to the public or to decision-makers when earthquakes are felt. This reinforces the notion that seismic monitoring is of little value and keeps the population in the blind about seismic hazard. Hence, citizens and businesses do nothing to protect themselves – or to demand protection – from the upcoming large events. The lack of reliable information also provides ground for fake seismo-news to develop and propagate – such as the notion that earthquake prediction has already been around for years so that earthquake monitoring is irrelevant.

Interestingly though, the public in Haiti is in demand for reliable information about earthquakes, tsunamis, and the associated risks. Some citizens, businesses, schools, are eager to know more about the hazard posed by earthquakes – they ask questions, they want to be informed, they want to understand. And some would even like to be able to help seismologists improve earthquake knowledge in Haiti.

This is where Raspberry Shake (RS) stations come into play (www.raspberryshake.org). Their low cost and ease of installation and maintenance makes it possible to imagine a situation where perhaps as many as 100 citizens, businesses, or schools throughout Haiti would host a RS station! Even though RS stations would most likely concentrate in major cities, their redundancy would alleviate inevitable operation and maintenance issues at any single station. Then our ability to detect small magnitude earthquakes on a continuous basis would be much improved, resulting in a better understanding of earthquake distribution and fault behavior in Haiti (Anthony et al., 2018). For instance, the recent installation of three short period seismic station across the border in SW Dominican Republic led to the discovery of an earthquake cluster underneath the Sierra de Bahoruco while the Enriquillo fault, in that same area, appears inactive (Rodriguez et al., 2018). In addition, seismometers in people's homes may be a way to initiate a conversation with the population on earthquake risk, for instance using felt earthquakes as "teachable moments" via social media in order to promote the emergence of a culture of earthquake safety.

We started with a pilot project of 9 one-component vertical velocimeters (RS1D), 4 of them additionally equipped with 3D accelerometers (RS4D), which we purchased and scattered throughout the country (Figure **1**). Except for one (Bureau of Mines and Energy), all RS station hosts are private individuals or hotels. We selected them amongst people we knew had quasi-continuous Internet and electricity – the latter being a major issue in Haiti where one rarely gets more than 4 hours of national electricity per day. Many people therefore have several backup systems with batteries and inverter, and/or generator, and/or solar panels. Internet access, on the other hand, is quite good in most cities – provided one has power!

We simply laid the RS instruments on the floor of the most quiet first story rooms we could find and connected them to power and Internet, in 6 cases directly to the router via an Ethernet cable, in 3 cases via WIFI (Figure **2**). Our intention was to put ourselves in the conditions most individuals would encounter so that we could also observe how the local anthropogenic noise would affect the usefulness of the measurements. In the future, we may install a few RS stations in locations that are specifically suited for seismic observation, with low noise levels, bedrock, and possibly underground. 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 asked whether their RS station could serve to predict earthquakes, or if at least they would sound an alarm if seismic waves were coming. We were of course very clear that it was not the case and explained that we were mostly interested in the smaller earthquakes, the ones they never feel but occur every day. *"What, there are earthquakes every day in Haiti!"* – yes indeed, and knowing were and how big they are tells us a lot about the future large ones… Many asked *"how to see the information"*. We showed them how to view the helicorder from their smartphone or computer on their local network: they were often not too impressed. Helicorders are indeed difficult to read as most wiggles are not earthquakes! Clearly, more work is needed on how to provide relevant and useful information to RS station hosts.

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

First, we have detected many local events (i.e., < 100 km from the station). The first one, shown on Figure **3**, was recorded on our second day of observation at station RS30E2, and 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 station RE7D0 – they were not reported by any regional seismic network. Regional events show very well too, as a M5.3 earthquake that struck the Dominican Republic on February 4, 2019. Even teleseismic events are recorded – at least the P and S arrivals – as shown by a M5.6 earthquake that occurred in Colombia on January 26, 2019.

Second, noise levels are of course very different from station to station – unless tight seismological prescriptions are enforced, but that is not the point of using low cost RS stations at individuals, businesses, or schools. The impact of this diversity of noise environments remains to be investigated. Our hope is that the redundancy of RS stations within a small footprint – a city – will suffice to ensure that enough reliable data is available. This remains to be investigated in a quantitative manner as more stations come online.

Third, we noticed that reliability and continuity of service are an issue, even though we tried our best to locate the RS instruments at locations with continuous power and reliable Internet. Continuous power is an issue, and even the best Internet connection shows significant bandwidth fluctuations. One RS station host wanted to negotiate communication costs and, after a few days, apparently disconnected his station. Another one, located in a power-secure part of Port-au-Prince such that no power backup was necessary until now, is now experiencing regular blackouts. The lesson is that nothing can be taken for granted. Hence the importance of observation redundancy, with many stations even at short distance from each other – one never knows which one will have an issue and stop operating when an interesting earthquake shows up.

Fourth, we were positively impressed by the response of the civil society and the private sector to this initiative. They long for institutional advances, but are also aware that they rarely suffice. Initiatives from individuals, the private sector, or the many civil associations are also places where action can be taken to proactively address the numerous issues Haiti is facing. However, in order to gain the support of the 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 km 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, hence use the (fortunately long!) time intervals between large earthquakes to educate and promote earthquake safety. Of course, achieving this goal requires setting up a real-time data analysis center, which could be mirrored in Haiti and in Europe to ensure continuity of service. We are currently working on these developments.

Having learned from this pilot experiment, our goal is now to push forward and engage the civil society and the private sector – at least entities that can afford continuous power and Internet – to be a bigger part of this project. For the sake of having more RS stations – hence redundancy and continuity of service – but also so that RS hosts are engaged 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. They will become more aware of the earthquake issue, will share information they will be privy to, and become the advocates of seismic monitoring, but more importantly of seismic risk reduction.

There is no answer yet to the question asked in this article's title. We have a few proposals pending to investigate it further, including one that involves sociologists interested in using this Raspberry Shake project as an experiment to understand how seismic risk is perceived, how information on risk is appropriated and acted upon. Another one calls to the private sector to purchase RS instruments and host them at their secured facilities. And there is more coming! With time we shall see whether complementing a high quality, but hard to maintain and operate, national seismic network with many low cost stations is an efficient long-term strategy in developing countries.

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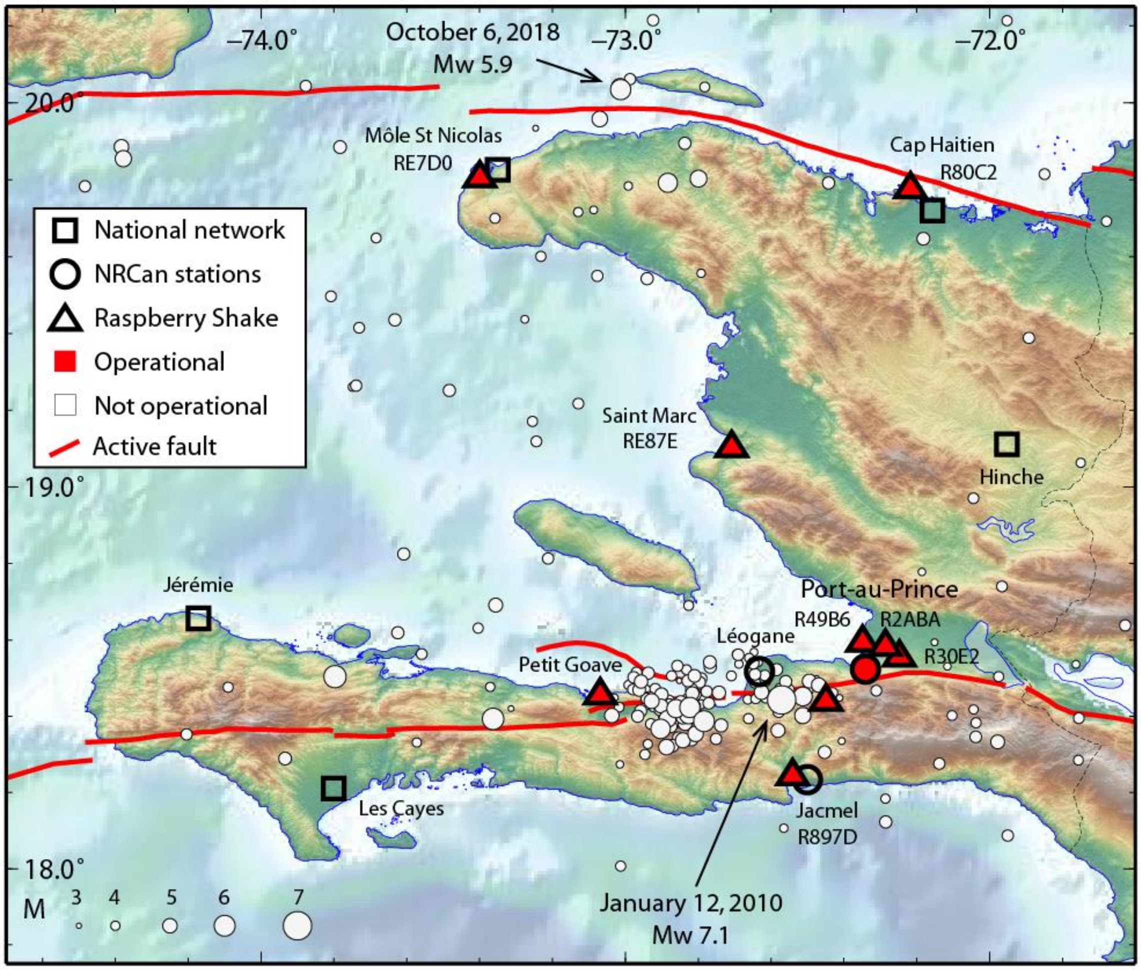

Figure 1. Seismic stations in Haiti (symbols) and seismic activity as recorded by the U.S. Geological Survey (white circles). NRCan broadband station PAPH (red circle) is usually operational. The nine Raspberry Shake stations shown on this map (with their code name) were installed in January 2019 and are operational as of February 20, 2019.

Figure 2. Raspberry Shake setup at station R897D in Jacmel (see Figure 1). The RS1D instrument is located on the first floor of a public notary's office, under a "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 in the background. From left to right: Berthony (technician from the Haiti Bureau of Mines and Energy), Mrs Beaulieu who hosts the station, Eric Calais, and Steeve Symithe (URGéo, State University of Haiti).

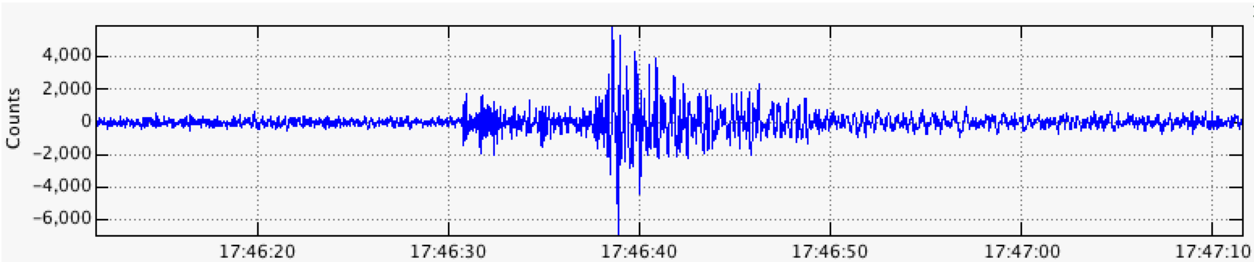

Figure 3. First recording of a local earthquake at a Raspberry Shake station in Haiti (station R30E2, see Figure 1, located downtown Pétionville). This event was not reported by the Haiti seismic network but was later reported by the Dominican Republic seismic network as a M3.1 event along the Enriquillo – Presqu'Ile du Sud fault close to the Haiti – Dominican Republic border.