

Australian Seismometers in Schools

M. Salmon, N. Balfour & M. Sambridge

Research School of Earth Sciences, Australian National University, Canberra, Australia.

ABSTRACT: The Australian Seismometers in Schools Network (AuSIS) is a program that combines education, outreach and research objectives. Research grade seismometers have been installed into 43 Australian schools. These instruments are run and monitored by students and teachers, providing good quality data to the seismological community. The instruments augment the Australian National Seismograph Network providing valuable data from urban and regional Australia. The increase in data from permanent stations in urban areas provides new opportunities for research into site effects. Data are made available through the IRIS data management center and are currently used by scientists for earthquake monitoring and location. We provide a simple web portal for students and the public to view data and report earthquakes. Students gain an awareness of seismic hazards locally and around the world and teaching materials are provided to help them understand seismic hazard, how earthquakes happen and how structures behave during an earthquake. Global earthquake activity provides ample opportunity to actively engage students and teachers. With earthquakes often making the news headlines the AuSIS program utilizes the resulting public awareness and curiosity. We provide tools for teachers and students to find out more, hopefully helping to recruit our next generation of seismologists and engineers.

1 INTRODUCTION

The Australian Seismometers in Schools network (Balfour et al. 2013, 2014) has been designed with two objectives, firstly to inspire students to consider science and engineering as career options by getting them to participate in a national science experiment collecting real seismic data. Secondly the program provides research quality data to the scientific community, filling some gaps in the National seismograph network (Fig. 1). At the same time we hope that the scientific community will continue to provide local support to the schools ensuring long-term data flow.

The 43 instruments already installed are three component Guralp CMG-6TD broadband sensors (30s – 100 Hz). These sensors have an onboard digitizer with network capability making them relatively simple for the schools to maintain. The schools provide the infrastructure around the instruments; power, secure ground floor location and network connectivity. We use the schools network infrastructure to stream continuous data back to servers at the Australian National University. We receive two data streams from each component one at 10 samples per second (sps) and the other at 100 sps. The 10 sps is used for quick web based data requests required by our website and mobile phone applications, while the high rate feed is necessary for research and monitoring.

A computer at the school acts as a local monitor and displays a 24-hour feed of the high resolution 100 sps streams. We provide the initial training to teachers and technicians showing them how to explore the 24-hour feed, how to recognize an earthquake and some simple checks they can do in order to keep the instrument running. The software used is simple enough for the students to be able use the seismograph.

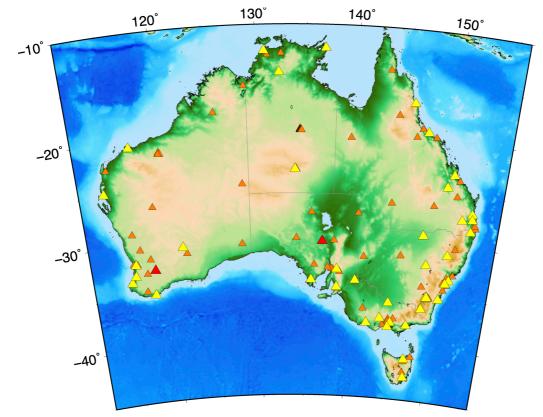


Figure 1 Map of the AuSIS stations. Yellow triangles show the AuSIS stations, red triangles show AuSIS stations which have network connection problems and orange triangles show the Australian National network stations.

2 DATA QUALITY

There is a compromise made between data quality and accessibility of the instrument to students, but at many of the schools this is negligible. The school environment can be noisy for some of the day, particularly at the start and end of the school day as students move around the school, but schools provide a quiet environment out of school hours and during school holidays. Extensive school grounds often provide a buffer around the instruments making them comparatively quiet urban sites.

Figure 2 shows the seismic power spectral density expressed as probability density functions for four seismic stations. These are a global network site and three representative AuSIS sites during 2014. The global network site (CAN, Fig 2a) is part of the global GEOSCOPE broadband seismic network (http://geoscope.ipgp.fr) and is co-located with the AuSIS AUMTS site in the Mt Stromlo seismic vault (Fig 2b). The distribution of the seismic power spectral density gives an indication of how noisy a site is. The GEOSCOPE instrument is a STS1 (360s - 10Hz) and is designed to record much longer periods than the CMG-6TD AuSIS instruments. Comparing the AUMTS site and the CAN site we can see that the CMG-6TD performs fairly well compared to the STS1 out to periods of about 10 s. The noise level is slightly higher than the STS1 but is mostly below the high noise model (Peterson 1993) out to periods of 10 s. The two other AuSIS sites shown in figure 2 are for a quiet site (Fig 2c) and a noisy site (Fig 2d). AUMHS is in Canberra and has been installed on an isolated concrete pad providing some cultural noise reduction. This site is slightly noisier than AUMTS but performs well from around from 10s to 5Hz. Not all of our sites are as quiet as AUMHS, AURSC is at the other end of the spectrum. This site is close to the ocean (less than 1 km to Port Phillip Bay and less than 10 km from the Southern Ocean) and the installation is near a main corridor in the school. We can see that this site has noise levels above the high noise model with a peak just below 1 Hz. The noise persists over months when the school is closed and is most likely due to ocean noise in the area and traffic along a busy nearby road (McNamara et al. 2009).

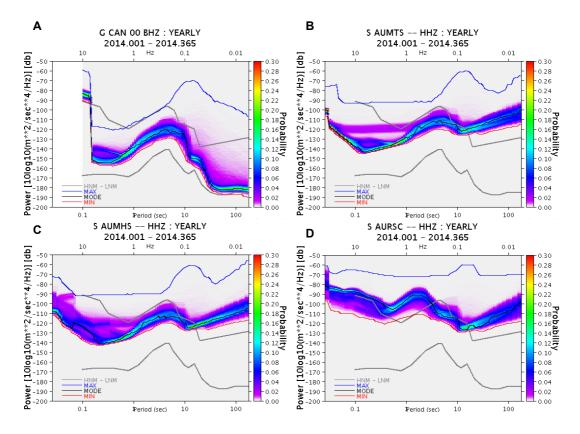


Figure 2 Probability density function plots displaying the distribution of the seismic power spectral density for 2014. The grey lines show the high noise model (HNM) and low noise model (LNM) (Peterson 1993). The red and blue lines respectively show the minima and maxima of the distribution for each station. The black line shows the mode of the distribution. A) Geoscope station CAN located in Mt Stromlo seismic vault, Canberra. B) AuSIS site co-located with CAN. C) AuSIS station MHS located at Melrose High School, Canberra. This is an example of a quiet school site. D) AuSIS station AURSC located at Rosebud Secondary College on the Mornington Peninsula. This is an example of a noisy site.

Despite the high noise both local and global earthquakes are still well recorded at AURSC. Figure 3 shows a magnitude 7.2 earthquake from Indonesia recorded at both AUMTS and AURSC. The P-wave can be clearly identified in the unfiltered vertical component data from the two sites. The P-waves and later arriving surface waves in fact seem to be amplified at AURSC, which is probably a result of the soft sandy site conditions.

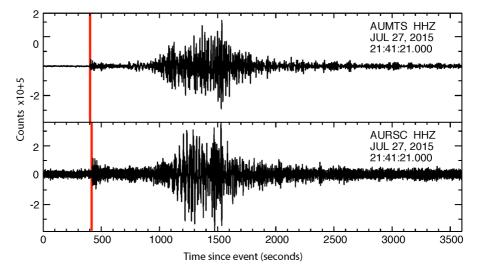


Figure 3 Irian Jaya, Indonesia earthquake recorded at AUMTS (top) and AURSC (bottom). Magnitude 7.2 (Mwp) Latitude -2.744, Longitude 138.552, depth 47 km, UTC 27 July 2015 21:41:21. The red lines indicate the

P wave arrival.

Figure 4 shows a local ML 3.3 earthquake recorded at AURSC at a distance of 56 km. Both the P- and S-waves are identifiable. Even some of the noisiest AuSIS sites can produce data with sufficient quality for earthquake location, scientific research and site investigations.

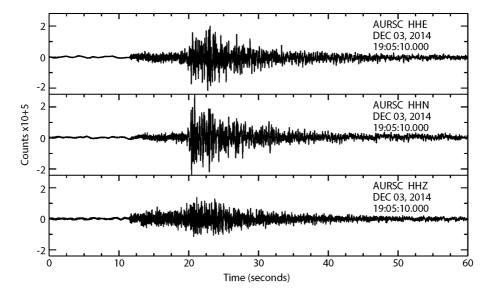


Figure 4 Magnitude 3.3 (ML) earthquake recorded at AURSC. Latitude -38.102, Longitude 145.442, Depth 10 km, UTC 03 December 2014 19:05:10

3 DATA ACCESSIBILITY AND AVAILABILITY

Data are sent to the Incorporated Research Institutions for Seismology (IRIS) data management center in the USA for storage and dissemination to interested parties.IRIS provide archive and near real time access with less than 10 minutes latency. The data is freely and easily available from IRIS in several formats, including: seed, miniseed, sac and ascii. We use the seismograms in schools network code (S) established by the Swiss Seismological Service and all station codes related to the AuSIS network start with AU.

Information about the station locations, installation date and instrument responses are provided in the MetaData Aggregator (http://ds.iris.edu/mda/S). For event data the WILBER3 portal (http://ds.iris.edu/wilber3/) provides easy access to data in SAC, SEED, miniSEED and ASCII formats. IRIS uses event catalogues from US National Earthquake Information Centre, the International Seismological Centre and US run arrays. This means that the catalogue of Australian events is incomplete and mostly lists earthquakes with magnitude 4 or greater. For data that is not in any of these catalogues or for continuous data IRIS uses the BREQ_FAST email request system (http://ds.iris.edu/ds/nodes/dmc/manuals/breq_fast/). This system only provides SEED data. IRIS also provides a SeedLink capability for access to real time data.

For schools and community access our web page (<u>http://ausis.edu.au</u>) provides a simple access point. We combine the Geoscience Australia and USGS earthquake catalogues giving a more complete catalogue of regional and global events so that schools don't miss local events. Event plots, day plots and user defined time window of the vertical component can be produced on the website without specialist software and saved as PNG images. We also provide the news feed from our Facebook page where we post news about the array and any noteworthy earthquake events.

Data recovery is generally above 80% but a few sites have had network connectivity issues or computer outages. Two stations where we are having difficulty resolving these problems are AUKUL and AUROX and we are currently looking for alternative sites for these instruments. Table 1 shows the mean daily data percentages available form IRIS for 2014. For details data availability for specific time periods IRIS provides a Quick Analysis Control Kit with information on daily percentage

availability, gap reports and data quality (<u>http://www.iris.washington.edu/servlet/quackquery/</u>). Some additional data is sent directly to Geoscience Australia as we have set up a direct link from the AuSIS feed allowing them some backfill data that is not accepted by IRIS.

Station	Mean DDP	Station	Mean DDP	Station	Mean DDP	Station	Mean DDP
AUALB	86	AUHPC	89	AUMAR	81	AUROX	2
AUAYR	85	AUJCS	73	AUMAZ	85	AURSC	94
AUBSH	87	AUKAL	85	AUMHS	93	AUSIS	97
AUBUS	67	AUKAR	12	AUMOU	77	AUSMG	56
AUCAR	59	AUKAT	79	AUMTC	90	AUSSC	86
AUCAS	85	AUKHS	97	AUMTS	92	AUTAR	76
AUCSH	66	AUKSC	50	AUMUL	95	AUTKS	92
AUDAR	98	AUKUL	0	AUNHS	76	AUTOO	94
AUDCS	98	AULHS	93	AUNRC	88	AUUHS	98
AUDHS	95	AULRC	92	AUPHS	97	AUWSH	74
AUHAR	65	AUMAG	95	AURMK	56		

Table 1: Mean daily data percentages (DDP) for the AuSIS network for 2014. Note that station AUALC was not installed untill August 2015 and does not appear on this table.

4 SCHOOL AND COMMUNITY ENGAGEMENT

The AuSIS program was designed to provide a teaching tool for earth science in schools. Large earthquakes are news events and seeing how the Earth beneath their feet shakes due to the passage of seismic waves from distant events provides an opportunity to engage students in learning about the physics of the event as well as the human side of a disaster. While Australia has a relatively low earthquake hazard many places that Australians visit have much higher earthquake hazard. Teaching people what to do in an earthquake can help to save lives and raises awareness of the dynamic nature of the planet on which we live. We provide teaching activities involving the school seismometer on how earthquakes occur and how buildings respond to shaking. We provide information on what to do in an earthquake sthey have seen on their seismometers using the 'Caught it? Report it!' feature on our web page and work on projects using the seismometer data.

Instruments run by the community are directly observing ground shaking at their location and as such are an independent and trusted information source; this may be particularly important where communities are concerned about the effects of mining, fracking and carbon sequestration. The AuSIS network covers four areas where local residents have identified these activities as a concern: Kalgoorlie, Harvey, the Latrobe Valley and the Hunter Valley. The school in Kalgoorlie advised us that they applied for their instrument because of the shaking from mine blasts. The school is less than then 3 km from the Kalgoorlie Consolidated Gold Mine Super Pit. The mine monitors vibrations from blasts but the AuSIS seismometer provides a nonpartisan source of information for residents. The School at Harvey in southern WA is positioned close to a proposed South West CO₂ Geosequestration hub. The WA Department of Mines and Petroleum and the University of Western Australia sponsored this instrument but running the instrument remains in the school's hands. This instrument will provide valuable information about any increase in seismicity during and after injection, while the sites in Perth and Busselton will help locate any larger earthquakes in the region. Our school seismometers in Rosebud, Melbourne and Sale surround the Latrobe Valley, which is also a proposed CO₂ geosequestration site. These schools will provide useful information on background seismicity in the region before any geosequestration activities begin. We also have four sites (AUPHS, AUDCS, AUTKS and AUKHS) surrounding the Hunter Valley where Coal Seam Gas projects are being explored.

5 SCIENTIFIC ENGAGEMENT AND OPPORTUNITIES

AuSIS data are currently being used by Geoscience Australia, ESS Earth Sciences and the Mineral Resources Division of the Department of State Development South Australia for earthquake monitoring and location. The data are also being used to extend our knowledge of Australia's lithospheric structure through receiver function analysis. We hope the uses of this data will expand in the near future. Many of the schools are located close to the coast and the data may be particularly useful for seismic noise studies that utilize the ocean noise as a source. In addition, several schools are located in large metropolitan areas providing an opportunity to examine site responses for earthquake hazard modeling. For example the site in Perth, which sits on the up thrust side of the Darling fault would provide and excellent base station for site response studies in the Perth Basin. We have already seen a good example of site amplification across the sites in ACT. Figure 5 shows the Moe earthquake recorded at three AuSIS sites in Canberra. The first two recordings look pretty similar but the third has much higher amplitudes indicating there is significant site amplification.

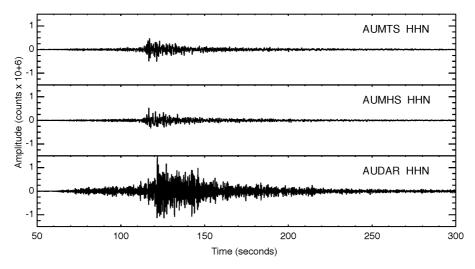


Figure 5 Site amplification across Canberra for the Moe ML 5.4 earthquake. Latitude -38.304, Longitude 146.200, Depth 10 km, UTC: 19 June 2012 10:53:29 (Glanville, 2013)

6 SUCCESSES AND LESSONS LEARNT

Small rural schools often have very limited IT support. In state schools we rely on state education departments to support the program so that the data flows through their firewalls. Getting the state education Information Communications and Technology (ICT) departments onboard has been crucial to the success of setting up the seismometer in public schools.

Rural schools have a high turnover of science teachers. It is therefore important to involve as many people as possible at the school with the installation and training so that the information can be passed on as staff moves on. Often it is the science lab technicians who do the day-to-day maintenance of the instrument and providing them with training and support is important to maintaining the data flow.

We have seen the engagement of students in unexpected ways. For example, at Ayr High School teachers used their seismometer installation phase as an opportunity to engage TAFE school students in the design and construction of a seismic vault, which acts to stabilize the environment and cultural seismic noise.

7 SUMMARY FUTURE DIRECTIONS

The AuSIS network is a citizen-run instrumentation program with the capacity to engage students in science and engineering while providing valuable data to researchers. The array produces data of sufficient quality to increase the capacity of earthquake location and monitoring within Australian, as well as being useful for a variety of research purposes. All instruments are callibrated research quality

seismometers providing near real-time digital data access to the public making this citizen-run network globally unique.

With the recent support for Citizen Science from the Australian Government's Chief Scientist's office we would like to get more of the community involved in this project, either by way of hosting future seismometers, or extending access to the instrument to local communities thereby developing a way for people to explore the data themselves to identify local and distant earthquakes. We hope to build on this program in the future through further expansion and also connecting with other citizen science programs which support the fascination the public has with the workings of the natural world.

REFERENCES:

- Balfour, N., Salmon, M. & Sambridge, M. 2013. The Australian Seismometers in Schools Network: a multipurpose network for education, research and monitoring. *Australian Earthquake Engineering Society Conference Proceedings, Hobart.*
- Balfour, N., Salmon, M. and Sambridge, M. 2014. The Australian Seismometers in Schools Network: Education, Outreach, Research, and Monitoring. *Seismological Research Letters*, 85 (5). 1063-1068. doi: 10.1785/0220140025
- Glanville, D.H., 2013. Australian Seismological Report 2012. Record 2013/032. Geoscience Australia, Canberra.
- McNamara, D.E. & Buland, R.P. W.D. 2004. Ambient Noise Levels in the Continental United States. *Bulletin of the Seismological Society of America*. 94 (4). 1517-1527. doi: 10.1785/012003001
- McNamara D.E., Hutt, C.R., Gee, L.S., Benz, H.M., Buland, R.P. 2009. A Method to Establish Seismic Noise Baselines for Automated Station Assessment. *Seismological Research Letters*. 80 (4). 628-637. doi: 10.1785/gssrl.80.4.628
- Peterson, J. 1993. Observation and modeling of seismic background noise, U.S. Geol. Surv. Tech. Rept., 93-322, 1-95.