The Australian Seismometers in Schools Network: Education, Outreach, Research, and Monitoring

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INTRODUCTION

Astronomy has space travel and supernovas, chemistry has goo and explosions, biology has creepy-crawlies and medical miracles, and the earth sciences have earthquakes and volcanoes. Each of the sciences has some way to engage and inspire the future generations of scientists. As researchers we are constantly seeking ways to communicate science to our peers, funding agencies, policy makers, and the general public in a way that they can appreciate its importance.

We often meet students who want to be astronauts and engineers but few who want to be earth scientists. The big question is how do we attract these students to the earth sciences? To start with, we can educate students that earth science is not just about exploration and rocks and that there is a diverse market of jobs that involve training in earth science; even some astronauts and engineers are trained in the earth sciences. We need programs that take advantage of the most exciting and varied aspects of the earth sciences, and we need to make those programs accessible and relevant to students.

Students are smart, curious, and proficient with technology so they excel at interacting with real data and often want to engage with things as they happen. The Australian Seismometers in Schools Network (AuSIS) is designed to do this with the installation of professional broadband seismometers in over 40 secondary schools across Australia. The program has a multipurpose approach by engaging students in monitoring the earth through seismology as well as contributing to earthquake detection and research in Australia.

MOTIVATION

Student enrollments are declining in Australia in physical and natural sciences at the tertiary level, as are literacy levels in high school mathematics and science (Dobson, 2007; Thomson *et al.*, 2013). Results from surveys of teachers suggest there needs to be an increase in relevance, enjoyment, and interest in early science lessons to motivate students to continue studying science. This could be achieved by more real world context, practical work, and closer links between students and practicing scientists (Lyons and Quinn, 2010). Educational seismology programs aim to achieve this by introducing this multidisciplinary subject into the classroom. We have experienced that the societal impacts of earthquakes sparks a natural fascination in many students and the general public, and this could be harnessed to improve learning about physics, earth sciences, engineering, and mathematics.

Introducing students to seismology through installing seismometers in schools is not a new concept. There are multiple networks around the world that have been successfully doing so for many years, for example, the U.K. School Seismology Project (United Kingdom), Sismos à l'École (France), Seismo@School (Switzerland), Princeton Earth Physics Project (U.S.A.), Boston College Educational Seismology Project (U.S.A.), and IRIS Seismographs in Schools (U.S.A.). The AuSIS is based on the best practices of these networks. By utilizing advancing technology and networking, AuSIS allows data to be shared and used by not just other schools, but by scientists, monitoring agencies, and the general public. The AuSIS program uses calibrated broadband seismometers in schools that send data in near-real time to the Incorporated Research Institutions for Seismology Data Management Centre (IRIS DMC). The goal is to create a multipurpose network that would be used for education, monitoring, and research. Because of Australia's intraplate setting, it is important that the seismometers are broadband to pick up detailed recordings from both local and distant earthquakes. Another important feature of the AuSIS network is that it is based on research-quality seismometers and in this way will be of interest to the professional seismological community, which we hope will ensure its long-term viability.

PROGRAM OVERVIEW

The AuSIS project aims to inspire the next generation of geoscientists by providing students with the opportunity to participate in a national science experiment. The ~40 selected schools get to host a research quality broadband seismometer and view seismic waves recorded at their school from local and distant earthquakes. The network is designed such that it uses professional seismometers to provide research quality data to the seismological community, including monitoring and research agencies. The AuSIS project's educational aims are to:

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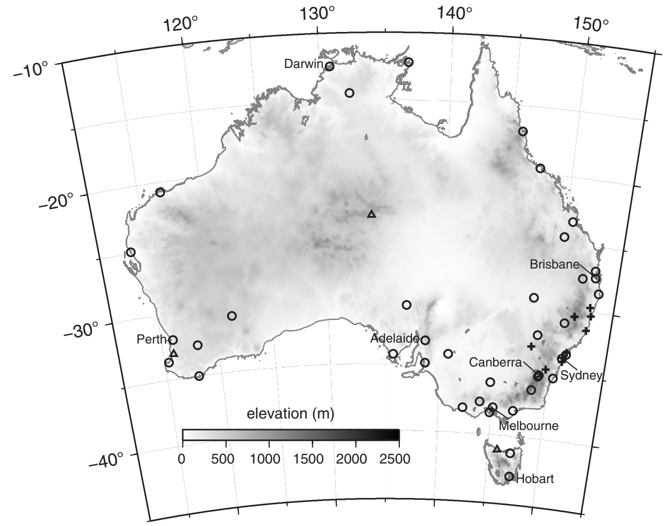
- raise community awareness of earthquakes because, despite Australia's relatively stable intraplate setting, it has a history of events up to magnitude 7.2;
- raise awareness of seismology and geoscience as fields of study;
- promote science as a possible career; and
- provide a tool to assist in teaching physics and earth science.

The AuSIS program began in 2011 with pilot installations in two schools in the Australian Capital Territory (ACT), a control site at the Mt. Stromlo seismic vault and an installation in the Research School of Earth Sciences, at The Australian National University (ANU), designed to assist with troubleshooting. Students and teachers from schools that volunteered for the pilot seemed to benefit from exposure to real world aspects of physics, geography, and social science. One teacher described his first impression of the program: "This is really, really exciting! I showed the kids the traces from the site test, and they were very interested. The idea of being able to detect earthquakes from other countries under their lab was so cool! I am hoping it will help ... inspire the odd geophysicist of the future." (Geoff McNamara, science teacher, Melrose High School, ACT, Australia, personal comm., 12 November 2012).

The AuSIS program was officially launched in May 2012, after which schools from across the country were invited to submit expressions of interest to host a seismometer. The program was oversubscribed by more than a factor of three with more than 125 schools wanting to participate. Schools were selected based on their levels of enthusiasm, geographical location, and community impact. For earthquakes to be recorded with such high-sensitivity low-noise environments are preferred, so the program gave more emphasis to schools in rural and remote communities. This was also beneficial in helping to distribute the seismometers broadly across the Australian continent (Fig. 1). Another consideration was that rural schools often miss out on such opportunities, and yet they are a focal point of their communities. In each of the main centers, we attempted to choose schools that have a track record of sharing their facilities and skills with surrounding schools.

In April 2013, the nationwide installation began; and, by December of that year, 39 seismometers had been installed as part of the growing 45-station network. The majority of the installation program was completed with support from a network of volunteers from universities, the government sector, industry, and amateur enthusiasts. Some sites occupy areas that are sparsely monitored in an attempt to complement existing national and regional networks, such as Geoscience Australia's National Network (http://www.ga.gov.au/earthquakes; last accessed June 2014), The Public Seismic Network (PSN; http://www.rsuw.daleh.id.au; last accessed June 2014), ES&S regional networks (http://www.esands.com; last accessed June 2014), and Department of Manufacturing, Innovation, Trade, Resources and Energy's (DMITRE) South Australian Seismic Network (http://www.pir.sa.gov.au/minerals/earthquakes; last accessed June 2014). There are some schools in Australia that already have seismometers as part of the PSN program and initiatives through DMITRE and University of Tasmania. AuSIS was assisted by these programs in the selection of schools and intends to share data and educational resources in the future. The continued success of the program hinges on maintaining the engagement of participating schools through partnership with local geoscientists who can provide support for schools, mentorship for students, and feedback. Delivering research quality data back to the seismological community provides an incentive for these relationships to be maintained.



▲ **Figure 1.** Locations of the AuSIS Network stations, including installed (circles) and planned (triangles) broadband sites and schools with slinky seismometers (plus symbols). Each state and territory capital city is also labeled.

INSTRUMENTATION AND INSTALLATION

The primary instruments used are Güralp CMG-6TD, which combine a broadband (30 s to 100 Hz) triaxial seismometer and digitizer into a single package. The instruments are networked using Ethernet or WiFi so that data can be streamed continuously from the school to the servers at ANU. Schools also have a display setup so the students can view the incoming data in real time (Fig. 2).

Where possible, the seismometers were installed in low-traffic areas. In some cases, the seismometer is installed on a concrete pier in the crawlspace beneath a building (Fig. 3a), however, more commonly they are installed directly on the concrete foundation of the building (Fig. 3b), where crawlspaces are often not available. One school went so far as to have their construction class build a seismic vault as part of an annual class project (Fig. 3c).

AuSIS aims to keep the schools that missed out on hosting a primary instrument involved by helping them source their own low-cost alternative, such as a slinky seismometer (TC-1) developed by Boise State University (http://cgiss.boisestate.edu/bsu-network/; last accessed June 2014). These single-component instruments are less sensitive than the CMG-6TDs

▲ **Figure 2.** Student examining the waveform and spectrogram display of a recording by the school's seismometer.

and are not calibrated. However, they are great for showing students how a seismometer works, are more affordable for schools, can still record local and large distant earthquakes, and can share data with other schools. AuSIS was able to supply 10 schools in New South Wales with slinky seismometers by the way of additional funding from the regional government. Another option we gave schools was to consider a Quake-Catcher Network (QCN; http://qcn.stanford.edu/, last accessed June 2014). These USB accelerometers are only sensitive to pick up felt local events, however, teachers have been keen to use them (and similar accelerometers in mobile devices) as classroom demonstration tools. In response, AuSIS developed some teaching tools that include these devices.

DATA QUALITY AND ACCESS

Despite initial concerns that school sites would be too noisy to collect research quality data, we have found local, regional, and teleseismic earthquakes well recorded at most schools (Fig. 4). For example, in 2011, the school seismometers in Canberra recorded explosions from a factory fire, and in 2012, the M_L 3.7 Wee Jasper earthquake was recorded, providing additional constraints for the location of this event. AuSIS sites clearly recorded a regional M_w 5.4 earthquake in South Australia and many large teleseismic events from Indonesia, Philippines, New Zealand, Japan, and Chile. The pilot program demonstrated that although there is some cultural noise during school hours, a well-chosen site within the school has the potential to provide high-quality seismic data.

Data collected at the schools are streamed to ANU, where it is sent on to the IRIS DMC for archiving and near-real-time public access. The data are freely available so that researchers, industries, and schools alike can all access the collected data. The AuSIS program shares the network code *S* with international seismometers in school programs. AuSIS stations are identified by having "AU" as the first two letters of the site code. The IRIS DMC (http://www.iris.edu/hq/; last accessed June 2014) provides services for the community to access the data in some of the following ways: web services (JWEED, MATLAB Library), web-based requests (Wilber3), web service interfaces for online displays, email-based requests (BREQ-FAST), real-time streaming (SeedLink), and metadata-only requests (SeismiQuery). Data can also be downloaded in a number of formats from the AuScope Discovery Portal (portal.auscope.org; last accessed June 2014).

Geoscience Australia, the national agency for earthquake monitoring, has begun to incorporate the data from the AuSIS network into national monitoring in the hope that it will prove useful for locating local and regional earthquakes. This is an important aspect of the program as it results in schools taking considerable pride and a sense of ownership of their seismometers, knowing that it provides a real-time data to monitor agencies and scientists.

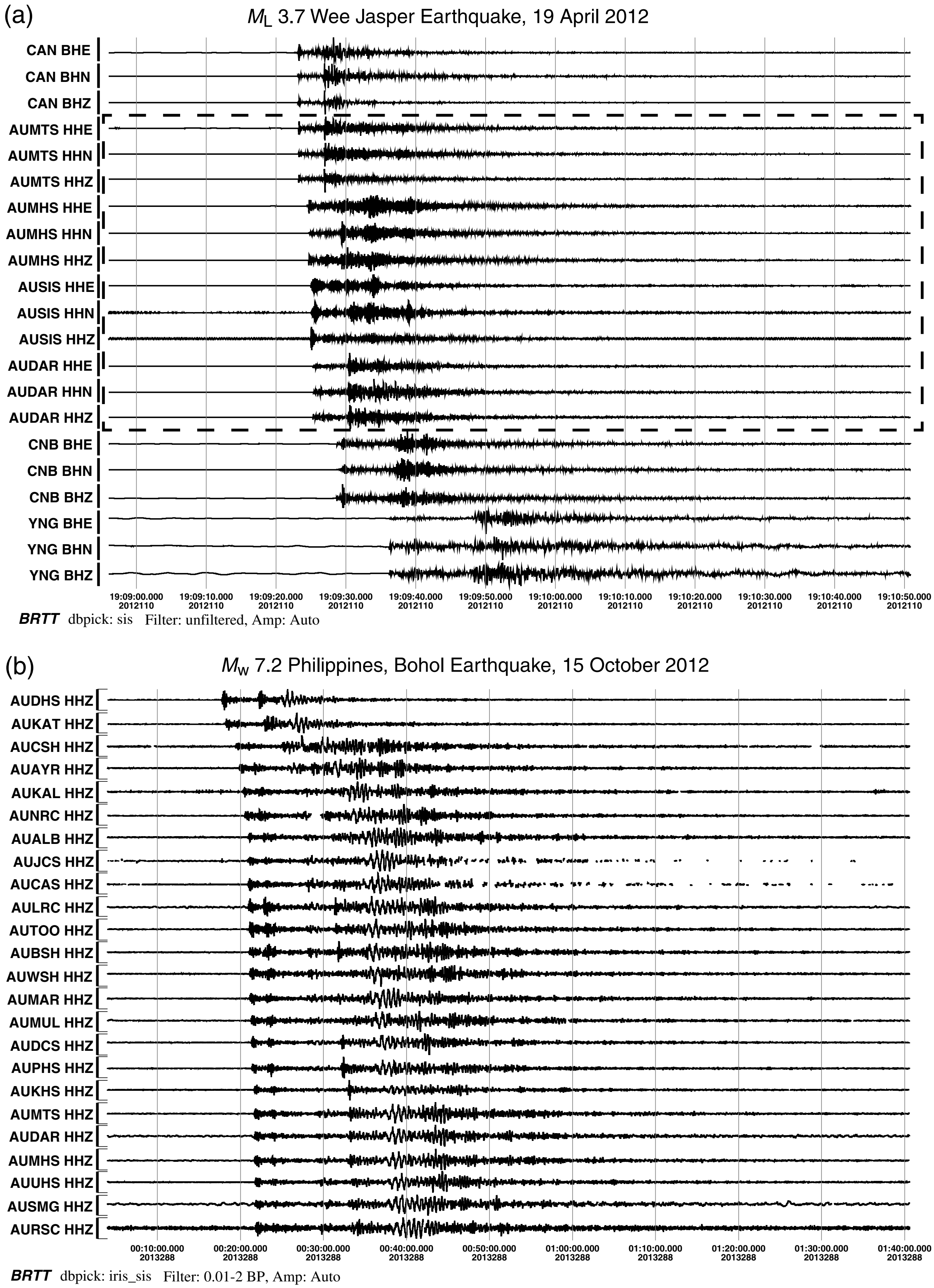
EDUCATION AND OUTREACH ACTIVITIES

The AuSIS team takes the opportunity when visiting schools to establish a connection between the scientists using the data and the students. We set up a live-data feed at the school so they have the opportunity to monitor and explore the seismic activity recorded. We also give 15–50 min presentations to up to six classes, which include discussions on the AuSIS program, basic introduction to seismology, what the students might see on their seismograph, and what seismic data are used for in Australia and around the world. We also take time to review the software and technical details with the teachers. Schools do not store more than 24 hours of data onsite unless configured to record on a local computer, so we also provide them with guidance on where and how to view previously recorded data online. This provides a fairly low-maintenance setup for teachers who would otherwise have to repeatedly delete or store locally stored data.

In Australia, the last few years have seen the introduction of the National Science Curriculum in each state and territory. Previously, each was responsible for their own programs. A welcome new component of the national curriculum is an introduction to earth sciences. This has resulted in teachers seeking out resources needed to help them teach about earth sciences. As part of the program, we have begun to develop teaching modules to assist teachers in integrating the seismometer, seismology, and earthquake engineering into their classes. To date, we have collated existing resources to produce modules on seismic waves, building response, earthquake location, and the earthquake cycle. In the future, we are planning to expand upon the Australian-specific examples and activities. We hope these teaching modules will give teachers an interactive and relevant way to introduce earth sciences in general, and specifically tectonics and natural hazards, into the classroom.

AuSIS has also been engaging with teachers around the country through workshops at Australian Sciences Teachers Association conferences (CONASTA) and National Youth Science Forum (NYSF). In July 2013, AuSIS combined resour-

▲ **Figure 3.** Types of installations: (a) seismometer installed in crawlspace beneath building and on a concrete pier, (b) standard installation of seismometer directly sitting on a concrete floor, and (c) impressive seismic vault built by the construction class at a school.



▲ **Figure 4.** Examples of recordings from (a) a local and (b) a distant earthquake. For the local event, Geoscience Australia's National Network stations are shown alongside AuSIS stations (outlined by dashed box). Some data gaps exist at stations that are remote and have poor Internet connectivity.

ces with the Teacher Earth Science Education Program (TESEP), Geoscience Australia (GA), and Geological Society of Australia (GSA) to have a Geoscience Education Exhibition booth at CONASTA to promote geoscience educational resources to teachers.

FUTURE DEVELOPMENT

In the future, depending on the resources available, we hope to design professional development courses for teachers to expand their skill base in seismology and earthquake engineering. We aim to have all schools accessing the data recorded by the entire network, connecting students, teachers, and scientists around Australia. We are currently exploring options to make the seismic data easier for schools to manage and explore, including allowing students to compare their recordings with those from different networks and providing a means to measure amplitudes to compute magnitudes and locate earthquakes. We are also working on connecting with similar programs run in Australia and other countries so we can share data and experiences in educational seismology.

The AuSIS website (www.ausis.edu.au) is still under development but will provide teaching resources and access to data feeds from the seismometers. In the meantime, we keep teachers, students, and the seismological community informed about recorded seismic events, installations, and progress using social media, such as our Facebook page (www.facebook.com/ausisnetwork). A recent shift to the use of tablets in Australian schools and by the general public has prompted AuScope, AuSIS's parent organization, to develop an application for these platforms. The aim is to make the AuScope data, including seismological and Global Positioning System data easy for the general public to explore.

The continued success of this program relies on support from the Australian seismological community, both professional and amateur. The program already has a broad network of volunteers, but we are always looking to expand it to provide regular support for schools in remote and rural areas. Another way we encourage the seismology community to support the program is by using the data the schools have been recording in their own work and by providing feedback to the program coordinators.

CONCLUSION

The goals of the AuSIS program are not only to promote careers in geoscience and raise awareness of earthquake hazards in Australia, but also to contribute to the seismological research and monitoring communities. Several schools hosting seismometers as part of the AuSIS network are in areas far from national network sites, and the data have the potential to be useful for local and regional earthquake monitoring. In addition, data collected in urban areas may be useful for seismologists and earthquake engineers interested in site response, a research topic that has ample scope for further attention in Australia.

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