ENVRIplus DELIVERABLE

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REPORT ON DEVELOPMENT AND IMPLEMENTATION OF A CITIZEN SEISMOLOGY SENSORS OBSERVATORY AND EDUCATION PLATFORM

WORK PACKAGE 14 – CITIZEN OBSERVATORIES AND PARTICIPATIVE SCIENCE

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ABSTRACT

The EMSC has been running the Euro-Med server for citizen operated seismic networks called Quake Catcher Network (QCN) in Europe since 2013. The main idea was to foster the development of citizen operated seismic networks in the Euro-Mediterranean region by offering the required infrastructure, easing the work at national and local levels and avoiding unnecessary duplication of efforts.

Several small deployments of half a dozen sensors were carried out in Greece, in the French Antilles and in Portugal thanks to the help of local seismologists interested in the project. We pursue this effort in the framework of WP14 of the ENVRIplus project with two main objectives: increasing the number of participants and improving participants' retention.

A basic principle in citizen science is to offer feedback to citizen scientists; this was not the case in the initial QCN approach implemented in the US, where participants were only data providers. The EMSC has developed a user web-interface allowing any participant to explore his own data and the data from other participants. This has been shared with IRIS (US) which has taken over the project lead from the USGS and now plans to adopt it. A call for volunteers to become citizen seismologists was launched through social media last April but success was limited. Only 28 new sensors have been connected to our QCN server since then.

There are many reasons to explain this limited success. Some are technical: QCN sensors still cost 40€, they are not so easy to install, they can be subject to data loss and they can only record significant shaking (typically felt ground motions). It also illustrates dramatic changes in the field of citizen seismology over the last few years.

After initial interest from both funders and the public which lead to many initiatives in citizen and school seismology around the Globe, this interest has been decreasing fast. Funding is now scarce and with the multiplication of citizen science projects it is more and more difficult to find volunteers, e.g. interested citizens that would engage for an extended period of time for a specific topic. Seismology requires a longer term engagement than other citizen science projects in which a volunteer can participate for a short period of time and then move to another project. QCN clearly illustrates these evolutions; there is no more funding to support the core infrastructure in the US, including the BOINC software without which QCN will stop, making the future of QCN uncertain even in Europe.

Beyond this decrease of interest, there is also the growing role of smartphones. Projects like QCN requiring a static desktop are unlikely to grow fast in the future.

These changes led us to adapt and complete our strategy to avoid relying only on the uncertain development of QCN. We have added 2 components to the strategy described in the initial ENVRIplus proposal. First, in order to make the best use of available resources, we believe that international collaboration and convergence of citizen and school seismology initiatives are required. We also need to explore the possibility of moving from desktops to smartphones based on the experience gathered at EMSC thanks its LastQuake app.

This report reflects this extension of our strategy. It contains 3 different parts:

The first part presents the developments based on QCN as well as the discussion with IRIS (USA) and TEC (Taiwan) to coordinate efforts.

The second part presents a new product, called Raspberry Shake that we will test during 2017 which interfaces professional grade commercial geophones with a Raspberry Pi. This autonomous station is more expensive than a simple QCN sensor (350€ compared to 40€) but they potentially present many –to be verified- advantages. They are autonomous and do not require a desktop, and they are far more sensitive than a QCN sensor. They can allegedly record a magnitude 2.0 earthquake at 80 kilometers which would dramatically increase the number of earthquakes recorded by volunteer participants. With such performance, it can be advantageous for national seismic networks to integrate some of these stations in their monitoring system to locally densify earthquake observations. If confirmed by our tests, their performance is equivalent to a short-period professional seismometer.

Finally they use a standard data format, meaning there is no more need for seismologists to maintain or develop specific software. This is essential for the long term sustainability of citizen observatory initiatives.

However, there is still a concern about long term data availability that needs to be clarified. Currently, the manufacturer ensures that all data that the owner agrees to open will be made available without constraint on one of its servers. But we have no insurance at the moment that such a service will be offered for free on an open ended basis.

The third part of the report presents the LastQuake app developed by EMSC and currently used by approximately 190,000 people worldwide. We will show that it is already a citizen observatory on its own. It makes use of crowdsourced earthquake detections, crowdsourced testimonies and comments at global scale and offers timely and geo-targeted safety tips after violent shaking. Citizens become actors of earthquake information, prevention and awareness.

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TERMINOLOGY

A complete project glossary is provided online here:
https://envriplus.manageprojects.com/s/text-documents/LFCMXHHCwS5hh

PROJECT SUMMARY

ENVRIplus is a Horizon 2020 project bringing together Environmental and Earth System Research Infrastructures, projects and networks together with technical specialist partners to create a more coherent, interdisciplinary and interoperable cluster of Environmental Research Infrastructures across Europe. It is driven by three overarching goals: 1) promoting cross-fertilization between infrastructures, 2) implementing innovative concepts and devices across RIs, and 3) facilitating research and innovation in the field of environment for an increasing number of users outside the RIs.

ENVRIplus aligns its activities to a core strategic plan where sharing multi-disciplinary expertise will be most effective. The project aims to improve Earth observation monitoring systems and strategies, including actions to improve harmonization and innovation, and generate common solutions to many shared information technology and data related challenges. It also seeks to harmonize policies for access and provide strategies for knowledge transfer amongst RIs. ENVRIplus develops guidelines to enhance transdisciplinary use of data and data-products supported by applied use-cases involving RIs from different domains. The project coordinates actions to improve communication and cooperation, addressing Environmental RIs at all levels, from management to end-users, implementing RI-staff exchange programs, generating material for RI personnel, and proposing common strategic developments and actions for enhancing services to users and evaluating the socio-economic impacts.

ENVRIplus is expected to facilitate structuration and improve quality of services offered both within single RIs and at the pan-RI level. It promotes efficient and multi-disciplinary research offering new opportunities to users, new tools to RI managers and new communication strategies for environmental RI communities. The resulting solutions, services and other project outcomes are made available to all environmental RI initiatives, thus contributing to the development of a coherent European RI ecosystem.

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DEVELOPMENT AND IMPLEMENTATION OF A CITIZEN SEISMOLOGY SENSORS OBSERVATORY AND EDUCATION PLATFORM

Developments based on QCN at the EMSC

The Quake-Catcher Network is a collaborative initiative for developing the world's largest, low-cost strong-motion seismic network by utilizing sensors in and attached to internet-connected computers. Microelectromechanical systems (MEMS) sensors detect vibrations within the frequency range of local seismic waves, so any internet-connected computer with an internal or external MEMS accelerometer can become a strong-motion seismic station (Cochran et al. 2009).

QCN was initiated by Stanford University and is now jointly operated by Southern California Department of Earth Sciences and the Incorporated Research Institutions for Seismology (IRIS).

Other QCN servers around the world

The University of Stanford developed the first QCN server (http://quakecatcher.net/) in 2005. The vast majority of the QCN sensors deployed around the world are today connected to this server. But other QCN servers are in operation in other countries to foster local deployments: for instance in Mexico (www.ras.unam.mx) or in Taiwan (http://qcn.twgrid.org/).

Principle

Several manufacturers offer low cost (as from 40€) accelerometers for purchase that are compatible with QCN and show nice performance (Evans et al. 2014; Cochran et al. 2009): for example the O-Navi-B (Figure 1) and the JoyWarrior 24F14 (Figure 2).

QCN also allows laptops equipped with accelerometers to connect. In this case the user doesn't need to purchase any sensor. However such embedded sensors are generally of lower quality than USB ones and can only record very strong ground motion.

FIGURE 1: O-NAVI-B 16 BITS SENSOR

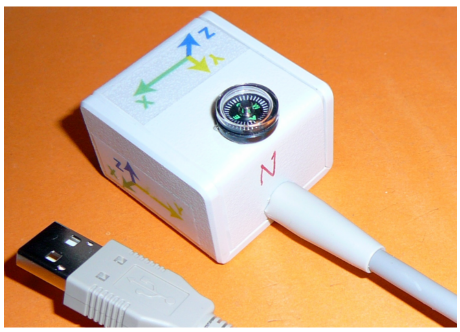

FIGURE 2: JOYWARRIOR 24F14 SENSOR

Sensor sensitivity and impact on the project

The QCN sensor is an accelerometer and accelerometers are not the most sensitive sensors of ground shaking. In practice a QCN sensor can detect ground movements which can be felt by a human being (Figure 3).

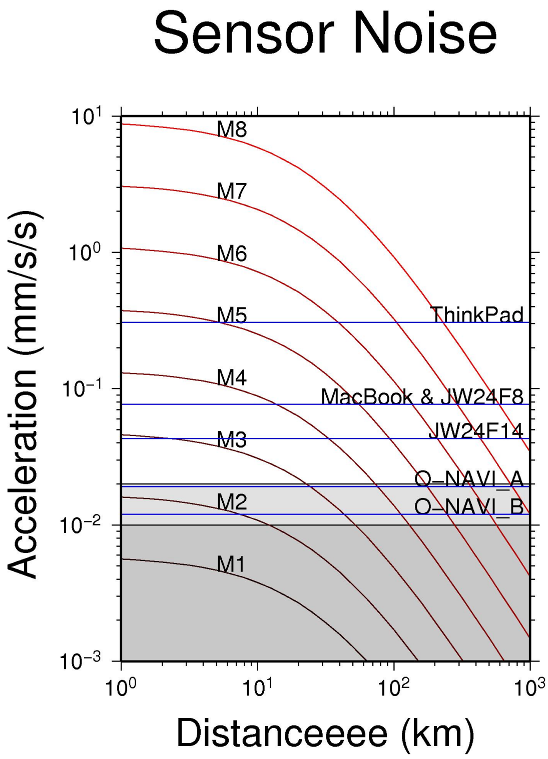

FIGURE 3: SENSITIVITY OF VARIOUS QCN SENSORS AND CORRESPONDING DETECTION CAPACITIES IN TERMS OF MAGNITUDE (FROM M1 TO M8) AND DISTANCE (SOURCE: HTTP://QUAKECATCHER.NET/SENSOR-PERFORMANCE)

A volunteer expects to record an earthquake at least once every few months otherwise he is likely to stop his/her participation. In practice, this limits the area where volunteers should be recruited to regions with significant seismic hazard, such as Italy, Greece, the Balkan countries or Turkey for the Euro-Mediterranean region. Installing a QCN sensor in France, Germany or the U.K. is unlikely to lead to any records during the life time of the desktop where it is plugged in.

Since sensitivity is low, the main benefit of a QCN sensor is not in earthquake detection – earthquakes able to generate such level of shaking are already located by existing networks – but in mapping the spatial variations of the shaking level, which is an important parameter for earthquake damage estimates. This is why we have initiated QCN networks in cities like Thessaloniki and Patras, in Greece.

A few words about Boinc

The Boinc web page gives the following description: "*Use the idle time on your computer (Windows, Mac, Linux, or Android) to cure diseases, study global warming, discover pulsars, and do many other types of scientific research*".

Boinc is a software developed by Berkeley University that allows distributed computing. By installing Boinc on your computer, you allow third parties (e.g. academic researchers) to use part of your CPU for computing purposes (Ex: in biology, in astrophysics, for climate studies …). The list of the main Boinc projects is available here: https://boinc.berkeley.edu/projects.php

QCN uses Boinc protocol to connect all sensors to the main server and automatically collect their data although the project itself doesn't require a lot of computing resources.

A QCN server at the EMSC

In 2013, jointly with the University of Stanford and the USGS, it was decided to implement a QCN server at the EMSC in order to profit from the visibility of the EMSC in European and Mediterranean countries to deploy sensors in the region, especially in urban areas where the seismic risk is high and heterogeneous. The technical implementation was carried out by IT people from the University of Stanford.

EMSC QCN server is accessible here: http://qcn.emsc-csem.org/

Our first QCN users

In the first months after our QCN server was online, we observed the connection of several tens of new users to it whereas we did not make any promotion during that time. The reason is that the Boinc community is very active and always keen on sharing their CPU with different Boinc projects. So we guess our project attracted several people already connected to Stanford QCN server who also wanted to share their data with the EMSC.

Deployment of QCN sensors in test sites

The first step was to deploy a few sensors in cities where the occurrence of earthquakes is relatively frequent to be sure to get interesting data. The second condition was to be in contact beforehand with a local seismologist interested in the project and ready to install half a dozen of sensors in different parts of the city. To deploy his sensors, this person has to be in contact with schools or administrative buildings for example.

Two Greek cities were identified. The first deployment took place in Thessaloniki, in Northern Greece in collaboration with Thessaloniki University (Figure 4), a second in Patras, on the West end of the Gulf of Corinth in collaboration with Patras University (Figure 5). Other deployments of few sensors were also carried out in Guadeloupe Island (French Antilles) and in Lisboa (Portugal).

For Patras, Thessaloniki and Lisboa deployments, the sensors were provided by the EMSC which purchased a bunch of 30 O-Navi-B sensors with the help of Stanford University.

Figure 4: USB sensors deployed in Thessaloniki, Greece

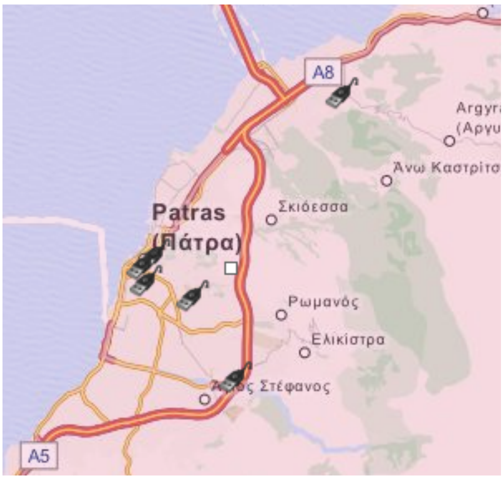

Figure 5: USB sensors deployed in Patras, Greece

Development of a user interface

Context

QCN provides a user interface via the QCN website to allow accessing the users' data and the data of the other sensors. But this interface is very simple, not user-friendly and makes difficult the querying of data back in time or its visualisation. Moreover, a QCN participant never gets any feedback and is not even aware if his sensor works properly or when it has recorded an earthquake.

Therefore in the framework ENVRIplus project, we developed a web graphic user interface to easily:

- Map the current active sensors
- Query, visualize and download the data of each sensor
- Highlight missing data in order to detect potential technical problems

Trigger Vs. Continual modes

It is important to notice that QCN has two modes called *trigger* and *continual* respectively:

- In *trigger* mode, the sensor provides data only if it has detected a strong motion, not necessarily associated to an earthquake.
- In *continual* mode, the sensor regularly sends 10-minute portions of continuous signal

User interface Version 1

When we started the development of the user interface, the initial QCN project was in a difficult situation due to a lack of funding. As a consequence, QCN developers were not available for support. Because of the lack of technical support, we had to dig into the code of QCN server and into the QCN databases in order to better understand how the whole code worked.

We rapidly realized that QCN database was not optimized to handle frequent and large queries. To solve this problem, it was necessary to create new tables and to automatically populate them as soon as new data were coming in. The technical development consisted of the following:

- Creation of two additional tables in the built-in QCN database
- Creation of daemon scripts that automatically populate these tables when new data are available (developed in Lua[1] language)
- Development of a web service to expose QCN data (developed in Lua language)
- Implementation of a Nginx web server
- Development of the User interface (developed in javascript)

Tests of user interface by identified users

A first version of the user interface was released in November 2015 and proposed for testing to the people responsible for the different test sites in Patras, Thessaloniki, Lisbon and Guadeloupe.

We collected their feedback. Many testers asked for a tool to download the waveform which did not exist in the first version. Several also complained that the interface was a bit too slow.

[1] The choice of Lua comes from its performance and the way it is fully interfaced with C++ libraries (http://www.lua.org/about.html).

User interface Version 2

Early 2016, we released a version 2 of the user interface after applying the corrections and improvements proposed by the testers. We also improved the performance of the interface by transferring part of the computing and data rendering on to the client side.

The final user interface is available here: http://vigogne.emsc-csem.org/qcn/

It's composed of 3 parts:

1. Selection of active sensors

The first part (Figure 6) allows the visualization of active sensors in the world and selection either:

- By database (or mode): *trigger* or *continual (see §*Context*)*
- By geographic location
- By date
- By Host id (i.e. sensor identifier as it appears in QCN database)
- By sensor type (e.g. O-Navi-B, JoyWarrior 24F14, HP laptop…). There are 18 different sensor types available in QCN database. They cover most of the MEMS compatible with QCN at the time QCN server was implemented at the EMSC. As this stage, we don't know if other MEMS could also connect to QCN server or if it would require an upgrade of QCN server code.

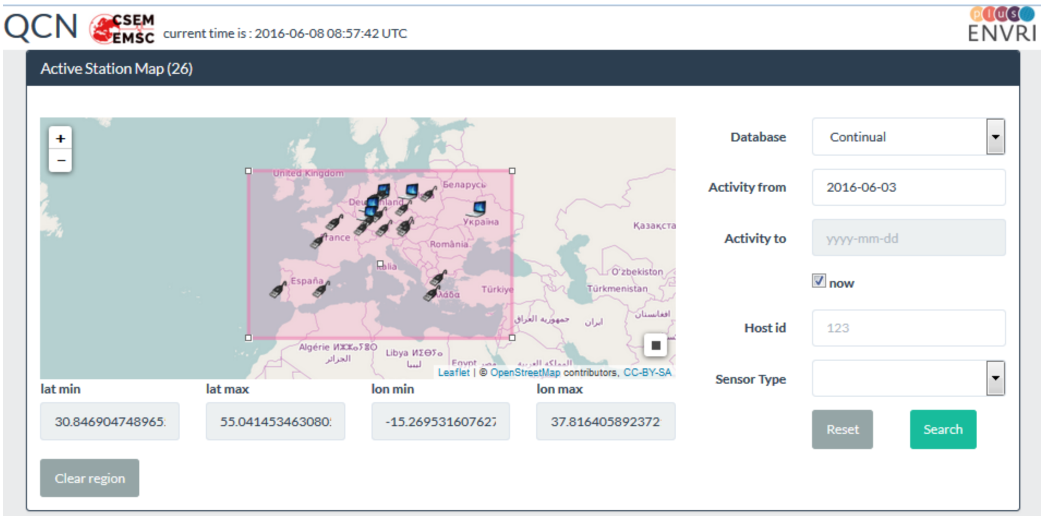

FIGURE 6: INTERFACE TO SELECT SENSORS BY DATE, GEOGRAPHIC LOCATIONS, SENSOR TYPES OR SENSOR ID

2. Display of data availability

The second part of the interface (Figure 7) displays all the data available for the sensors selected at the previous step.

Thanks to the optimization of the QCN database and the use of Lua language, the interface is capable of displaying the sensors' activities over a long period of time (e.g. 2 years).

Most of all, this interface allows someone to highlight the missing data (in blue on Figure 7). By looking at Figure 7, we realize that many sensors are barely active. The main reasons are:

- The Internet access or the computer is not active 24/7
- The computer is not time synchronized with the QCN server

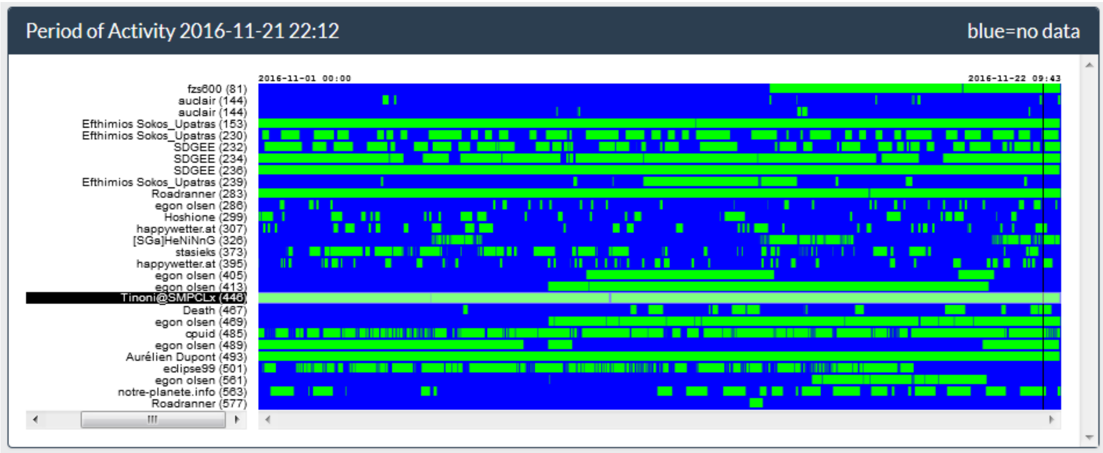

FIGURE 7: VISUALIZATION OF DATA AVAILABILITY

3. Display of sensors' data

With his mouse, the user can click on the portion of time he is interested in and the signal of all selected sensors will be displayed in the 3rd part of the interface (Figure 8).

For performance purposes, this 3rd part is limited to 30-minute portions of signal. However it is possible to scroll to the previous or the next portion of signal and to zoom in and out.

As each sensor records the ground motion on three directions (one vertical (Z) and two horizontal (X and Y)), it is possible to switch to each of the three components.

After having zoomed on the desired portion of signal, it is possible to download the signal either as a PNG image or to download the SAC file, a widely used seismological data format (Figure 9 and Figure 10).

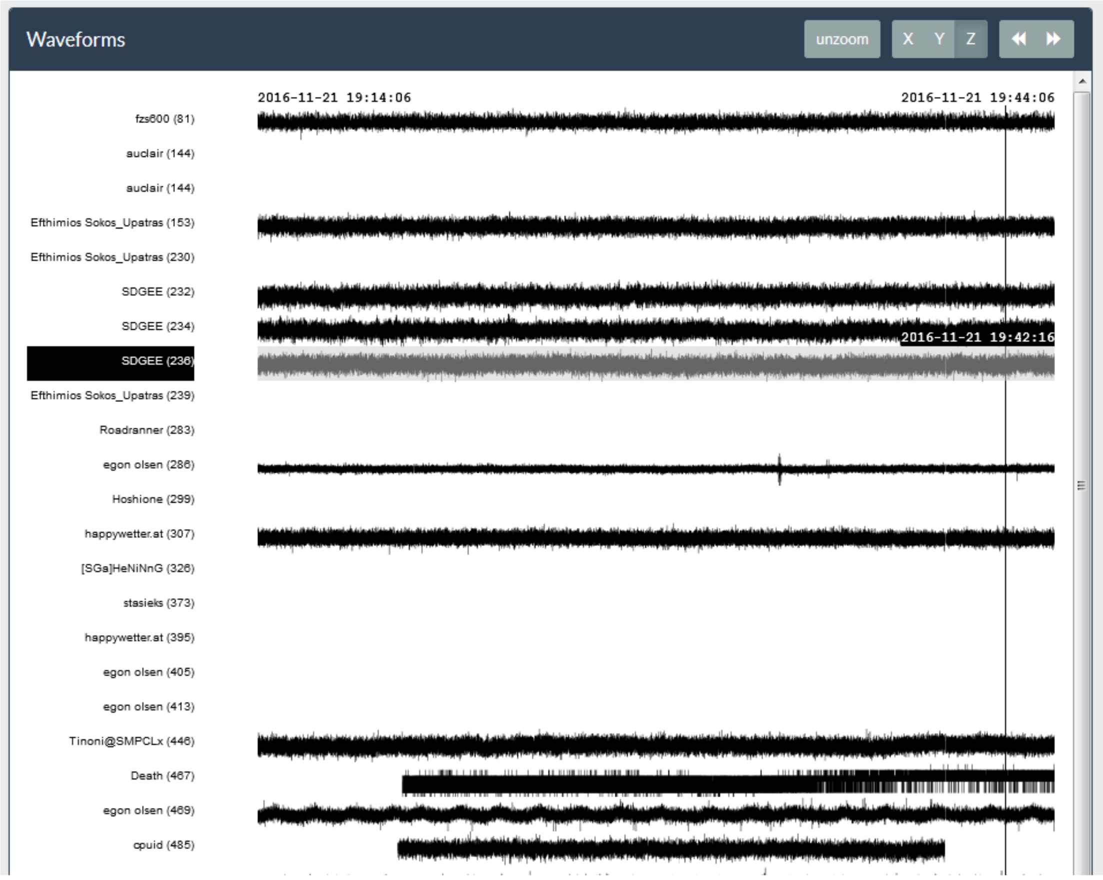

FIGURE 8: VISUALIZATION OF A 30-MINUTE PORTION OF SIGNAL PROVIDED BY EACH SELECTED SENSOR

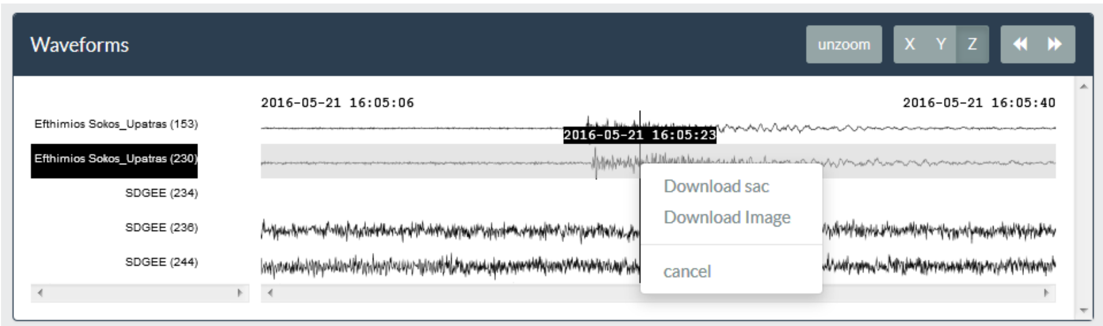

FIGURE 9: TOOL TO DOWNLOAD THE DATA OF A GIVEN SENSOR EITHER IN SAC FORMAT OR AS AN IMAGE

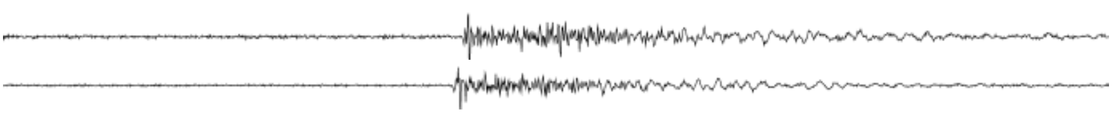

FIGURE 10: PNG IMAGE DOWNLOADED VIA THE USER INTERFACE FOR A M4.7 EARTHQUAKE NEAR PATRAS, GREECE ON 21/05/2016 RECORDED ON TWO O-NAVI-B SENSORS LOCATED IN PATRAS, AT A DISTANCE OF APPROXIMATELY 12 KM

Tests of the user interface by a larger set of users

Early 2016, we submitted version 2 of the user interface to a larger group of users especially to the people in Stanford University and in IRIS formerly or currently in charge of QCN developments.

We received a very positive feedback from Danielle Sumy from IRIS who said she would be very interested in implementing the user interface on the US data. This is a very good sign for us as it means that our interface could be interesting also for other QCN server operators (e.g. in Taiwan or in Mexico).

Call for volunteers

In order to bring more people in the project we launched a call for volunteers early April 2016.

Prior to that, it was necessary to write documentation describing in detail the different steps for the installation of a QCN sensor and its connection to the EMSC server. The documentation provided by the QCN website was a bit outdated and wasn't complete. In order to make the installation a bit smoother for the new participant, we presented the process in 8 steps.

The installation instructions are available here:

http://www.emsc-csem.org/Doc/QCN_call_for_volunteers/QCN_sensor_installation_instructions.pdf

We published a web page dedicated to the call for volunteers (Figure 11) explaining the goal of the project, why we needed new participants and what they could benefit from it. Indeed, volunteers not only contribute data, but could help seismologists to better understand earthquake phenomenon. Finally, by better understanding earthquakes and their effects, participants will improve their earthquake preparedness.

However, we clearly state that QCN sensors are less sensitive than professional seismometers and can only record local earthquakes. If the volunteer lives in a low seismicity region, there is only little chance that his sensor will record an earthquake.

The call for volunteers web page is available here: http://www.emsc-csem.org/service/QCN/

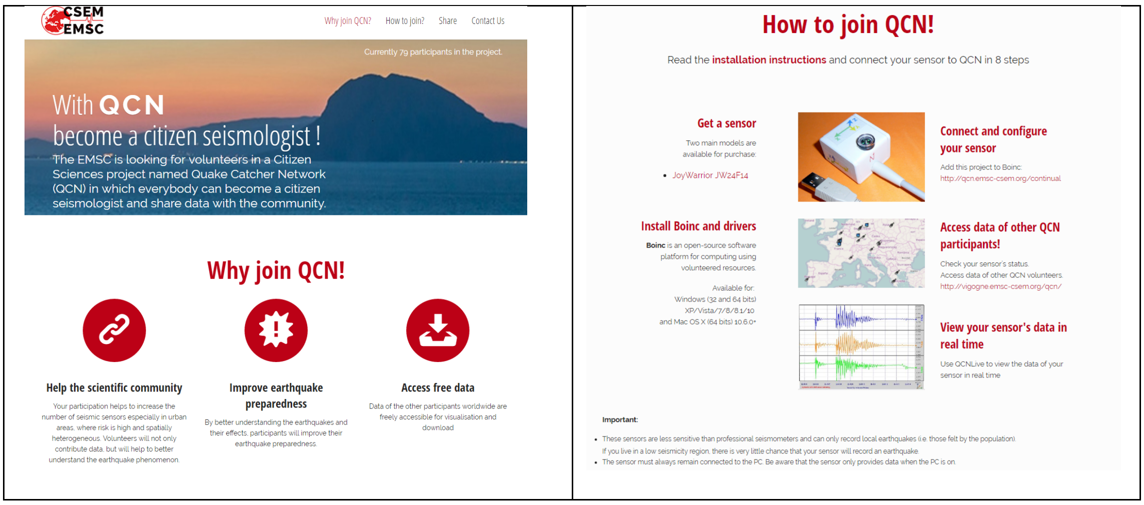

FIGURE 11: EXTRACT OF THE WEB PAGE DEDICATED TO THE CALL FOR VOLUNTEERS

We promoted the call for volunteers on different media:

- On EMSC website: http://www.emsc-csem.org
- On EMSC Facebook page: https://www.facebook.com/EMSC.CSEM/ (Figure 12)
- On EMSC Twitter account https://twitter.com/LastQuake

We also registered our project on SciStarter (Figure 13), a platform that promotes Citizen Science:

http://scistarter.com/project/1490-Quake%20Catcher%20Network%20(QCN)

FIGURE 12: POST ON EMSC'S FACEBOOK PAGE TO PROMOTE QCN AND THE CALL FOR VOLUNTEERS

FIGURE 13: REGISTRATION ON SCISTARTER OF THE CALL FOR VOLUNTEERS

Status of QCN deployments

Active sensors

Since the call for volunteers has been launched in April 2016, 28 new sensors have been connected to our QCN server. At the time of this report, a total of 93 sensors worldwide, 63 in the Euro-Med region (Figure 14) are active:

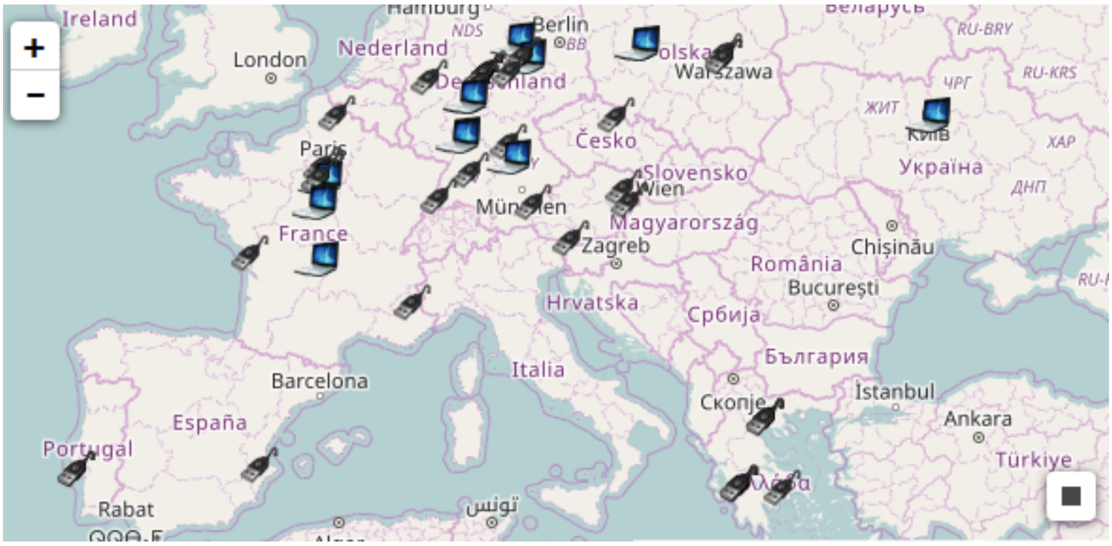

FIGURE 14: THE 63 ACTIVE SENSORS IN THE EURO-MED REGION. LAPTOP SYMBOLS CORRESPONDS TO LAPTOPS WITH AN EMBEDDED ACCELEROMETER. USB SYMBOLS CORRESPONDS TO SENSORS CONNECTED TO A DESKTOP PC IN USB.

Earthquakes recorded

In 2 years, more than 25 earthquakes have been recorded by the 2 deployments in Patras and in Thessaloniki. The sensors (all O-Navi-B types) were able to detect a M3.5 earthquake within 10km, or a M4.0 within 30km (Figure 15) which gives a good indication of the detection capacity of such sensors.

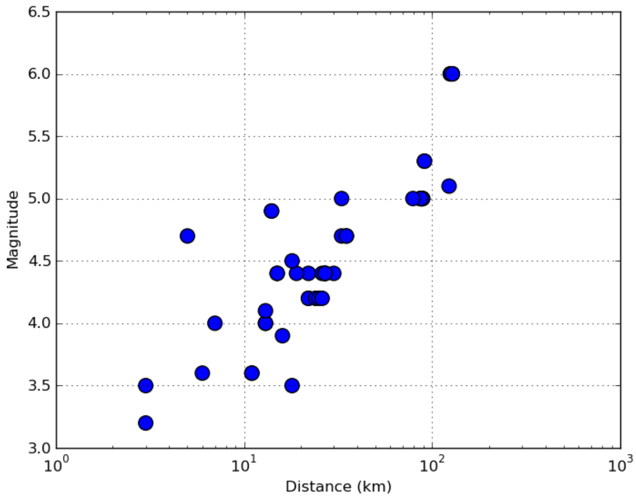

FIGURE 15: MAGNITUDE VS. DISTANCE PLOT FOR EARTHQUAKES DETECTED BY THE QCN DEPLOYMENTS IN PATRAS AND IN THESSALONIKI IN

Concluding remarks

- The price of the sensor (40 €) prevents large deployments made by individuals. We got several messages from people who were interested in the project but not ready to spend that amount of money to participate. However, BOINC and QCN are now available for Android phones (making use of built-in phone accelerometers). It only works when the phone is charging overnight it is a zero cost option for volunteers as they do not need to buy a sensor. We plan to test it in the second part of ENVRIplus project.
- Requires a desktop PC running 24/7
- Not plug-and-play devices. Installation is not straightforward.
- QCN sensors are accelerometers and therefore can only record strong ground motions. They can’t be used to record small earthquakes or large remote earthquakes. Even in earthquake prone regions, they record too few earthquakes.
- The users must check regularly that his sensor works properly. Time synchronization problems occur frequently and make QCN data unusable.
- Even with the help of a local active contact person, it is difficult to maintain a deployment of QCN sensors.
- Some sensors can’t be purchased anymore by individuals (ex: O-Navi)
- Some sensors are of too low quality (ex: O-Navi-A) to be usable for our purpose.

Collaborative project with Taiwan TEC

Presentation: A platform for earthquake data processing!

As presented earlier, other seismological institutes around the world run QCN servers such as the Taiwan Earthquake Research Center (TEC), of the Academia Sinica in Taiwan. They have an interesting experience in citizen seismology especially with schools as they developed a near-real time earthquake games competition (Liang et al.; 2016).

The game is presented here: http://katepil6.wixsite.com/earthquake-school/slideshow

For a participant, it consists in the following:

Step 1: *Get the certificates:* After registration, the participant has to play 4 different games in order to get the certificates to become a citizen seismologist.

Step 2: *Act as a citizen seismologist*: Once an earthquake occurs, the participant can contribute to earthquake information by:

1. Finding the earthquake
2. Measuring earthquake shaking
3. Estimate the size of the earthquake
4. Measuring how a fault moves

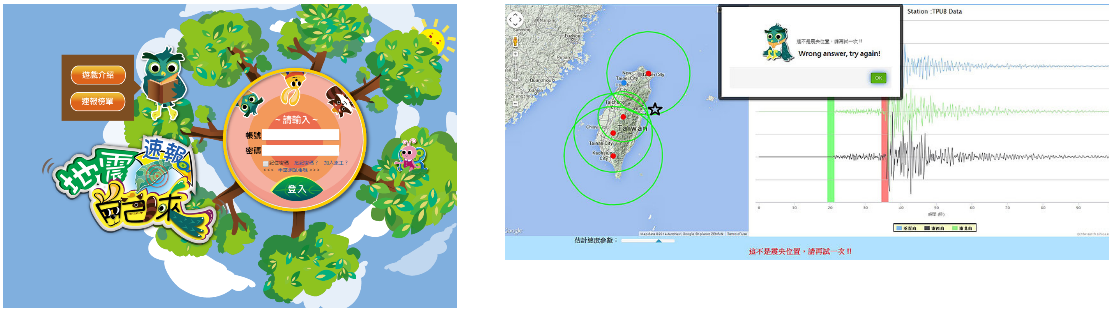

FIGURE 16: TAIWAN NEAR-REAL TIME EARTHQUAKE GAME COMPETITION

Project

In June 2015, we initiated a scientific collaboration with Kate Huihsuan Chen and Wen-Tzong Liang from the Taiwan Earthquake Research Center (TEC). Our idea was to adapt their earthquake game to the international context, to limit it first to global crustal M5+ earthquakes and to benefit from EMSC's international visibility to promote it.

The current earthquake game has been conceived and developed in the specific national Taiwanese context. Therefore, it is only available in Taiwanese language, it only uses local seismic stations (among which are QCN sensors) and the interface is adapted to this context. To adapt the earthquake game to the international context, the following actions are required:

- Translate it in English
- Adapt it to the general public (current interface targets 8-12 years children)
- Subscribe to real-time seismic data worldwide (ex: IRIS Global Seismic Network)
- Adapt the seismological software and the interface (current software adapted to local earthquakes)

To start with, we first planned to restrict the platform to larger earthquakes only (Mag>6), by proposing a few examples of recent significant earthquakes to play with (Nepal 2015, Central Italy 2016, New-Zealand 2016 …). The goal is to see how the development is perceived and adopted by the population before going to a large scale development. We proposed to the TEC that the game is split in three:

- An educational platform: Get trained in seismology!
- A citizen observatory: Process seismological data, locate earthquake!
- Competition: Be the first to locate the earthquake!

On the other hand, the TEC proposed to make a video clip to introduce the games that the EMSC will promote though various media (web, social networks).

Most of these planned developments concern TEC. They plan to coordinate their efforts with IRIS and to release a first version of the new game during spring 2017.

The role of EMSC here is mainly to propose an innovative engagement strategy based on its visibility on social media. Every felt earthquake creates a teachable moment: eyewitnesses are actively looking for information on our websites and social networks. We propose, that when the earthquake is not damaging and once the visitors have found the information they have been looking for, to invite them to test the education platform and evaluate the efficiency of this strategy. We believe, although it has yet to be demonstrated, that we are more likely to identify motivated volunteers by such a timely approach. And based on these results, we will evaluate the best strategy forward.

Last August 2016, Rémy Bossu met Kate Huihsuan Chen and Wen-Tzong Liang from TEC at the last AOGS meeting in Beijing. The discussions went well and both parties agreed upon the goals to be achieved. However it is difficult to know exactly what will be developed and implemented on the TEC side. They are also hit by budget cuts. We both hope this project will succeed but it is not certain at all.

Raspberry Shake

Raspberry Shake is sensor-digitizer developed by OSOP (http://www.osop.com.pa/), which interfaces professional grade commercial 4.5Hz geophones with a Raspberry Pi. This autonomous station is more expensive than a simple QCN sensor (350€ compared to 40€) but they present many potential advantages that we want to verify. The EMSC bought one of these sensors in order to test it and validate all the following alleged characteristics:

Autonomy:

Contrary to QCN sensors that need to be plugged on a PC running 24/7, Raspberry Shake sensors only need to be powered via USB. They don't need an Operating System so they could be plugged on an Internet box for instance.

Sensitivity:

Their sensitivity is claimed to be incomparably higher than accelerometers as they can record a magnitude 2.0 within 80 km and also large earthquakes worldwide. This is one of the greatest advantages over QCN sensors as they should be capable of recording several earthquakes per week, even in regions with low seismic hazard like in northern Europe.

Standard data format:

A user can share his data with seismic observatories worldwide in standard data format (seedLink). It means that a user can see and plot the data from any other Raspberry Shakes but also that these sensors have a real scientific value as they can complement classic academic seismological networks to locally densify earthquake observations systems (a comparable short period professional station would cost at least 15-20k€). It could also help to discriminate earthquakes from explosions if such sensors are deployed near mines or quarries for example.

Sustainability:

Because Raspberry Shake uses standard sensors and standard data format, there should no more need for seismologist to maintain or develop specific software which is essential for the long term sustainability of citizen observatory initiatives.

Raspberry Shake uses a mix of open source and commercial software licenses for data sharing. According to their terms of use[2] the license is available at no additional coast for personal and educational purposes only.

[2] https://shop.raspberryshake.org/product/osop-raspberry-shake-client-side-software-license/

FIGURE 17: RASPBERRY SHAKE: A SEISMOMETER COUPLED WITH A RASPBERRY PI CARD

However, there is still a concern about long term data availability as we still need to clarify with OSOP where the waveform data will be made available. Currently, the manufacturer ensures that all data that the owner agrees to open will be made available without constraint on one of its servers. We have no insurance at the moment that such a service will be offered for free on an open ended basis and we do not know what would happen in case of bankruptcy or other unpredicted developments.

Smartphones and citizen seismology

Why move to smartphones?

At the end of 2016, there will be more than 2 billion smartphones users around the world and today a majority of people access the internet through mobile devices. Citizen science has to move to mobile devices to ensure its long term sustainability. That is what the EMSC has done with its application LastQuake.

The goal was not to propose just another app, similar to the numerous earthquake apps already available. Our app is more focused on earthquake eyewitnesses and on the interaction with them. As described below, it integrates crowdsourced earthquake detections and it crowdsources earthquake testimonies, comments and geo-located pics which are then redistributed to the users.

The EMSC developed app, called LastQuake, is available on Android and iOS (http://www.emsc-csem.org/service/application/) and was initially released in July 2014. At the time of this report, we have more than 190,000 users.

FIGURE 18: LASTQUAKE SMARTPHONE APP

Crowdsourced detection of felt earthquakes

The principle of LastQuake app is that we detect felt earthquakes with crowdsourced data. When people feel an earthquake, they rush on the internet to find out what caused the shake. As a result, our web and app users generate a surge in the traffic activity on our web servers that we can detect and geolocate thanks to the users' GPS location or IP address (Figure 19). We also monitor public reaction on Twitter (following a method developed by the US Geological Survey).

This counts the number of tweets containing the keyword “earthquake” in various languages to detect sudden increases (e.g. “OMG, earthquake!”)

These complementary crowdsourced detections are fast, typically within 1 to 2 minutes of the earthquake occurrence, and in the vast majority of cases, faster than seismic locations. Once we detect a public reaction, we inform the users on our websites and on the LastQuake app that shaking has been reported in a given region; we also ask for testimonies and geo-located pictures to document its effects and keep the public updated.

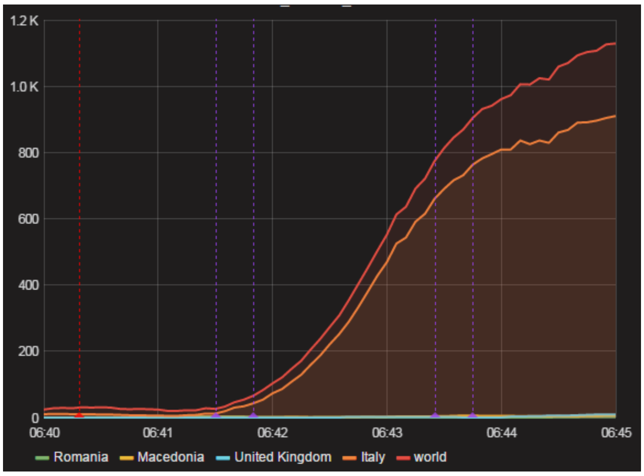

FIGURE 19: WEB TRAFFIC SURGE CONSECUTIVE TO THE MAGNITUDE 6.5 EARTHQUAKE THAT HIT CENTRAL ITALY ON 30/10/216 AT 06:40 UTC. THIS EARTHQUAKE WAS DETECTED BY FLASH CROWDSOURCING WITHIN 72 SECONDS OF ITS OCCURRENCE.

Rapid collection of testimonies, comments and geo-located pics

For a number of years, EMSC has replaced the traditional online macroseismic questionnaire by a set of 12 cartoons depicting different levels of shaking to collect earthquake testimonies at global scale (Figure 20). The idea was first to simplify the act of providing a testimony on the user side especially for mobile users. The second point was to embrace visual communication, essential for avoiding language issues in an international context. The consequence has been quite convincing, we collect far more testimonies via these cartoons and we collect them much faster.

70% of the nearly 90,000 testimonies that we collected during a 22-month period were collected through cartoons, and 40% of them were collected within 10 min of an earthquake! For example 780 testimonies were collected within 10 minutes of the magnitude 6.5 earthquake that hit Central Italy, near Norcia, on October 30th, 2016 (Figure 21 and Figure 22).

Finally we have shown that the cartoon-based data compare well with traditionally collected macroseismic data (Bossu et al.; 2016) (Figure 23), which shows that they are a very good complement to classical questionnaires-based data.

FIGURE 20: THE 12 CARTOONS THAT DESCRIBE THE 12 LEVELS OF SHAKING PROPOSED TO EARTHQUAKES EYEWITNESSES IN LASTQUAKE APP AND ON EMSC WEBSITES

FIGURE 21: TESTIMONIES COLLECTED FOR THE MAGNITUDE 6.5 EARTHQUAKE THAT HITS CENTRAL ITALY ON 30/10/2016 AT 06:40 UTC

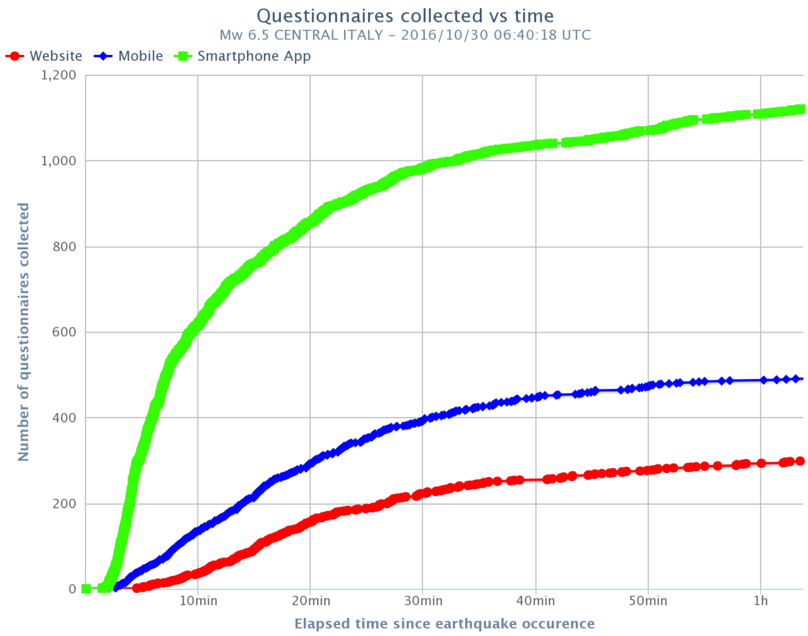

FIGURE 22: NUMBER OF TESTIMONIES COLLECTED VIA LASTQUAKE APP (IN GREEN), EMSC MOBILE WEBSITE (IN BLUE) AND EMSC CLASSIC WEBSITE (IN RED) FOR THE MAGNITUDE 6.5 EARTHQUAKE THAT HIS CENTRAL ITALY ON 30/10/2016 AT 06:40 UTC

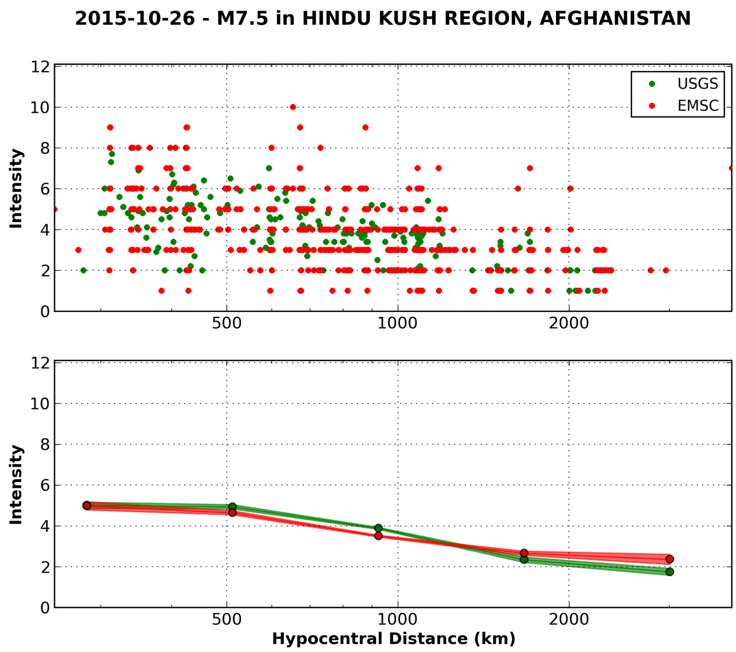

FIGURE 23: (TOP) INDIVIDUAL INTENSITY ASSIGNMENTS FROM EMSC INDIVIDUAL INTENSITIES (RED DOTS) AND USGS GEOCODED DATA (GREEN DOTS) FOR THE M7.5 HINDU KUSH, AFGHANISTAN EARTHQUAKE ON 26/10/2015. (BOTTOM) BIN-AVERAGED MEAN VALUES FOR THE SAME DATASET. SHADING INDICATES +/- 1 STANDARD DEVIATION OF THE MEAN CALCULATED FOR EACH (LOGARITHMIC) DISTANCE BIN. (BOSSU ET AL.; 2016)

Through EMSC websites and app, we also collect comments (Figure 24) and geo-located pictures or videos (Figure 25) sent by the eyewitnesses. They provide rapid complementary information on the level of shaking, of the damage and on witnesses' feelings ("Scared!", "I felt dizzy"…) and reaction ("I ran away!" …)

FIGURE 24: EXAMPLE OF COMMENTS PROVIDED BY EARTHQUAKE WITNESSES

FIGURE 25: PICTURES PROVIDED BY EYEWITNESSES SHOWING THE DAMAGE CAUSED BY THE M6.5 EARTHQUAKE THAT HIT THE REGION OF NORCIA, CENTRAL ITALY, ON 30/11/2016

Improving earthquake preparedness

By collecting within minutes of an earthquake hundreds of testimonies even from remote regions, it is possible to improve rapid situational awareness, which in turn contributes to efficient response.

Thanks to the LastQuake app, we are in contact with eyewitnesses immediately after the shaking and thanks to smartphone geolocation and seismological data we know very rapidly who has experienced the most violent shaking and may need some advice. The best way to deliver this is through cartoons which can be easily understood regardless of native language or stress level (Figure 26).

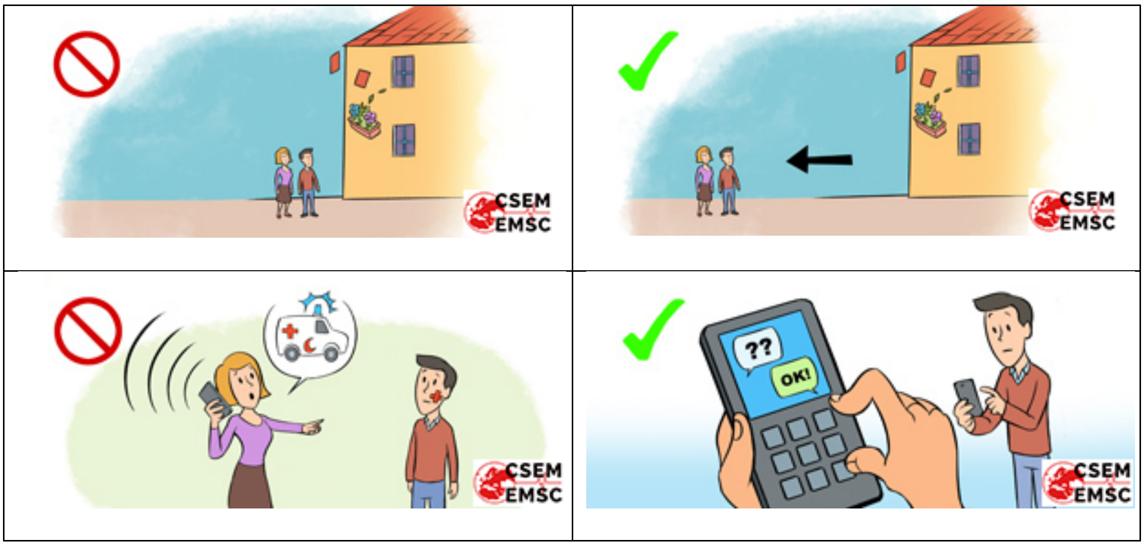

FIGURE 26: EXAMPLE OF "DO'S AND DON'TS" CARTOONS PROVIDED TO LASTQUAKE USERS THAT EXPERIENCED A VIOLENT SHAKING AFTER AN EARTHQUAKE

Conclusions and perspectives

This report presents the current status of the developments of the citizen seismology observatory led by the EMSC within the ENVRIplus project.

The web user interface developed by the EMSC is a significant achievement as it is the only interface of its kind in QNC world. It proved to be robust and very handy to easily display data availability and query data. We received a very positive feedback from Danielle Sumy from IRIS who said she would be very interested in implementing the user interface on the US data. This is a very good sign for us as it means that our interface could be interesting for other QCN server operators (e.g. in Taiwan or in Mexico).

Recently, BOINC and QCN for BOINC have been made available for Android phones making use of built-in phone accelerometers which means zero cost option for volunteers as they do not need to buy a sensor. We plan to test it in the second part of the ENVRIplus project.

The actions initially planned in the proposal have been amended to take into account the major changes which are the decrease in public interest and financial resource available and the ever increasing role of smartphones in Internet accesses.

This had led us to strengthen international cooperation, explore the possibility of technical convergence between the different citizen and school seismology initiatives and to strengthen the role of our LastQuake smartphone app. We do not know at this stage whether broadening our approaches will end in a successful and sustainable citizen seismology initiative but we believe that this adaptation was unavoidable in a fast evolving context: as an example since the beginning of ENVRIplus there has been a MyShake App developed by Berkeley University which uses accelerometers embedded in smartphones as part of a citizen science network. However, they face exactly the same issue of retaining participants. MyShake benefited from a global media coverage leading to 200,000 downloads in a few weeks but they have finally only 8 to 13,000 active users at the time of this report.

Finally, there is a new promising type of sensors called Raspberry Shake that we will test during 2017 which interfaces professional grade commercial geophones with a Raspberry Pi. This sensor is more expensive than a simple QCN sensor but presents several advantages: it is far more sensitive than a QCN sensor and it uses a standard data format. There is still a concern about long term data availability that needs to be clarified with the manufacturer.

IMPACT ON PROJECT

It is difficult to evaluate the impact of our developments on the project at this stage. The difficulties we have encountered in attracting participants might be linked to seismology, which requires a longer term engagement than other citizen science projects in which a volunteer can participate for a short period of time and then move to another project. If no earthquake occurs for some time, people might walk away.

It might be interesting to further compare with other citizen science projects and coordinate within ENVRIplus to get a broader view on changing landscape of citizen science.

IMPACT ON STAKEHOLDERS

If one considers the stakeholders as the other actors of school and citizen seismology initiatives, the impact has been growing collaboration at global scale.

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