Geoscience Australia's Geophysical Network: critical infrastructure and observed and derived data for earth monitoring and community safety.

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SUMMARY

Geoscience Australia operates and maintains a state-of-the-art network of stations and sophisticated instrumentation that monitors natural and anthropogenic (human-made) hazards in Australia and around the globe through its Geophysical Networks.

Key responsibilities are to: operate and maintain the Australian National Seismograph Network (ANSN) and Urban Monitoring (UM) networks; operate and maintain Australian Comprehensive Nuclear-Test-Ban Treaty (CTBT) seismic, hydro-acoustic and infrasound technologies, as part of Australia's commitment to support monitoring of worldwide nuclear testing; operate and maintain a national network of geomagnetic observatories which form part of a global observatory network; provide technical expertise and advice to Geoscience Australia projects, such as the National Geospatial Reference Systems, Hazard and Risk Infrastructure and Applications, Regional Development, Vulnerability, Resilience and Mitigation and the JATWS (Joint Australian Tsunami Warning System); and, provide technical and operational support for significant Australian earthquake events and aftershock deployment studies.

Geophysical data archives are stored on-site and can be freely downloaded from GA or international data centres. Seismic data can be accessed at GA and Incorporated Research Institutions for Seismology (IRIS) and geomagnetic data at INTERMAGNET.

Seismic data from Geoscience Australia's Geophysical Networks feeds into important hazard maps including the probabilistic national earthquake hazard map and the probabilistic Tsunami hazard map. Geomagnetic data feeds into the International Geomagnetic Reference Field and has been used to develop the first 3-D conductivity map of Australia.

Key words: *Geophysical Networks, geomagnetism, earthquake, tsunami, nuclear monitoring.*

INTRODUCTION

Geoscience Australia (GA) is Australia's national geoscience organisation and exists to apply geoscience to Australia's most important challenges. Geoscience Australia constructs, operates and maintains infrastructure for magnetometers, seismometers, accelerometers, microbarometers and hydrophones known as the Geophysical Network. The Geophysical Network infrastructure is located across Australia, Antarctica, Papua New Guinea and Niue. Geophysical data is acquired, quality controlled and delivered 24 hours a day 7 days a week in near real-time and distributed the same way for magnetic field monitoring, tsunami monitoring, national and international earthquake detection. The Network supports the Australian Government's role in the detection of nuclear explosions. This data is used by GA and shared with the world-wide users through international data centres using international data standards.

The Australian National Seismograph Network (ANSN) is one component of the Geophysical Network. The first permanently established seismograph was installed at Riverview College in Sydney, New South Wales, with continuous seismic measurements recorded since 17 March 1909. The number of permanent installations increased significantly over the next 100 years with landmark events generating a better awareness of seismicity within Australia. These events include: The International Geophysical Year 1957–58; Newcastle Earthquake 1989; and, the Indonesian Earthquake and Tsunami 2004. The creation of the Urban Monitoring network in the aftermath of the Newcastle Earthquake led to an increase in number of Seismic recording stations. In 2011, GA commissioned the 13 element Pilbara Seismic Array (PSAR), which is the only un-staffed seismic array in the world. The Array was designed and built to allow GA to monitor the seismic activity of the Indonesian trenches to provide rapid evaluation of the location and tsunami threat from this area.

GA monitors, models and maps the magnetic field over 1/8 of the Earth's surface within the Geomagnetism component of the Geophysical Network. The calibrated data measured from the geomagnetic observatories form the basis of a number of products and services, including: time-series data; magnetic-activity analyses; magnetic-field models; and, a magnetometer and compass calibration service. This data is used by GA and shared with the world-wide users through INTERMAGNET using international data standards.

GA helps Australia fulfil its obligations under the Comprehensive Nuclear-Test-Ban Treaty (CTBT) by monitoring for nuclear explosions worldwide and by contributing to the development of the CTBT verification regime. GA is responsible for the operation and maintenance of Australia's seismo-acoustic International Monitoring System facilities (seismic stations, infrasound stations and one hydroacoustic station). Additionally, GA is in the process of building a station in Antarctica to complete Australia's seismo-acoustic International Monitoring System network.

SEISMIC

GA operates and maintains the Australian National Seismograph Network (ANSN), a state-of-the-art network of stations and sophisticated instrumentation that monitors natural and anthropogenic (human-made) hazards in Australia and around the globe. Temporary installations may be linked into the network from time to time. Urban Monitoring (UM) stations are located close to population centres with 50 000 people or more; this secondary network is located around urban Australia and is used to improve the response to Australian earthquakes and for hazard modelling. Following a significant seismic event short-term aftershock deployments are typically installed in the first hours or days and are located in a radius less than 100 km of the earthquake epicentre.

Current best practice design principles call for sensors to be buried in a vault (Figure 1), designed to reduce the effects of localised noise interference from wind as well as maintaining a thermally stable environment for the sensor. The received signal is sent to a digitiser or field processor, then transmitted via satellite, internet or mobile communications in real-time to GA where it is analysed both automatically and manually for seismic events. Data are captured and made available within one minute of acquisition, via a public server at GA from which a number of organisations access the data for operational and research purposes. These organisations include the Pacific Tsunami Warning Center (PTWC), Incorporated Research Institutions for Seismology (IRIS), and GNS Science. Table 1 lists the main equipment used in the network to collect the seismic data.

The data are quality controlled using software that calculates the distribution of power spectral density using probability density functions to determine the noise performance of an installation (McNamara and Boaz, 2005). The state of health of an installation is also monitored in an effort to minimise downtime and maximise data availability. Parameters such as power levels and equipment temperatures are monitored because they can provide an indication of an emerging issue at the remote site. Seismic data are freely available either directly from GA or from IRIS in standard formats that are compatible with all modern seismic processing software and are used continuously for operational monitoring activities such as earthquake monitoring for community safety response activities (tsunami warnings and potentially damaging earthquakes) and infrastructure safety response (power stations, dams, train lines).

Data is fed into the Joint Australian Tsunami Warning Centre (JATWC) from the Australian network and 130 international seismic stations in real-time. The seismic information is automatically analysed by GAs seismic monitoring and analysis systems that form part of the 24 hours a day, seven days a week JATWC operations centre. When an earthquake occurs, this system automatically computes preliminary information on the earthquake's origin time (time at which the earthquake happened), location, depth and magnitude. The potential for the earthquake to cause a tsunami is then assessed. The seismic data are also used by GA and organisations world-wide: to assess which areas have the greatest earthquake and tsunami hazard potential; assess the likelihood of earthquake or tsunami hazards occurring; model the impact of the hazards; estimate the potential loss to communities; and, collect data when a hazard occurs to help prepare for future events.

FIGURE 1: The seismic monitoring station at Lord Howe Island. In the foreground are the top of the seismic vault and vault cover with the hut containing the electronic processing equipment and battery bank in the background.

Sensor Type	
	RefTek 131A-02/BH Accelerometer
	RefTek 131A Accelerometer
	Streckeisen STS-2 Seismometer
	Geotech KS54000 Seismometer
	Geotech KS2000 Seismometer
	Streckeisen STS-2 Seismometer
	Geotech KS54000 Seismometer
	Geotech PA-23 Accelerometer
	Guralp CMG3T Seismometer
	Guralp CMG3ESP Seismometer
	Guralp CMG40T Seismometer
	Guralp CMG5 Accelerometer
	Guralp CMG40T-1 Seismometer
	Guralp CMG3TB Seismometer
	Lennartz LE 3Dlite Seismometer
Digitiser Type	
	RefTek 130-01
	Kinemetrics Quanterra Q330HR
	Kelunji EchoPro
	Nanometrics Taurus
	Nanometrics Trident
Field Processer Type	
	Kinemetrics Marmot
Communications	
	Speedcast
	Telstra NextG Wireless

Table 1: Equipment currently used in seismic station installations and upgrades.

GEOMAGNETISM

GA maintains a national network of 10 geomagnetic observatories in Australia and Australian Antarctic Territory which contributes to a global observatory network. All the GA magnetic observatories are members of the INTERMAGNET network and comply with international data quality and delivery standards. Magnetometers in Australia have been acquiring data since the 1840s. Data measured at the observatories monitor the Earth's magnetic field changes in the Australian region due to processes taking place beneath the Earth's surface, in the upper atmosphere and in the Earth-Sun space environment. These data are used in regional and global mathematical models of the geomagnetic field, in resource exploration and exploitation, to monitor space weather, to study the electrical structure of the Australian lithosphere and for other scientific research. The resulting information can be used for compass-based navigation, magnetic direction finding and to help protect communities by mitigating the potential hazards generated by magnetic storms. GA also promotes public safety through the provision of compass and magnetometer calibration services.

The Total Magnetic Intensity (TMI) Anomaly Grid of Australia (Figure 2) is a fundamental dataset that improves the understanding of the composition and structure of the geology of the continent. The grid is a compilation of numerous aeromagnetic surveys conducted over more than 50 years by Geoscience Australia, the State and Territory Geological Surveys and industry. Geomagnetic data underpin each individual aeromagnetic survey; used for diurnal corrections and regional field or IGRF corrections. The removal of diurnal effects and regional trends (IGRF) allow for the interpretation of geological features and structures at depth.

In 2014 GA released a 3-D conductivity model of the Australian continent using the geomagnetic observatory and magnetometer array data (Wang *et al*., 2014). This is the first fully seamless 3-D representation of the electrical properties of the Australian continental geology and is derived from the inversion of multi-period VTF data from 57 sites across Australia, refining the understanding of the continent's evolution and mineral and petroleum prospectivity. This national scale model of crustal electrical conductivity better defines broad-scale geological features such as conductivity anomalies, provides a context in which to analyse magnetotelluric and airborne electromagnetic data (particularly when used as a reference model in inversions), contributes to studies of geomagnetically-induced currents in power grids and pipelines, and assists in interpretations of crustal depths.

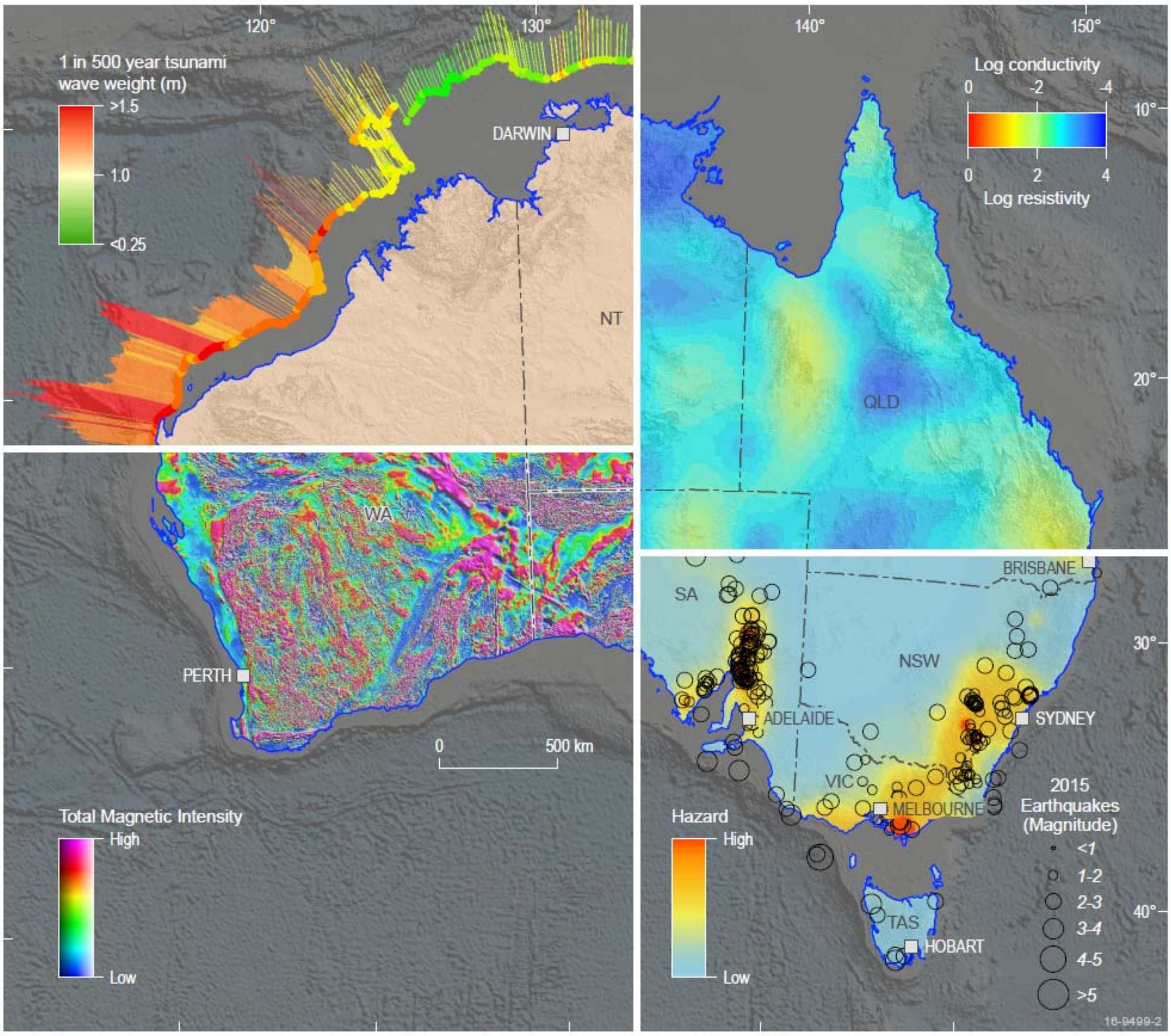

FIGURE 2: Clockwise from the top right: Depth slice of the present 3-D conductivity model of the Australian continent at 132 km (Wang *et al*., 2014); Probabilistic national earthquake hazard map (Burbidge, 2012); Sixth edition Total Magnetic Intensity (TMI) Anomaly Grid of Australia (Geoscience Australia, 2015); Probabilistic Tsunami hazard map (Thomas and Burbidge, 2008).

INFRASOUND AND HYDRO-ACOUSTIC

GA operates and maintains three infrasound arrays (Figure 3) and is in the process of building another near Davis Station in Antarctica. Data from these arrays form part of the verification regime for the enforcement of the CTBT by detecting low frequency acoustic waves that are generated by atmospheric explosions. These acoustic waves cause changes in atmospheric pressure that are detected by arrays of microbarometers. The arrays are used to determine the direction of the arriving pressure wave and locate the sources of the potential explosion. Natural sources of infrasound waves are from volcanic eruptions, meteorites and storms. The data from the arrays are sent directly to the Comprehensive Nuclear-Test-Ban Treaty Organisation CTBTO for analysis and directly to GA for data quality monitoring.

GA also operates and maintains a hydroacoustic station in Augusta, Western Australia as part of the CTBTO's verification regime. The system consists of an array of three hydrophones that are deployed in deep water and cabled back to recording equipment on the shore. The station is used to monitor for underwater explosions but the data have also been used for other scientific purposes such as monitoring whale migrations. The data are transmitted in near real-time to the CTBTO and GA for data quality monitoring.

FIGURE 3: An infrasound element at Infrasound Station ISO6, Cocos (Keeling) Islands.

CONCLUSIONS

GA maintains critical infrastructure and delivers standards-compliant observed and derived data for earth monitoring and community safety in Australia and neighbouring countries and links to similar organisations world-wide to add to global coverage. The networks detect seismic, infrasound, hydro-acoustic and geomagnetic activity in Australia and the Antarctic regions, and is the foundation upon which the earthquake, tsunami, nuclear test, and geomagnetic monitoring functions of GA and the Department of Foreign Affairs and Trade are built.

The collected data feed into modelling risks associated with natural hazards, and the vulnerability of infrastructure to hazards, coordinates emergency management support assisting regional disaster management projects. The Geophysical Network underpins the work on earthquakes and tsunamis in the JATWS and significantly contributes to international efforts to monitor nuclear tests.

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