EDUQUAKES

How Students Can Experience Science and Become Researchers: Tracking MERMAID Floats in the Oceans

by F. Bigot-Cormier and J.-L. Berenguer

ABSTRACT

Many of our students at the Shanghai French Middle-High School have been living in Asia for extended periods of time and have thus experienced an earthquake; this has fostered a curiosity among the students in regards to these phenomena. As such, the science faculty has aimed at using this natural interest and has had the students take part in educational programs focused on the detection of earthquakes and seismic-wave analysis. By working in collaboration with the MERMAID (Mobile Earthquakes Recording in Marine Areas by Independent Divers) project, our students are able to work on specific data recorded by several free-floating captors located in the Indian Ocean. Because these sensors are mobile, they can record more complex signals that are then analyzed by our students working in a research setting.

The article shows the ability of 8th grade students (14-yr-olds) to analyze unusual signals and introduces the methods they employed. The article also strongly advocates for the benefits that students acquire when research programs are open to collaboration with students, allowing them the opportunity to work with real world data.

INTRODUCTION

The French school in Shanghai named the "Lycée Français de Shanghai" (LFS) is one of the schools involved in the "SISMOS à l'École" (SaE: meaning "Earthquakes at School") program (Courboulex *et al.*, 2012; Berenguer *et al.*, 2013), and has been operating a seismic station since 2013. Although the LFS is not located in a very seismically active area, our students are aware that earthquakes occur in western China, Asia, and around the Pacific area. Many students in our school come from one of these highly active seismic areas and have already experienced an earthquake. Also, some students hosted pupils from the French school of Tokyo following the seismic events that occurred in Fukushima in 2011. These students are aware that earthquakes happen on a daily basis, and our 8th grade educational seismic workshop session is greatly appreciated by our students (14-yr-olds), who engage in class, enjoy recording and analyzing seismic waves, and understanding Earth's internal dynamics.

Here, we introduce an educational activity combining a research program (Mobile Earthquakes Recording in Marine Areas by Independent Divers [MERMAID project]; Hello *et al.*, 2011) and students' research skills using specific numerical tools to analyze seismic data.

This article aims to show how collaboration between researchers and students via a long-term educational activity can stimulate the students' curiosity and promote their autonomy, and encourage them to increase their understanding of the world around them through their own observations. We first introduce project MERMAID and present the data used by our students. We then describe how we designed an educational experience in which students learn to discover new ways to use and analyze the data, while applying their own experience of earthquakes to develop a critical mind and achieve an understanding of how science affects us in everyday life.

PROJECT MERMAID

The aim of this project, managed by Guust Nolet (from the Géoazur Laboratory, France), is to use mobile hydrophones as independent floats to record seismic *P* waves in the oceans. The oceans cover about 71% of Earth's surface and have been so far virtually inaccessible for seismic recording. By creating MERMAID, this team of researchers and engineers has created a marine laboratory (Simons *et al.*, 2006, 2009; Hello *et al.*, 2011) comprising 17 free-floating seismometers continuously monitoring and transmitting detected seismograms in quasi-real time (Fig. 1). These sensors not only record the local seismic activity, often too weak to be recorded on land, but also the major ones occurring worldwide (Lubick, 2011). Operating in the Indian and Pacific Oceans and the Mediterranean Sea, these free-floating MERMAIDs give us access to information

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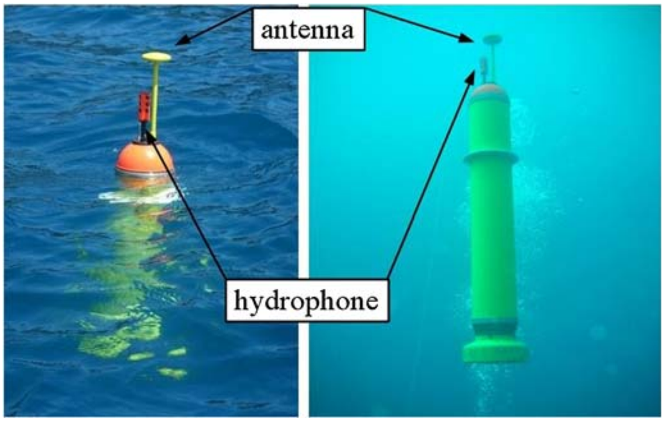
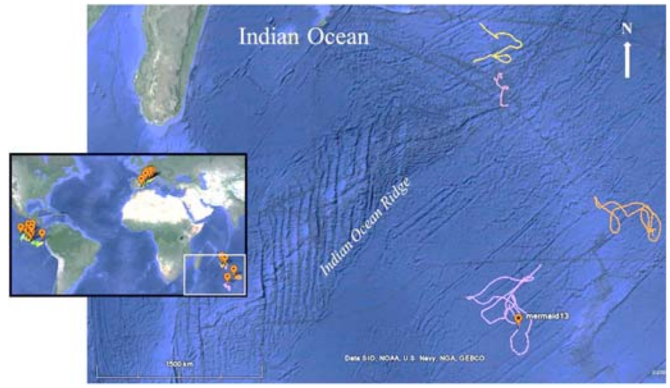


▲ **Figure 1.** Picture of a Mobile Earthquakes Recording in Marine Areas by Independent Divers (MERMAID) float (Hello *et al.*, 2011). The color version of this figure is available only in the electronic edition.



▲ **Figure 2.** Location of 17 free-floating seismometers continuously monitoring and transmitting detected seismograms in quasi-real time, between 2009 and June 2014. Four MERMAID captors are located in the Indian Ocean. LOL (Long yu—dragon in Chinese for its special shape—and Onde at the Lycee français de Shanghai) (MERMAID 13), located on the southern part of the map, was launched in the Indian Ocean on 7 March 2013 (modified from Google map). The color version of this figure is available only in the electronic edition.

about seismic events along the midocean ridges, whose microseismic events are usually not recorded. Additionally, they allow researchers to map small deviations in seismic-wavespeeds, enabling more detailed and accurate tomographic images of Earth's mantle beneath the oceans.

These free-floating seismometers record acoustic signals under water and ascend to the surface after detection of a major event or at least once a week to transmit their position. After reaching the surface, they transmit their current Global Positioning System position, as well as the seismogram that triggered the surfacing, by satellite. They also transmit any other low-frequency signals that may be weaker earthquakes, or false triggers from the ocean's swell and other nonseismic waves. These signals are then archived on Géoazur's Laboratory server into two directories labeled "identified" and "unidentified." The first directory corresponds to earthquakes reported by the National Earthquake Information Center, whereas the second directory contains both false triggers as well as less-significant earthquakes that have not been recorded by land-based stations, but only locally by a MERMAID float (usually mid-ocean ridge events).

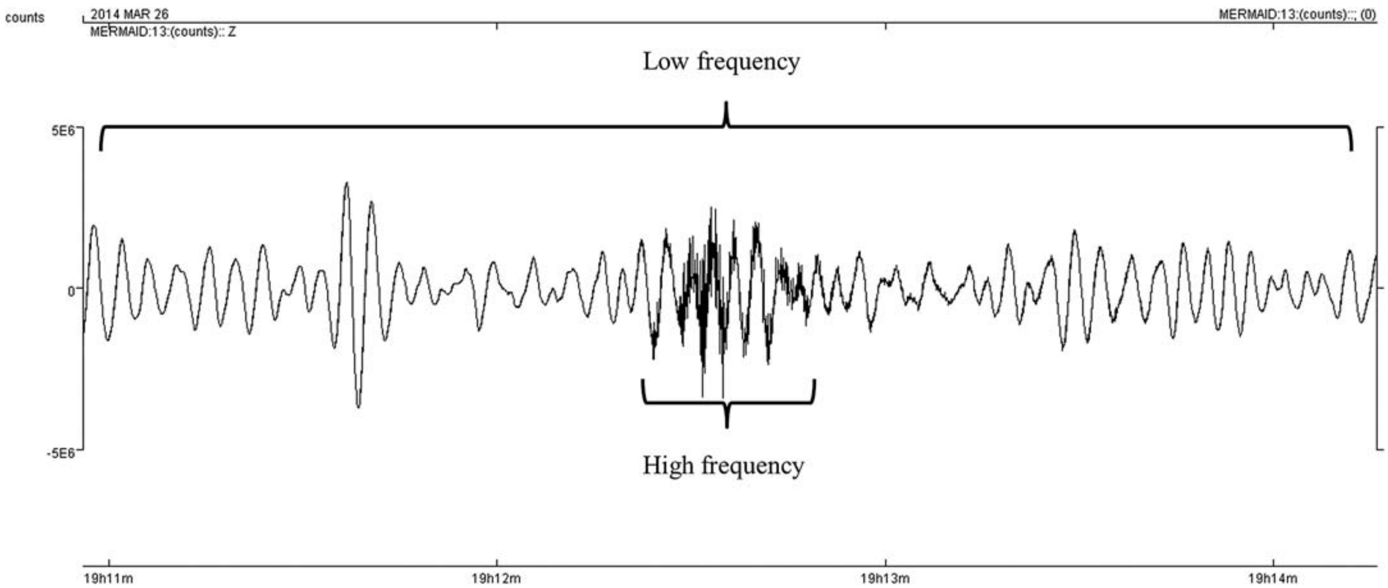
Researchers from Géoazur asked middle- and high-school students to adopt a MERMAID project and analyze the numerous unanalyzed data in its unidentified directory. This is how the LFS came to adopt "MERMAID 13," renamed as LOL by the students (Long yu—dragon in Chinese for its special shape—and Onde at the Lycee Français de Shanghai). LOL was launched in the Indian Ocean on 7 March 2013 (Fig. 2). Since then, it has been following deep-ocean abyssal currents between 1500 and 2000 m depth, regularly coming back to the surface to send data.

METHODOLOGY IN CLASS WITH STUDENTS

Since 2012, we have created a "Seismo" workshop for 8th graders at the LFS. Every week for one term, two groups of 15–20 students work at different times for a 1-hr period on activities linked to earthquakes. Students use software (described below) named "SeisGram2K" (see Data and Resources) to plot and analyze seismic waves, and a Geographic Information Systems program "EduCarte" (see Data and Resources) that plots locations of floats and recorded earthquakes (Fig. 3).

▲ **Figure 3.** Students in class working on "EduCarte" to locate LOL (MERMAID float). The color version of this figure is available only in the electronic edition.

When students start to work on the MERMAID project, the instructions they receive are: "From LOL's unidentified data in the 'unidentified' directory, find which of the signals correspond to a significant earthquake recorded on land, to a weak earthquake on the mid-ocean ridge, to a storm, or to something else...."



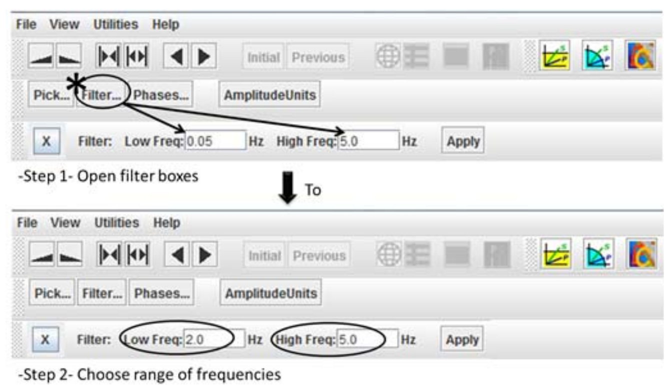
▲ **Figure 4.** Example of one of our 24 unusual signals (0–5 Hz). Recorded on 26 March 2014, we can see both a high frequency (seismic waves) and a low frequency (storm) displayed on "SeisGram2K."

Students then use a computer in pairs and mark on the blackboard which file they are going to work on.

DATA AND RESULTS

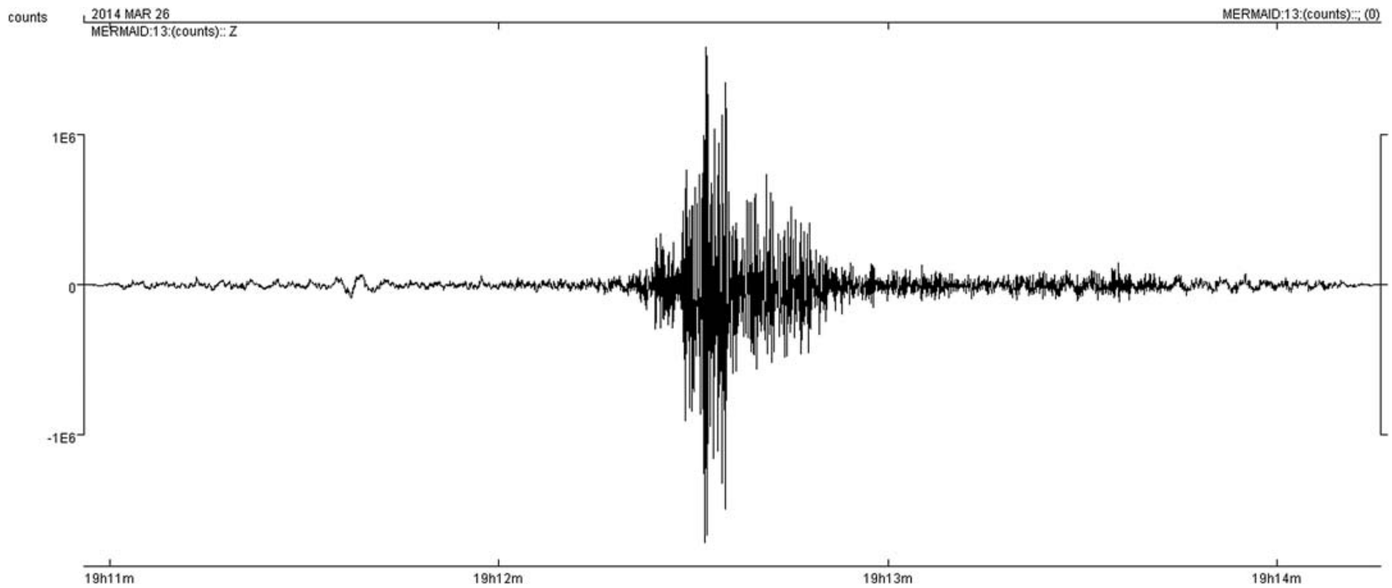
This year, students have worked on unidentified earthquakes recorded between August 2013 and August 2014. Out of 153 files, we only concentrated on 24 specific recordings, which occurred between 28 December 2013 and 30 August 2014. After opening the first recordings, students were surprised to find both low- and high-frequency signals on a single seismogram (Fig. 4). As a matter of fact, in our school we have our own seismometer named "SHAN" (for Shanghai) from the "SaE" network. For the last 4 yr, students have been used to analyzing seismograms from an immobile standard captor within various educational activities. They know that an earthquake signal corresponds to a high frequency. Thus, it was a short time before they saw that both high and low frequency on a same signal meant that there was something more than just an earthquake recorded.

The software we used to work with during our study is "Seisgram2K," which was devised for students. It is user friendly and educational; this software allows analysis of complex signals in an incredibly simple way. Hence, after learning from the teacher that there was a tool to filter the signals on "SeisGram2K," they just played with it (Fig. 5). They decided to filter the signal to get rid of the low frequency. After a couple of tests, they decided to filter out frequencies ranging from 0 to 2 Hz. Left with only high frequencies, they obtained the earthquake's unique signature as well as a noise signal familiar to them from earlier exercises studying the effects of a passing hurricane (Fig. 6). After discussion, they suggested that LOL had recorded an earthquake while simultaneously recording the ocean's swell during a storm (hurricane season 2013–2014).



▲ **Figure 5.** Extraction from the "Seisgram2k" toolbar. In this figure, the asterisk is the filter button. When students click on it, the bottom area appears, and students can choose a range of frequencies. In our case, they only wanted the high frequencies to appear, so they did several tests and decided by themselves to remove 0.05–2 Hz and to keep only 2–5 Hz to get a better high-frequency signal. Then, they clicked on "apply" to get signals, as shown in Figure 6. They used the same process for the entire batch of studied signals. The color version of this figure is available only in the electronic edition.

From the 24 signals recorded during storms, while working with the global database, they found that more than half of the earthquakes (15 in total) were small earthquakes from the central Indian ridge, 6 were earthquakes already identified by stations on land, and 3 appeared to be aftershocks only recorded by LOL. A chart showing these results was sent to Géoazur's laboratory.



▲ **Figure 6.** Same signal as in Figure 4 with frequencies between 2 and 5 Hz, after students manipulated the data using "SeisGram2K." Only the seismic waves are saved; the storm frequencies are not included.

DEVELOPING AUTONOMY AND MOTIVATION

For probably the first time, these students, usually accustomed to uncomplicated and oversimplified textbook-type seismograms, were faced with both high and low frequencies in the same signal. When they understood that a signal had recorded both a storm and an earthquake at the same time, they recognized that this signal was specific and that the noise was related to the fact that their sensor is floating under water, unlike the majority of seismometers located on land. Their work and their motivation at that moment reached a new level because they realized that they were really at the heart of research. They recognized the privilege of having discovered original signals of a special nature, because only a few stations of this type exist and only a few seismologists can record and analyze such signals. They became researchers.

Confronted with data coming from a sensor transmitting in quasi-real time, the students reflected, tested, deducted, and learned that every physical phenomenon can have a different frequency signature and can be detected at multiple stations, depending on its location.

Their motivation for this work empowered them to be autonomous while using different numerical tools and software with global databases. Finally, the results they obtained on their own allowed them to develop a capacity for critical analysis when being faced with maps of global seismicity. Indeed, out of the 24 recordings analyzed, more than half seemed to be located on the midocean ridge, but on the global seismicity map (showing any magnitude), it appears that only a few such earthquakes are displayed. The students concluded that the global seismicity maps misrepresent true earthquake activity because they depend on the number, if any, of sensors close enough to record every earthquake in every zone. Hence, we would need more MERMAID sites to have a more complete record of the midocean ridge's seismic activity.

CONCLUSION

Through this activity, created in collaboration with Géoazur's laboratory and project MERMAID, students entered the world of scientific research. They were able to take part in this world, usually restricted to adults and specialists, while being confronted with unanswered questions and the need to understand the goals and value of research projects. Moreover, the motivation produced by this realization enabled the students to autonomously face and handle physics, wave phenomena, to use different numerical tools, to explore global databases, to discover limitations in our geoscience knowledge, and to understand the seismic activity at the midocean ridges, all of which are notions that are required at their level in the French scientific curriculum.

Other examples of citizen participation exist, such as the Quake-Catcher Network associated with laptops (Cochran *et al.*, 2009). It makes use of computers fitted with inbuilt accelerometers to act as seismometers. Each time an event is detected, the results are collected by the Quake-Catcher control center at Stanford University, making it possible for citizens to take part of the research network. Another example is the launch of SETI Live that opens the door for anyone to help search for intelligent life on other planets (Tarter, 2011). Data being received by the Allen Telescope Array in Hat Creek (California, United States) will be made public, allowing any citizen to be able to scan it for potential signals. Nevertheless, citizen science should not be restricted to adults but can, and should, easily start at school.

We conclude that collaborations between research programs and middle- to high-school students can be profitable for both parties. First of all, they help create a possible motivation among some of the students to become future researchers, through the experience of being part of the world that, at least at first glance, may seem closed or out of reach to them. Second, and even more importantly, they encourage the students to learn by discovering and understanding natural phenomena, Earth processes, and scientific tools on their own, and by developing their capacity to analyze scientific data.

We encourage more research programs to continue to open up and to collaborate with students.

DATA AND RESOURCES

Seismograms used in this study were collected from project Mobile Earthquakes Recording in Marine Areas by Independent Divers' (MERMAID) "unidentified" directories, available for general public through at https://www.geoazur.fr/GLOBALSEIS/Data.html (last accessed September 2016), and specially MERMAID 13, renamed LOL (Long yu—dragon in Chinese for its special shape—and Onde at the Lycee français de Shanghai) by the students. "Educarte" software (A. Lomax and J.-L. Berenguer) can be found online at http://www.edusismo.org/educarte.php (last accessed September 2016) with its tutorial at http://www.edusismo.org/docs/outils/educarte/educarte_decouverte.pdf (last accessed September 2016). As well as "SeisGram2K" (A. Lomax) software at http://alomax.free.fr/seisgram/SeisGram2K.htmlwithitstutorialathttp://www.edusismo.org/docs/res_peda/SG2k/SG2K_tutorial.pdf (last accessed September 2016).

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