Newsletter of the Seismological Association of Australia Inc.

Jan-Feb 2019

Seismological Association of Australia Inc.

Newsletter of the
Seismological Association of Australia Inc.
PO Box 682, Mylor SA 5153

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Membership of the SAA is open to all, with the only prerequisite being an interest in seismology. Membership applies for the calendar year (January through to December)

Membership fees are:
Full member $50

A Membership application form can be obtained from the Treasurer.

Member Submissions

Submissions for inclusion in the Newsletter are welcome from all members; please note that submissions may be held over for later editions. Wherever possible, text submissions should be sent via email in almost any word processing format. Your name may be withheld only if requested at the time of submitting. Images should be high resolution and uncompressed, although high resolution JPEGs are acceptable.

All enquiries and submissions should be addressed to the Editor and preferably sent by email to weaksignals@iinet.net.au

A word from the Editor

Again, the cover image for this edition of our newsletter was taken from Google Maps. This is included to help highlight some of the difficulties that might be experienced when trying to find suitable seismic sites in remote areas. Centred just south of the Ikara-Flinders Ranges National Park and Wilpena Pound, the larger circles represent 10km step range markers from the proposed National Radioactive Waste Management Facility site. This area has featured in the media in the recent past and will continue to do so for some time into the future. The smaller circles represent 5km step range markers from local mobile phone towers, Optus at Rawnsley Park Station and both Optus & Telstra at Hawker. As we increasingly rely on current 3G and 4G mobile communications to return data back to our server(s), finding sites within range of a phone tower and strategically suitable to the network will become increasingly difficult. Another option would be to find host properties with alternate internet arrangements such as satellite NBN and hope that access to these services will be granted by the owners. As we endeavour to expand our seismic network, there will be obstacles such as these that need to be overcome, not just the tyranny of distance. Are we up to the challenge?

Peter Gray

Planning for the Future

Article submitted by Peter Gray

A look at the current state of the SAA Seismic Network and how it might be developed further

The growth of the Adelaide Uni / GSSA seismic network, now run by the SAA, over the past five decades has produced a unique tool for studying small earthquakes and focal mechanisms.

Recent developments have presented an opportunity to upgrade and enhance the SAA seismic network. It is now within the capability of the SAA to expand the concentrated coverage required for earthquake focal mechanisims beyond the Mount Lofty Ranges (Adelaide), into the Southern Flinders Ranges (Mid North) and possibly into the Flinders District.

These areas are the most seismically active areas in South Australia and arguably, amongst the most seismically active areas in Australia.

By the inclusion of additional data from the Flinders Ranges, more detailed research into the nature of these mechanisims will be possible due to the higher occurence of seismic events in this region. The Flinders Ranges has a sparse population and a correspondingly low background noise level. It also has more rock outcrop. These characteristics make the region ideal for this research.

Several contributing factors have occurred to make this expansion proposal possible:

* transition of the GSSA Seismic Network to the SAA in 2017

* transition of several SAA sites to GA in 2018.
  This will allow some existing SAA assets to be redeployed at new or existing sites

* receipt of nine EchoPro recorders from GA in late 2018.
  This will allow some obsolete SAA assets to be retired or redeployed at new or existing sites

Planning for the Future

The seismic resources of the SAA, GA (Geosciences Australia) and the ANU (Australian National University) Seismometers in Schools programme provide a level of seismic coverage which, when combined, formed a strong network around the city which has been the data source for determining focal mechanisims in the vicinity of Adelaide.

As of Saturday, January 12th 2019, there had been 32 earthquakes recorded in SA for the previous 30 days. Of the 32 quakes recorded, 75% occurred along the Adelaide Geosyncline, primarily in the Flinders Ranges. This small sample may be typical for this region of SA.

The locations published at https://earthquakes.mappage.net.au/q.htm website are plotted in Image 1. Listed by region, we can determine that:

* there were none within 50km in any direction of the Adelaide CBD

* there were none within 50 to 150km South of Adelaide

* there were two within 50 to 150km North of Adelaide

* there were five within 150 to 250km North of Adelaide

* there were five within 250 to 350km North of Adelaide

* there were eight within 350 to 450km North of Adelaide

* there were four within 450 to 550km North of Adelaide

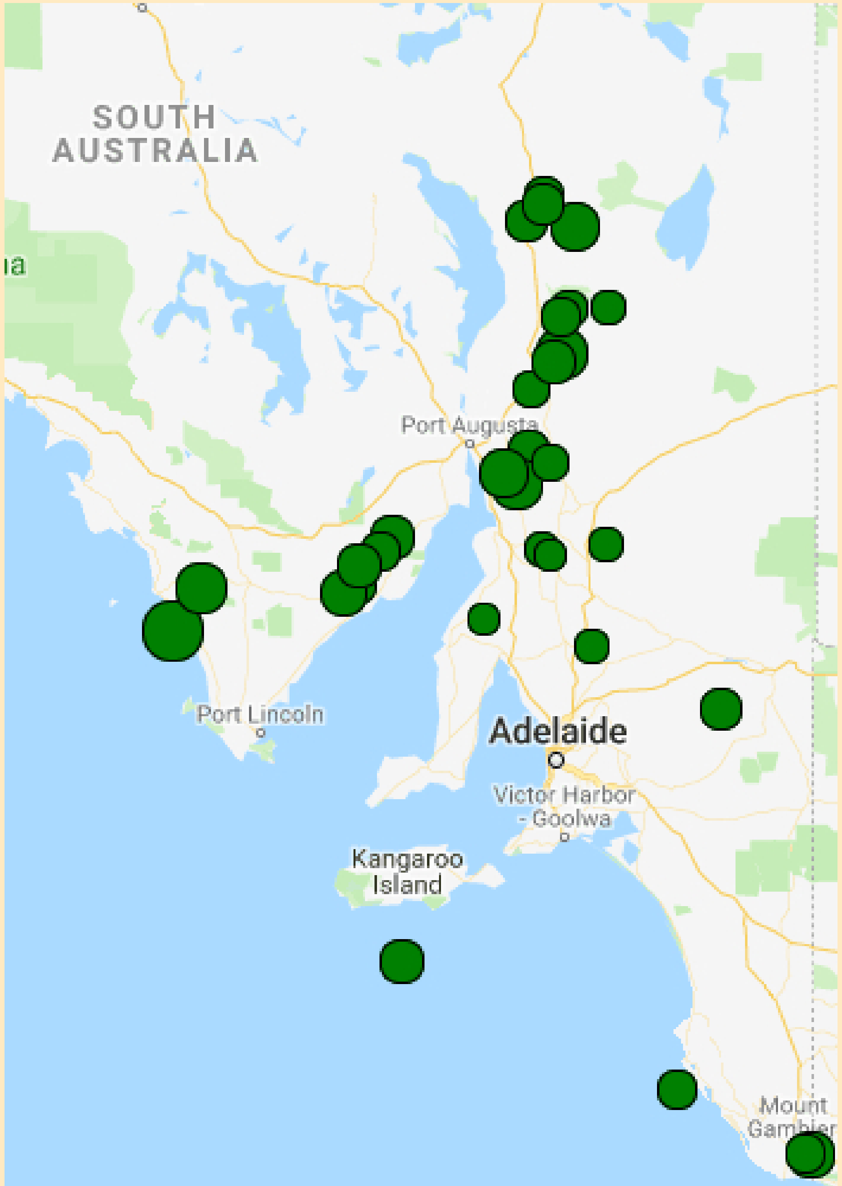


Image 1 - Recent earthquakes

Planning for the Future

It would be beyond the resources of most not-for-profit associations to replicate this level of seismic data overlap over a very large rural area. With careful site placement and access to the data from the GA and ANU stations, the combined data could provide new research capabilities in areas previously considered too remote.

In the recent past, the Mid-North District bounded by Wilmington in the North and Mount Bryan in the South as shown in Image 2, was possibly an ideal model for rural areas. For various technical reasons, the NBK and PBR1 stations have been closed, but alternate sites are being actively sought.

The following images (3 to 9) provide 10,000 square kilometre snapshots of areas, primarily to the North of Adelaide. Each image shows the 20km and 40km radii marks from either SAA, GA or ANU seismic stations within or adjoining each area.

The seismic stations are identified by their FDSN:AU Network Codes, where possible.

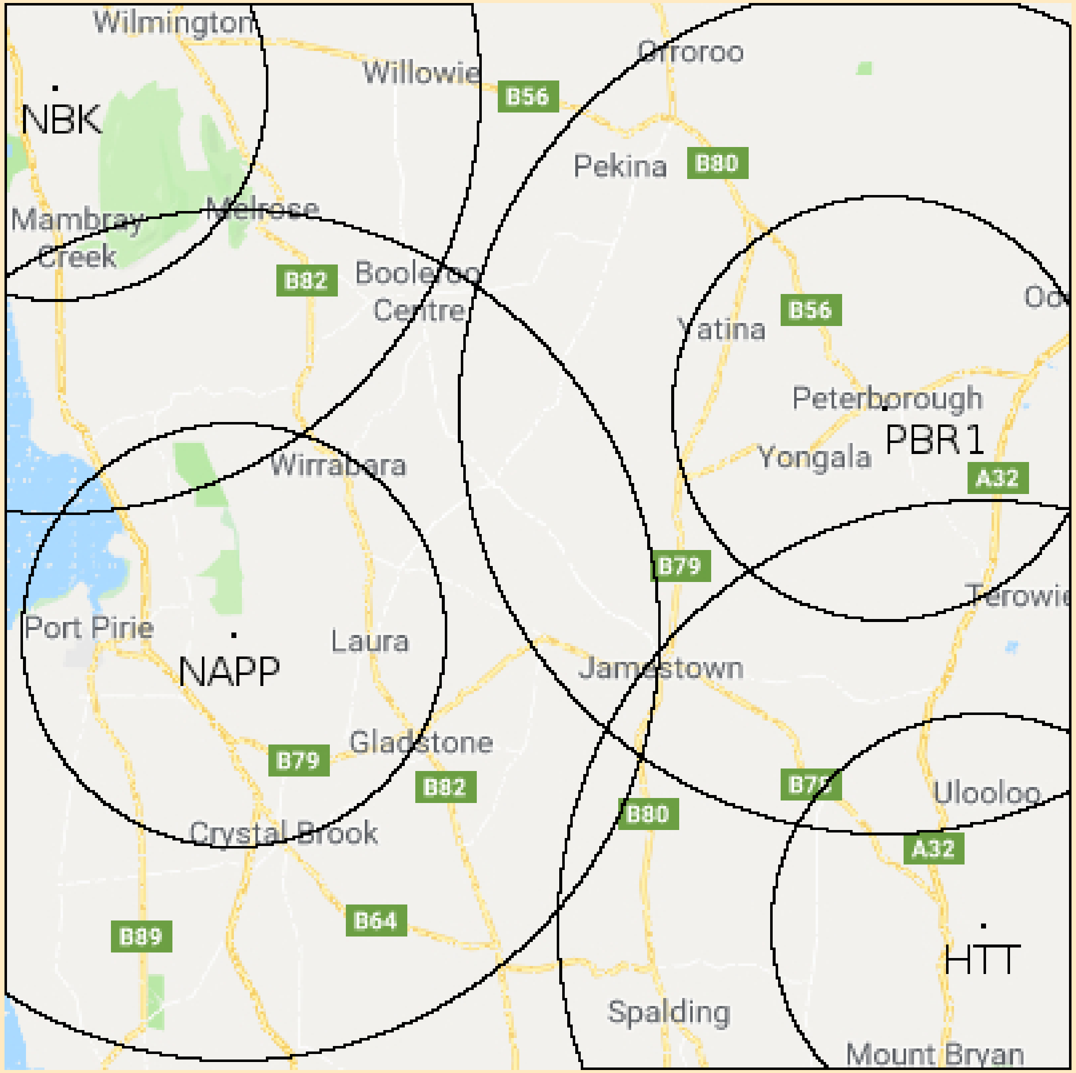


Image 2 - An ideal rural cluster?

Planning for the Future

Adelaide and Mt. Lofty Ranges

Only six of the area's seismic stations have been shown with radii marks:

THS is located 26.1km NE of Adelaide.

LIHL is located 27.8km ESE of the GPO

MPTV is located 23.1km SSW of the GPO

STR2 is located 45.7km SSE of the GPO

HML1 is located just to the North of this map but the radii have been included here for clarity
TPSO is located to the South of this map but the radii have been included here for clarity
In addition to the four stations shown, the following sites within 50km of the city make up the remainder of the Adelaide network:
ABFP is located 5.3km SSE of the GPO
AUMAR (ANU) is located 5.3km NE of the GPO
BRTS is located 12.5km SW of the GPO
LBTL is located 23.9km ENE of the GPO
MBKR is located 27.4km SE of the GPO
PLMR is located 50.6km ENE of the GPO
UTT is located 17.3km NE of the GPO

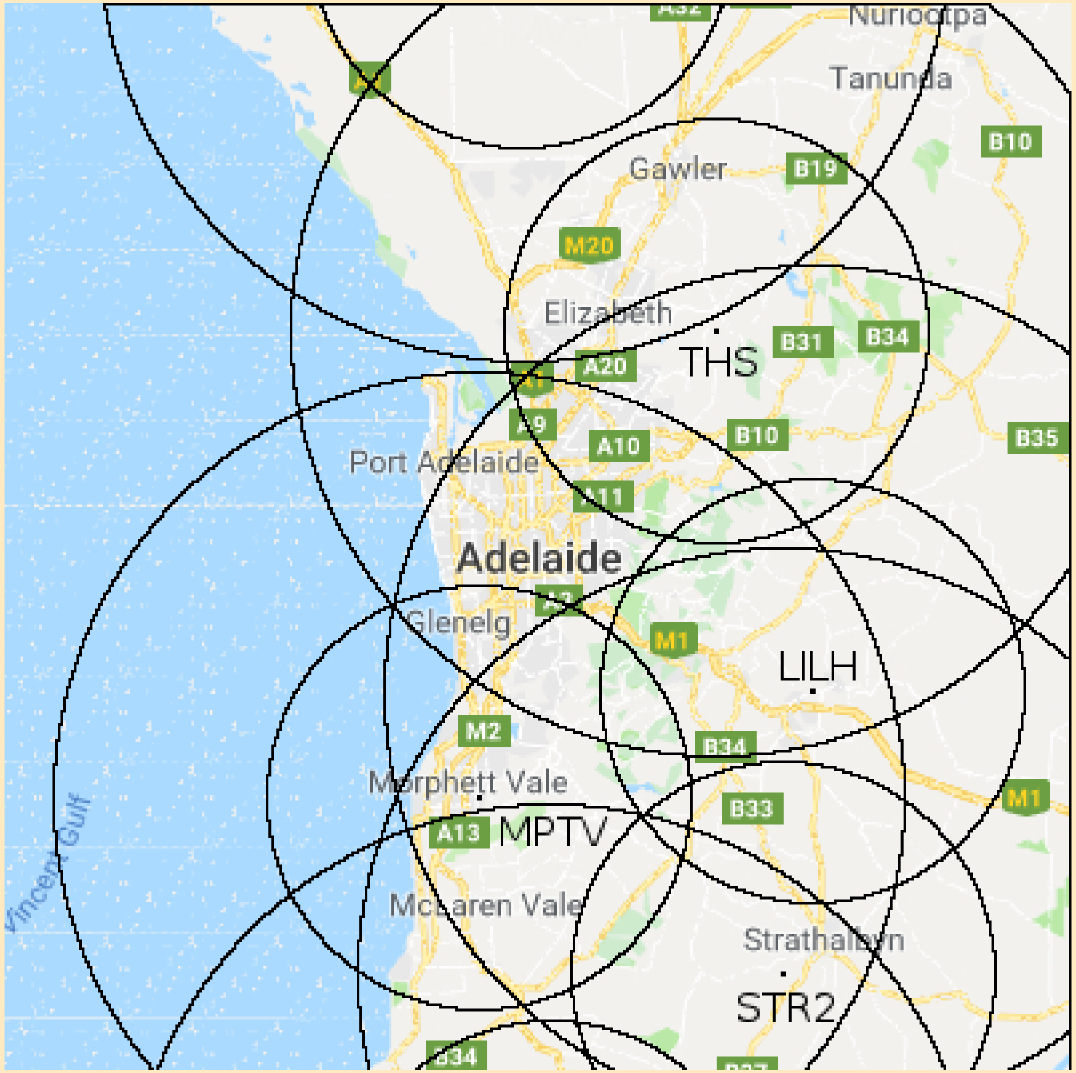


Image 3 - 50km South to 50km North

Planning for the Future

Mid-North region

Only one established seismic station has been shown with radii marks in Image 4, which shows the Mid-North region located 50 to 150km from Adelaide.

HML1 is located 58.4km North of the GPO.

HTT, operated by GA, is located to the north of this map. Its radii have been included here for clarity.

WALR is located approx. 100km WNW of HML1, 100km SSW of NAPP and 130km WSW of HTT.

The green radii marks are centred at Penwortham in the Clare Valley, which is a potential station site currently under investigation with good prospects.
A trial site (PENW) using a Ranger SS-1 and EchoPro was installed on Sunday, January 20th 2019 to evaluate its suitability for noise, communications reliability etc.
You can check it out on the SAA EqServer site, along with some of our other site's data including the adjoining HTT and AUJCS.

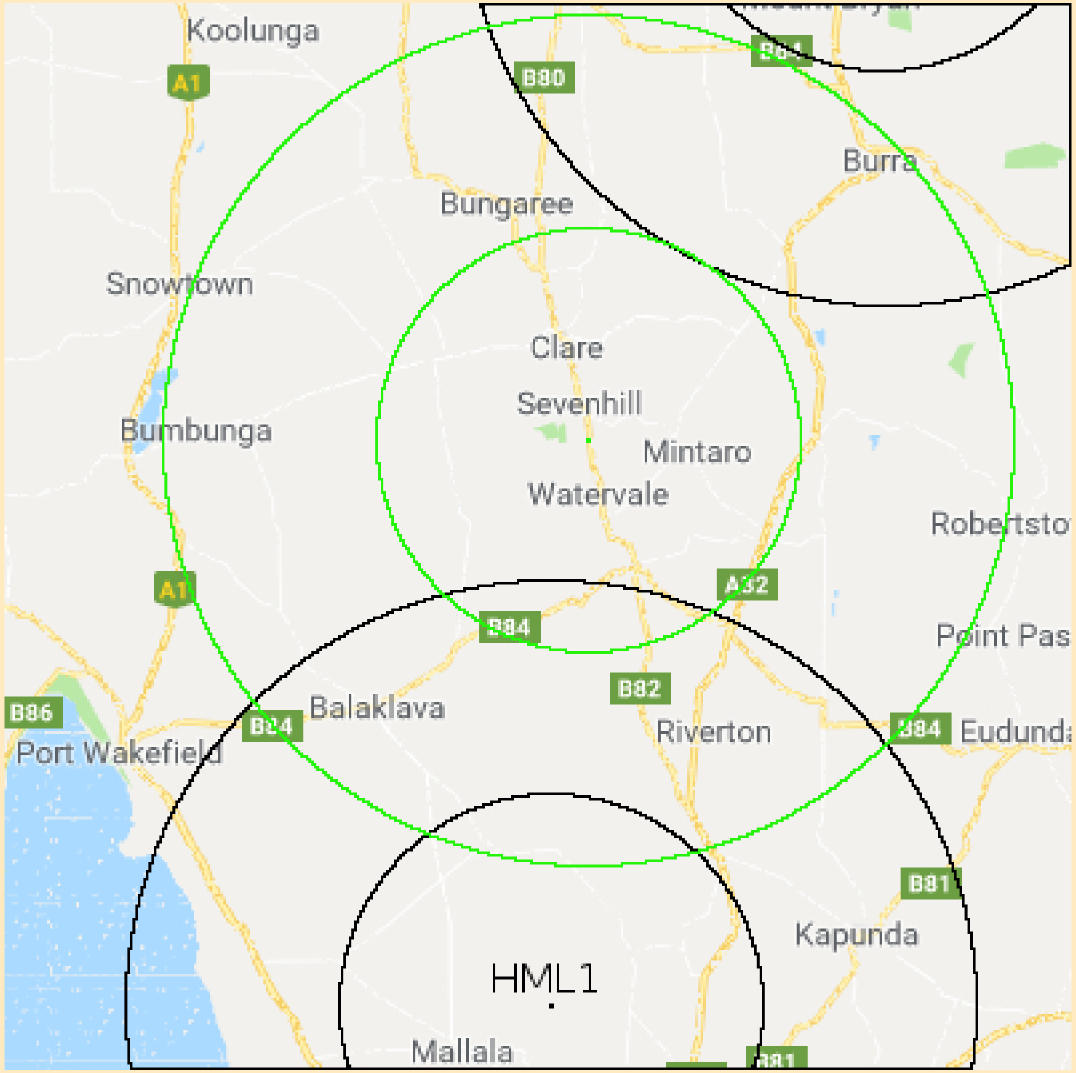


Image 4 - 50 to 150km North

Planning for the Future

Mid-North & Flinders region

Three established seismic stations have been shown with radii marks in Image 5, covering the Mid-North & Flinders regions located 150 to 250km North of Adelaide.

HTT, operated by GA, is located 169km North of the GPO.

AUJCS, operated by the ANU, is located 192km North of the GPO.

NAPP (GA) is located 199km North of the GPO.

PTPS (GA) is located approx. 13.3km West of NAPP.
WHYH (GA) is located approx. 56km WNW of NAPP.

The green radii marks are centred at Pekina, a potential station site currently under investigation with reasonable prospects.
Other opportunities for new sites might be around the settlements / towns of Orroroo, Yatina, Willowie or Morchard.

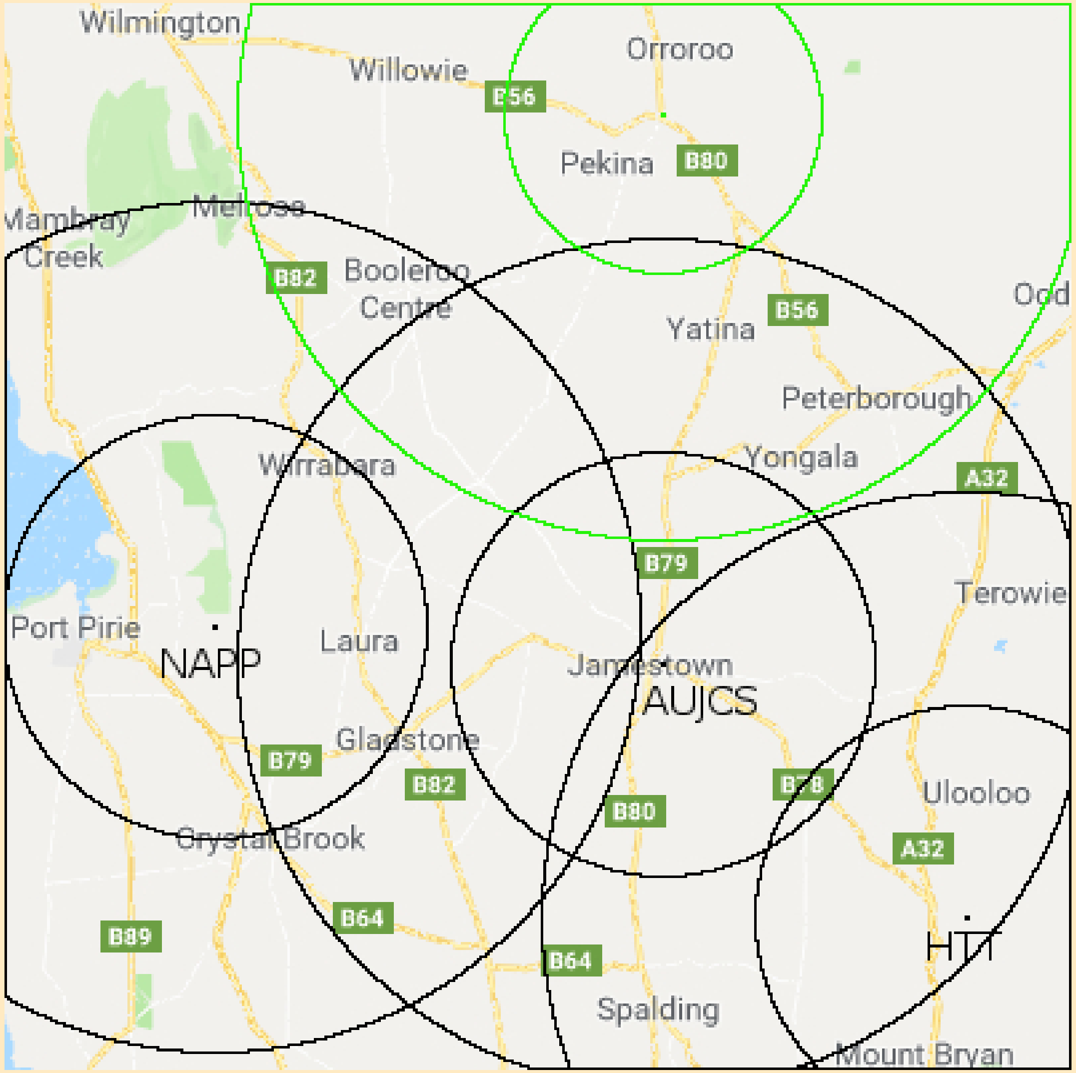


Image 5 - 150 to 250km North

Planning for the Future

Flinders region

Only one established seismic station has been shown with radii marks in Image 6, which shows a section of the Flinders Ranges located 250 to 350km North of Adelaide.

YAPP, operated by GA, is located 342km North of the GPO.

HKER is located just to the north of this map. Its radii have been included here for clarity.

Possible opportunities for new sites might be around the settlements / towns of Quorn, Bruce, Carrieton, Bendleby Ranges or Johnburgh.

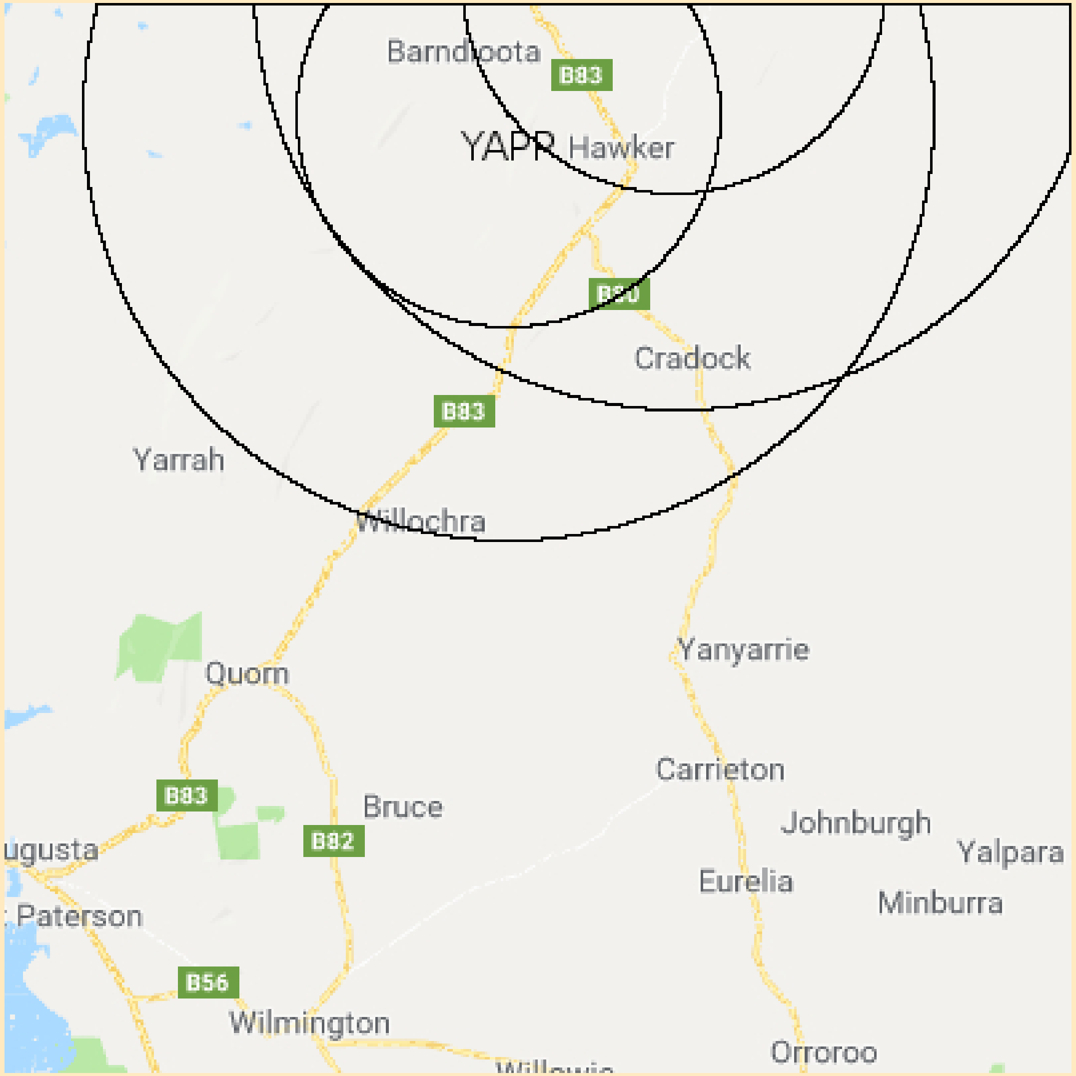


Image 6 - 250 to 350km North

Planning for the Future

Flinders region

Only one established seismic station has been shown with radii marks in Image 7, which shows a section of the Flinders Ranges located 350 to 450km North of Adelaide.

HKER is located 352km North of the GPO.
Upgrading the existing HKER station to an EchoPro and a 3 axis seismometer should be a priority project.

YAPP, operated by GA, is located to the south of this map. Its radii have been included here for clarity.

The green radii marks are centred around Blinman, to the North of the Ikara-Flinders Ranges National Park.

Two potential station site opportunities are currently under investigation, both with good prospects.
Other opportunities for new sites might be within the boundaries of Mount Little Station, Ediowie Station or Moralana Station.

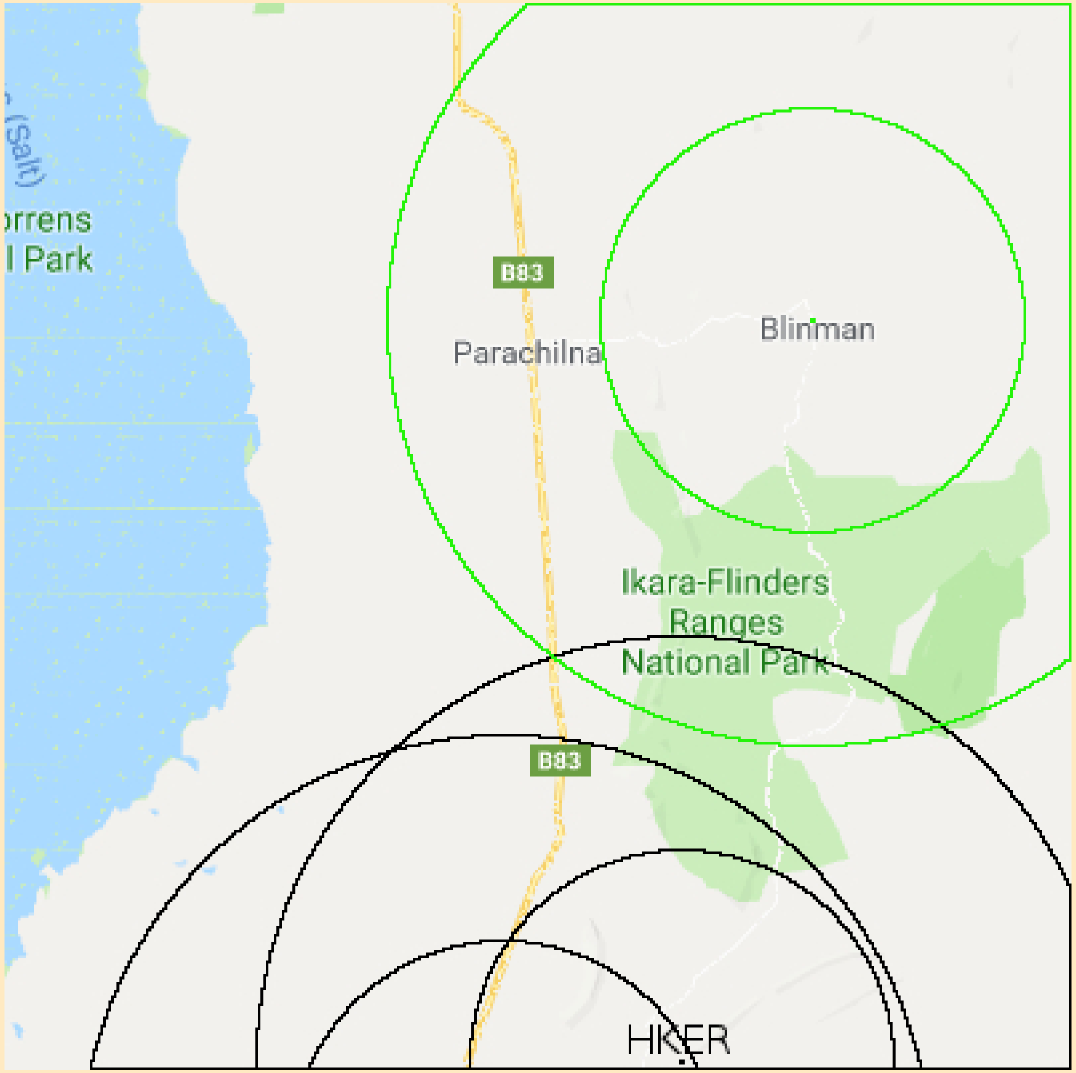


Image 7 - 350 to 450km North

Planning for the Future

Flinders region

Only one established seismic station has been shown with radii marks in Image 8, which shows a section of the Flinders Ranges located 450 to 550km North of Adelaide.

LCRK, operated by GA, is located 500km North of the GPO.

ARKL is located about 100km to the east LCRK. Its 40km radii line has been included here for clarity.

The green radii marks are centred around Blinman, to the South of this map.
Other opportunities for new sites might be found around Beltana.

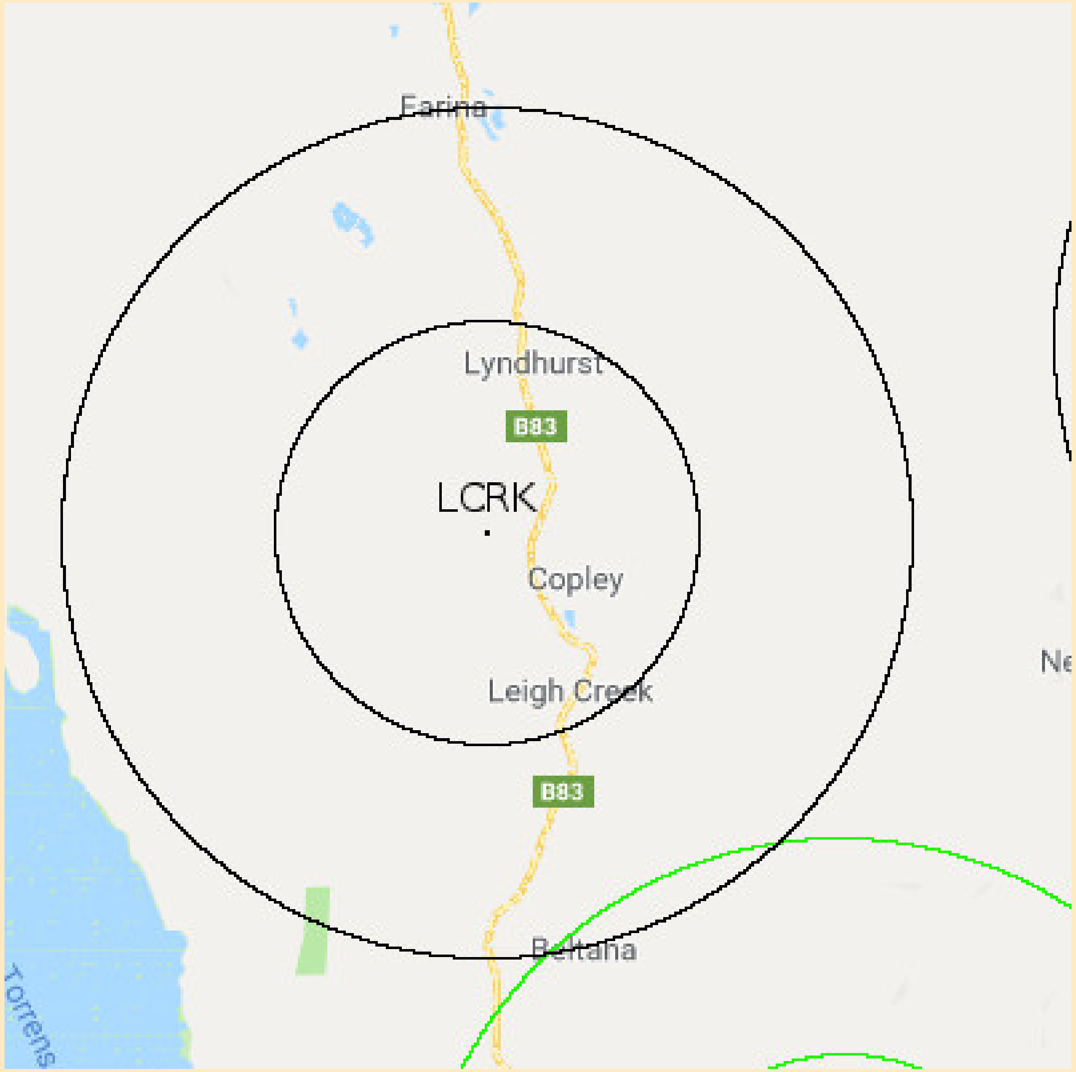


Image 8 - 450 to 550km North

Planning for the Future

Fleurieu Peninsula region

Only one established seismic station has been shown with radii marks in Image 9, which covers a section of the Fleurieu Peninsula located 50 to 150km South of Adelaide.

TPSO is located 62.6km South of the GPO.

MPTV is located north of this map but the radii marks have been included for clarity.
STR2 is located north of this map but the radii marks have been included for clarity.

The green radii marks are centred around Wattle Flat, south west of the Myponga Reservior.
The original station was removed from service back in March 2017 (see Newsletter #1) due to the high cost of landline phone and poor seismometer pit.

A new site has been identified and planning/costing for another installation is currently underway for action in the near future.

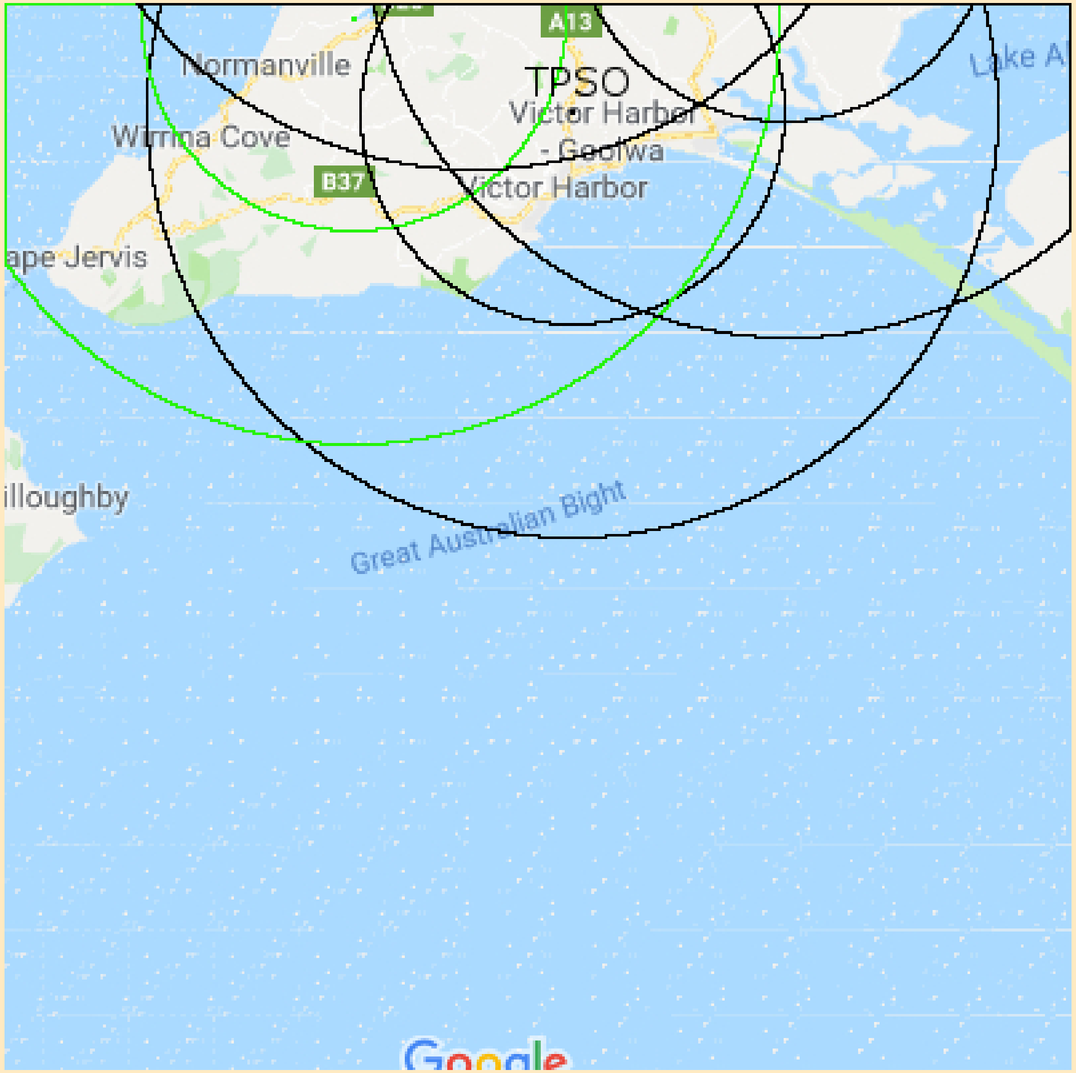
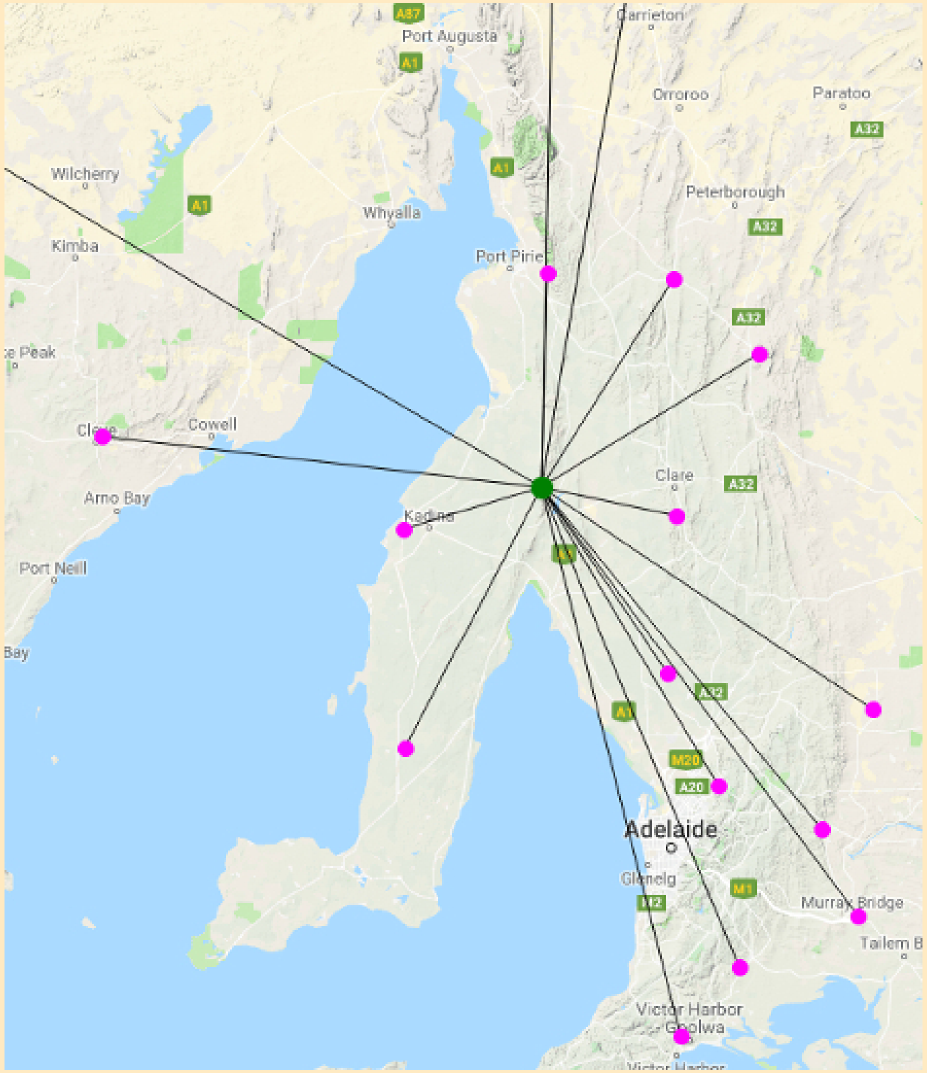
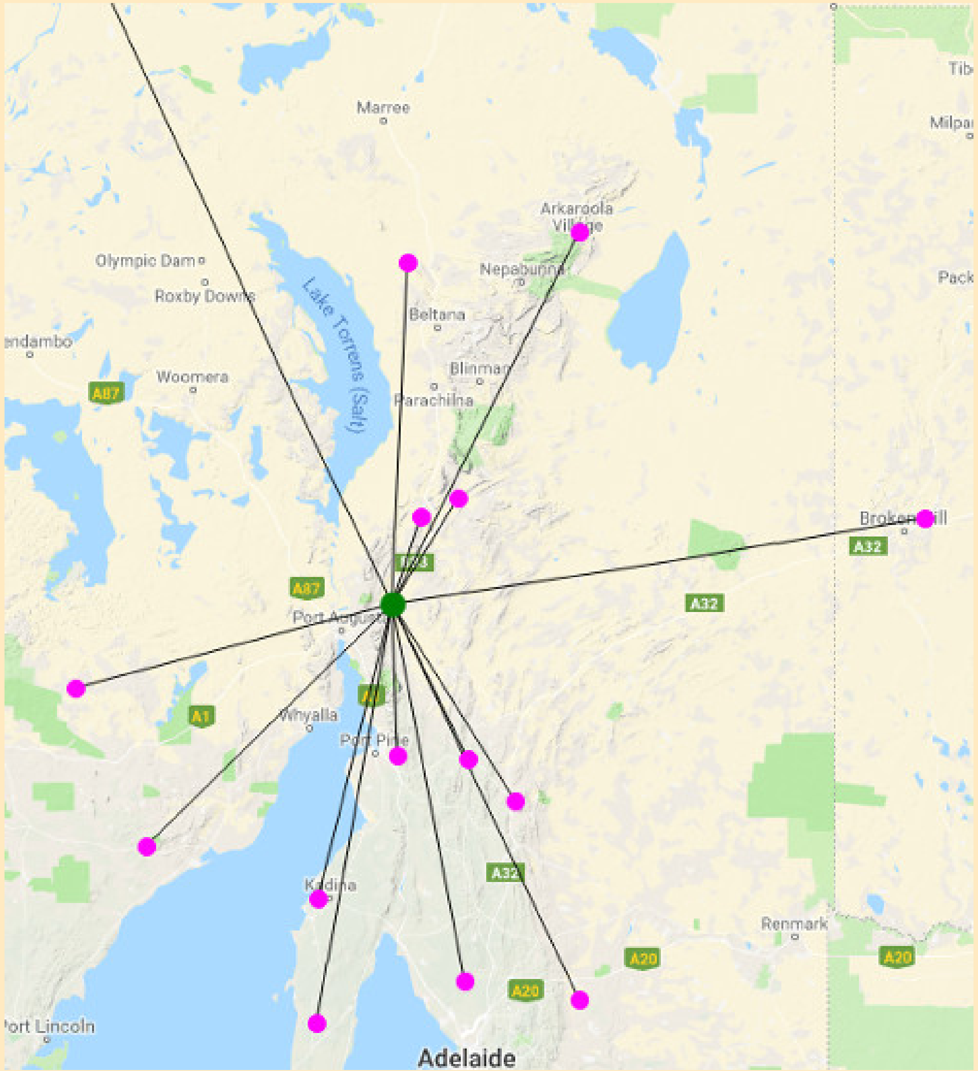


Image 9 - 50 to 150km South

Recent Seismic Activity

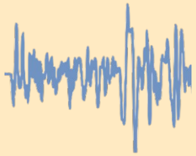


Snowtown 2019-01-27 00:00 ML2.7



Quorn 2019-01-28 18:28 ML2.6

Two very recent quakes of similar magnitude in the Mid-North & Flinders regions, good examples of our current capability.



Quantitative seismology is a relatively young science

Article text kindly submitted by Kevin McCue

The first seismometers built in the late 1890s were undamped low-gain mechanical levers that were only sensitive to major earthquakes at a distance. Phase arrival time, not ground amplitude, was the main measurement required by the then seismologists. Earthquake magnitude was not introduced for another 30 years. The 1906 San Francisco earthquake was recorded on a Milne seismograph under test in London, England before delivery to Adelaide as part of the first international seismograph network. It wasn't capable of recording local Adelaide earthquakes.

Yet engineers are to this day still trying to estimate ground shaking in San Francisco during that earthquake by analysing a local train derailment – not from any seismograms.

Over the next century electromagnetic seismometers became more sensitive and broadband, a2d converters enabled computer processing, GPS more precise timing. Good for the seismologist but no help to engineers who still needed to know the characteristics of the ground shaking at the epicentre where damage occurred. How else to design structures to accommodate the ground shaking?

The early 1970 saw the introduction, by engineers, of strong motion instruments that recorded the ground acceleration up to 1g for a few tens of seconds but without the capacity to record absolute time. The observation that ground motion exceeded 1g (in the 1971 San Fernando earthquake) and that timing was important (which recording corresponded to which aftershock) led in the next 40 years to the development of a single instrument satisfying the needs of both seismologist and engineer, the type of digital accelerographs AEES' Gibson and McCue took to Papua New Guinea with such success in March 2018.

This has brought the two communities together to try to understand earthquakes from the source to plate tectonics.

But buildings? Engineers can design and construct a structure according to the Australian Loading Code and estimate its response but how will it respond in practice? As per the design? In the 1990s, a new hospital for the Meckering WA region had a design natural frequency that was 6 times lower than that measured after construction. Those nasty in-fill masonry walls weren't included in the dynamic analysis! To get the 6 storey building to respond as designed the earthquake had first to knock out all the masonry and the interconnecting walkways – hardly satisfactory.

But few buildings are ever put to the test. Take a tall tower in Sydney. The measured natural frequency was 10s and the damping about 1%, and that was after damping cables were added. No wonder the structure is closed when the wind exceeds 100km/hr at which point the lifts stop working due to the large tower deflection. Engineers acting for the owner's would not divulge if this behaviour was as designed.

We need to test some of our typical buildings on a range of foundations in each city to compare their response to that predicted. Engineers need some feedback and should not just rely on the design code, for their own peace of mind. In that way there won't be nasty surprises for owners, governments or the public.

The test measuring the response to background noise is relatively quick although it would be ideal to monitor some buildings for their lifetime, or until an earthquake has given them a good shake.

If we knew what it was we were doing, it would not be called research, would it?

Article kindly submitted by Paul Hutchinson

An update on research using solid Earth tilt data from SAA's The Peters Seismic Observatory (TPSO)

Resolving "doublets" in solid Earth tides.
SAA member Prof. Randall Peters has performed extreme high resolution Power Spectral Density (PSD) analysis on 169 days of solid Earth tilt data from a pendulous seismometer having nanorad resolution and resting on the seismic pier of TPSO.

This solid Earth tilt data showing the lunar tidal period of 12 hours and 25 minutes[1] being the passage of the "Near Bulge" and then again some 12 hours 25 minutes later the passage of the "Far Bulge" of the solid crust of the Earth under the influence of the Moon's gravitational pull as the Moon passes overhead about once each 24 hours and 50 minutes. Refer Figure 1.

And the passing of the Sun overhead each approximately 24 hours causes a solar solid Earth tidal period of some 12 hours, but such Solar Earth tide being considerably less in effect on the solid Earth crust, than the Moon's.

This twice a day tilting of the solid earth bedrock resulting from Earth tides (Sun and Moon) is typically in the order of +/- 70 nanorads[3], but varies throughout the month. 70 nanorads is the angle subtended by the width of a human hair [1/10th mm] at a distance of 1.4 kms.

Typically a Fast Fourier Transform (FFT) analysis of such tilt data reveals but just a double "spike" at a period of about some 12 hours. FFT algorithms can reduce the computational time to process large data sets by factors of one or even two magnitudes of time[4], but require the number of data points in the set to only be a number to the power of 2. This approximation, this "fast" Fourier Transform results in inaccuracies and loss of high resolution.

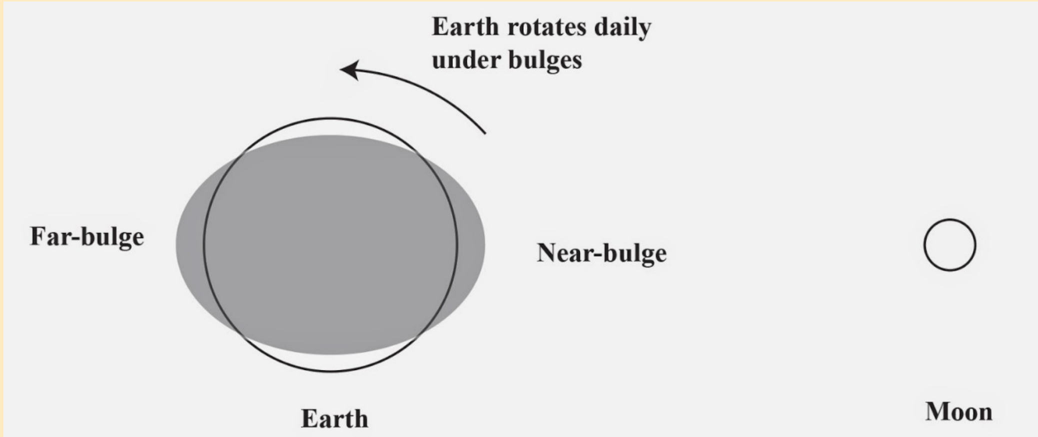


Figure 1: The two "bulges" of the Earth resulting from the gravitational pull of the Moon[2]

By using Wolfram's Mathematica, which alone has the speed-coupled-with-power to do the full mathematically precise Fourier transform on 169 days of data taken at 10 samples per second (being some 14.6 million data points) (not the quick approximation of an FFT), and by way of using high resolution analysis of the data, and by maintaining strict adherence to basic laws of physics relating to power (energy), Prof. Randall Peters has been able to show the phenomenon in solid Earth tilt data of the doublet in very high resolution.

If we knew what it was we were doing, it would not be called research, would it?

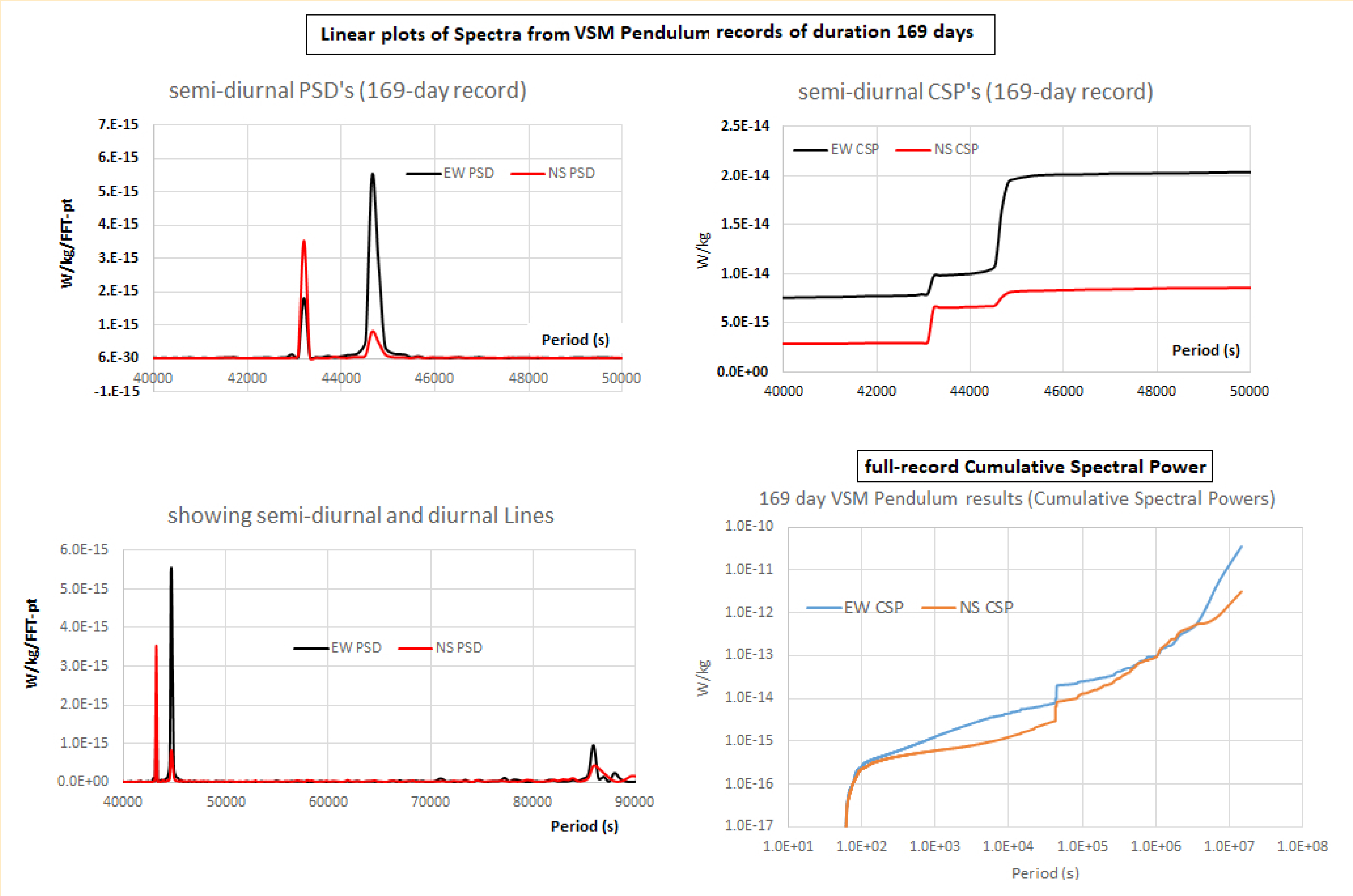
Figure 2: Showing from top LHS and rotating clockwise:

PSD in w/kg/FFT-pt, showing doublet at 12hr and 12hr 25 minutes

Cumulative Spectral Power in Watts/kg showing differences between E/W and N/S traces

Cumulative Spectral Power in Watts/kg from periods 100s to some 5,000,000s [60 days]

PSD in w/kg/FFT -pt showing periodicity from 4,000s to 9,000s being approx. 12hrs to 24hr period.



If we knew what it was we were doing, it would not be called research, would it?

As can be seen in Figure 2 on the previous page, **"semi-diurnal PSD's (169-day record)"** there is a "spike" at 43,200 seconds (12 hours), with another "spike" at 44,700 seconds (12 hours and 25 minutes).

On closer observation it is apparent that for.

- the 12 hour period [being the Solar solid Earth tides] the N/S trace shows the greater power, whereas for:
- the 12 hour 25 minute period [the Lunar solid Earth Tides] the E/W trace shows the greater power.

The high resolution PSD of Prof. Randall Peters resolving the "doublet" that shows differential effect of the Sun/Moon upon the N/S and E/W components is certainly something not expected.

Question?
Which raises the question as to how do you explain that when the path of the Moon and the Sun overhead over a period of 169 days, averages out to be pretty much the same general pathway, yet at TPSO the:

- Sun's tidal effect on the solid Earth crust is shown to be most pronounced on the N/S component, and the,
- Moon's tidal effect on the solid Earth crust is shown to be most pronounced on the E/W component.

This raises questions as to what is the dynamic response of the solid Earth crust to the continuously changing gravitational pull of the Moon and Sun and to a much lesser extent the gravitational pull of the planets.

Solid Earth Tide Research at TPSO – Lippmann tiltmeter.
Four months of solid Earth tilt data has now been collected from the Lippmann high resolution tiltmeter[5] on the seismic pier of TPSO.
This Lippmann tilt data has been processed by Dr. Gabor Papp, senior researcher, Geodetic and Geophysical Institute, Hungarian Academy of Science, using TSoft[6] software developed by the Royal Observatory of Belgium. Dr Gabor Papp is also the Project Leader of a consortium of four European scientific institutes in Austria, Finland and Hungary. In Figure 3 on the next page, [being for 10 days] Dr. Papp shows the actual ground tilts at TPSO as compared with the COBS (Conrad Observatory, Austria) synthetic tidal tilt model determined by Hannu Ruotsalainen, senior researcher, Finnish Geospatial Research Institute, Masala, Finland and predicted for the location of TPSO.

Whilst for the first five days in the graph above, there is general agreement with the synthetic tidal tilt model, it is noted that in the last five days the actual ground tilts and the synthetic tilts get to be some 180 degrees out of phase.

Question?
Why is there over a period of just a few days, a 180 degrees change in tilt, between actual ground motion and theoretical predictions? Does it come from the significant differences of the geographical environment of the two stations COBS and TPSO located at intra-continental and coastal area, respectively? Can the ocean loading effect at TPSO, being just 7 kms from the ocean, explain the observed phase shifts?

If we knew what it was we were doing, it would not be called research, would it?

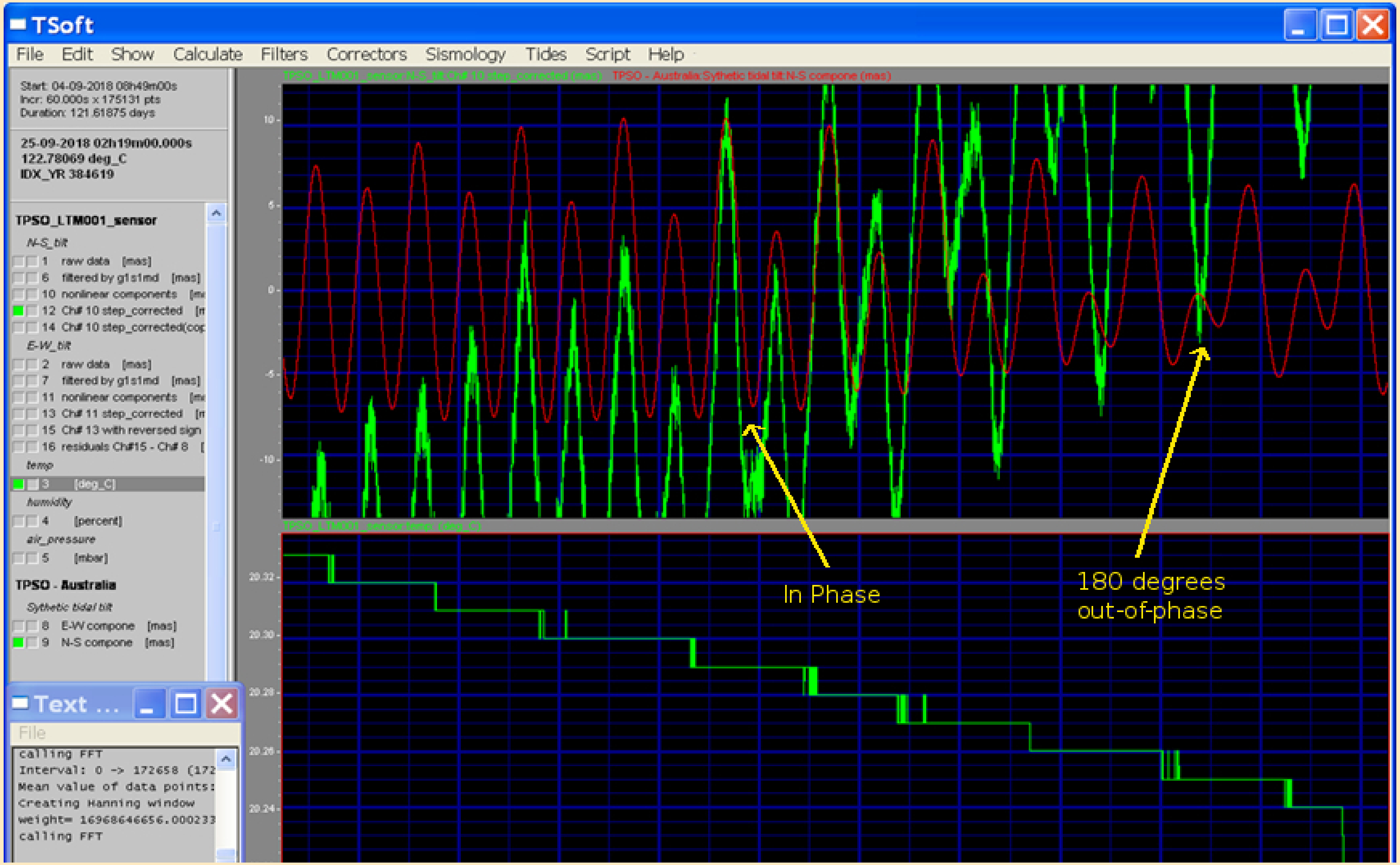


Image 3:

Actual ground motion tilt [green trace] at TPSO as measured by Lippmann tiltmeter vs [red trace] synthetic solid Earth tides predicted for the TPSO. The lower trace being the temperature on the PCB inside the Lipmann tiltmeter dropping at ~ 0.01 Deg. C per day.

If we knew what it was we were doing, it would not be called research, would it?

It is understood that Prof. Dr. Bruno Meures, University of Vienna, and Hannu Ruotsalainen both experienced in analysis of solid Earth tidal signals will be investigating this matter.

Further analysis on Lippman tiltmeter data from TPSO.
Figure 4 is shown on the following page.
The FFT in the insert of Figure No. 4 shows:

- At the red arrow, the approximately 24 hour and 50 minute passage of the Moon overhead each day, being a frequency of 0.996 cycles/day.
- At the blue arrow, the approximately 24 hourly passage of the Sun overhead each day, being a frequency of 1 cycle/day.
- At the green arrow, the semi diurnal [twice a day] wave group being a doublet, peaking for the Sun at 12 hours [a frequency of 2 cycles/day] and peaking for the Moon at 12 hours 25 minutes [a frequency of 1.932 cycles/ day].
- At the orange arrow, a higher harmonic appears of approximately 4 cycles/day.

Future analysis of TPSO Lippmann tilt data.
Prof. Randall is to analyse this four months of high resolution solid Earth tilt data from the Lippmann tiltmeter on the seismic pier of TPSO. Firstly to perform a high resolution full Fourier Transform of Power Spectral Density and then to show the Cumulative Spectral Power (Watts/Kg) for N/S and for E/W ground motions.

Questions?
Using this four months of solid Earth tilt data from the Lippmann tiltmeter on the seismic pier of TPSO, will Prof. Randall Peters' high resolution PSD be able to show in the "doublet" at approximately 12 hours, will this also show that the Sun's tidal effect on the solid Earth crust is most pronounced on the N/S component, and the Moon's tidal effect on the solid Earth crust to be most pronounced on the E/W component.
For if so, then this will raise questions as to the validity of using a simple dynamic response modelling of the solid Earth crust in which the crust immediately reacts in a homogenous manner to the gravitational vector pull of the Moon and Sun [and planets] simply determined by the astronomical position of these heavenly bodies. These questions point to a much more complex variable time delayed dynamic response of the crust possibly due to its non-homogenous nature both laterally and with increasing depth.

For as it has been said before, "If we knew what it was we were doing, it would not be called research, would it?"[7]

Paul Hutchinson

References

[1] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2001JB000569
[2] http://artofwayfinding.blogspot.com/2014/10/origin-of-tides-part-1.html
[3] http://physics.mercer.edu/hpage/volksmeter/Response%20of%20VolksMeter%20Seismometer%20FINAL.pdf see Section 2.4 Page 26
[4] https://en.wikipedia.org/wiki/Fast_Fourier_transform
[5] https://www.l-gm.de/en/en_tiltmeter.html
[6] http://seismologie.oma.be/en/downloads/tsoft
[7] https://www.tandfonline.com/doi/abs/10.1080/08941920701561031

If we knew what it was we were doing, it would not be called research, would it?

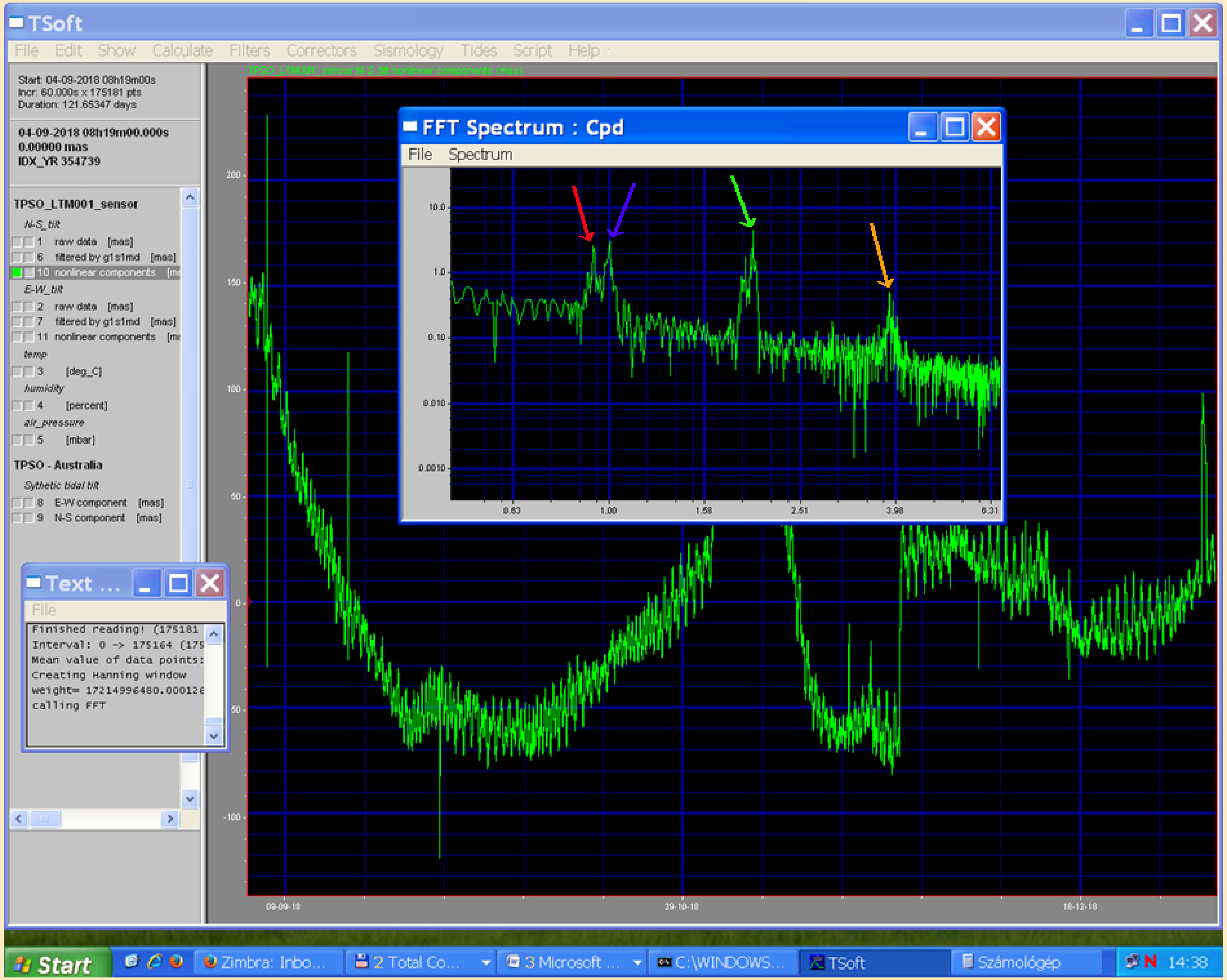


Figure 4:

N/S solid Earth tilt recorded by Lippmann tiltmeter S/N 001, on the seismic pier of TPSO for some four months ending 2nd January 2019.

Insert: FFT spectrum performed by Dr. Gabor using the TSoft software (frequency being cycles/day).

Enhancing the long term stability of the Lippmann High Resolution Tiltmeter

Article kindly submitted
by Paul Hutchinson

How a recent power failure at TPSO has provided useful insights into achieving more stable tiltmeter measurements. (By showing the need for a tightly regulated power supply to the Lippmann High Resolution Tiltmeters (HRTM) both at TPSO and at the Conrad Observatory in Austria, in order to achieve a more stable long term tilt trace).

Image 1: The Conrad Observatory at Trafelberg

The Central Institute for Meteorology and Geodynamics (ZAMG)[1] in Austria, was founded in 1851 and is the oldest weather service in the world. Its task is not only to operate monitoring networks and to conduct research in various fields, but also to make the results available to the public. The Conrad Observatory[2] is an underground geophysical research facility of ZAMG. The observatory features facilities for seismology, gravity, magnetic and infrasound research, and is a part of the Comprehensive Test Ban Treaty Organization for monitoring two different procedures, infrasound and seismology.

Image 2 shows the utilities room providing, amongst other things, uninterrupted power supplies to the various instruments and supporting equipment, being at various nominal voltages, including a nominal 13.8 volts to various instruments including the HTRM.

Image 2: The utilities room of the Conrad Observatory

Dr. Gabor Papp and Dr. Judit Benedek of the Geodetic and Geophysical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Sopron, Hungary have in collaboration with ZAMG, placed a HRTM on one of the seismic piers in the Seismic Gravimetric Observatory (SGO) of the Conrad Observatory. Refer to Image 3 on the following page.

In Image 4, the blue case of the HRTM is bolted to a green heavyduty base, in order to ensure the greatest mechanical stability of the instrument resting on the seismic pier. Note the pipe running alongside the Lippmann tiltmeter. This is a part of the 5.5 metre long interferometric water level tiltmeter (single end setup) also operated by Dr Gabor Papp (Ruotsalainen et al, 2016)i.

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Image 3: The Seismic Gravimetric Observatory (SGO) at the end of a 145 metre long tunnel. The temperature is a constant 6.9 Degrees C, all year round.

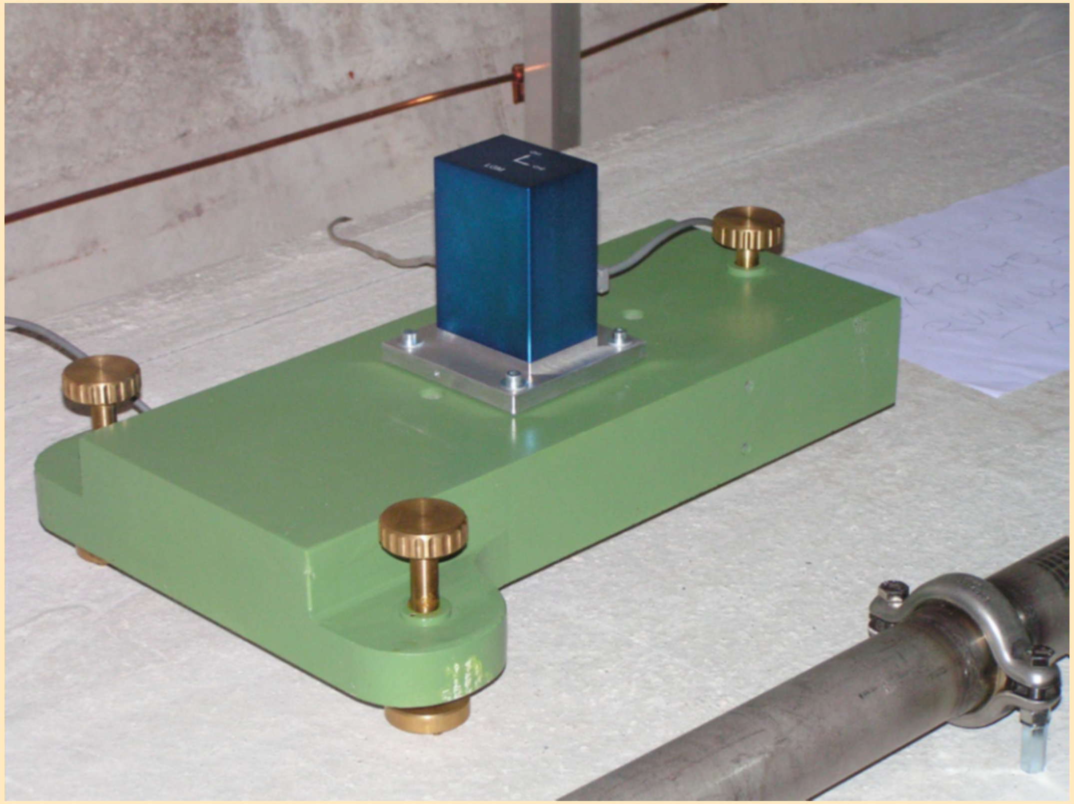

Image 4: The bi-axial (N/S and E/W) HRTM on the SGO seismic pier

The superconducting gravimeter (SG), shown in Image 6 on the following page, is currently the most precise instrument for investigating temporal gravity variations both in the time and the frequency domain.[4]
Dr Papp and Dr Benedek, together with colleagues from the Finnish Geospatial Research Institute, FGI, National Land Survey of Finland, colleagues from the University of Vienna, Department of Meteorology and Geophysics, Wien, Austria, and colleagues from ZAMG, presented a research paper, ***"Comparison of Tilt and SG-Gravity Residuals at the Conrad Observatory."*** [5] to the 1st Worskshop on the International Geodynamics and Earth Tide Service (IGETS), 18-20 June 2018, Potsdam (Germany).

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Conclusion of ZAMG research paper. The conclusion was that long term signatures showed a clear correlation between the tilt and the super gravimeter sensor data. But local rainfall and snowfall, air pressure variations, cavity effect of the actual seismic tunnel, and tilt decrease delayed by two to five hours with respect to gravity increase, all caused changes in drift and instability in the traces. Surprisingly, with the tilt meter, TEMPERATURE changes caused a slight instability in the Lippmann tilt traces.

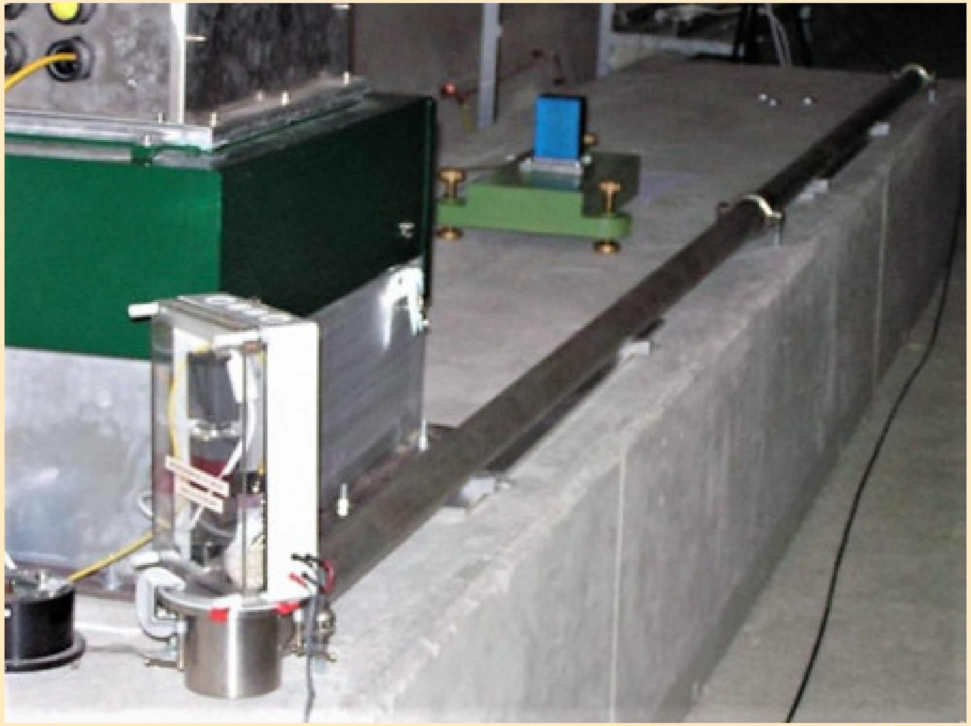

Image 5: Showing on one of the seismic piers in the SGO and the 5.5 metre long interferometric water level tilt meter (single end setup E/W). The Lippmann HRTM is in the background.

Image 6: The Super Conducting Gravimeter SG GWR C025

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But not so with the Super Conducting Gravimeter SG GWR C025 because in its cryogenic environment (liquid helium at -270 Degrees C or 4 Degrees Kelvin) it is totally insensitive to local changes in temperature, relative humidity or pressure. That is, a change in temperature of +0.1 Degree C as measured on the PCB located inside the Lippmann HRTM instrument, an instrument surrounded by a thick aluminium casing, was shown to change the tilt by almost some minus 100 mas. An absolutely miniscule amount, but for long term high resolution stable tilt measurements it was a concern.

And it being absolutely essential that the stability of the tiltmeter be maintained over many years, in order to be able to detect minute long term changes in tilt that may herald tectonic changes. Such uncalled for changes in the level of the Lippmann tilt traces, because of temperature, were a significant distraction to the goal of having long term stable Lippmann tilt data from the temperature constant Conrad Observatory SGO.

Temperature

But the SGO, at the end of a 145 metre long tunnel, has a constant year round temperature of 6.9 Degrees C, buried as it is deep within a mountain. So the ambient temperature around the Lippmann HRTM in the SGO, was not changing. Rather it was the temperature of the actual instrument changing. So as a result, thermal insulation was installed on the HRTM in August 2017.

The problem of temperature changes continued to cause the trace of the HRTM in the Conrad Observatory to be slightly affected by what seemed to be at the time, varying temperature.

(Note: Dr. Papp advised that there is a slight yearly change in temperature of less than 0.1 deg C peak to peak at the SGO at Conrad Observatory. Although it is small it may give a long term periodic tilt signal driven by the yearly change of the air temperature outside. Of course with a significant time delay...
In the first years the visits of the staff of COBS disturbed sometimes the measurements. Even lights on had serious effect on tilt! Therefore the sensors and the full iWT tube were insulated by polystyrene plates to minimize the disturbances.)

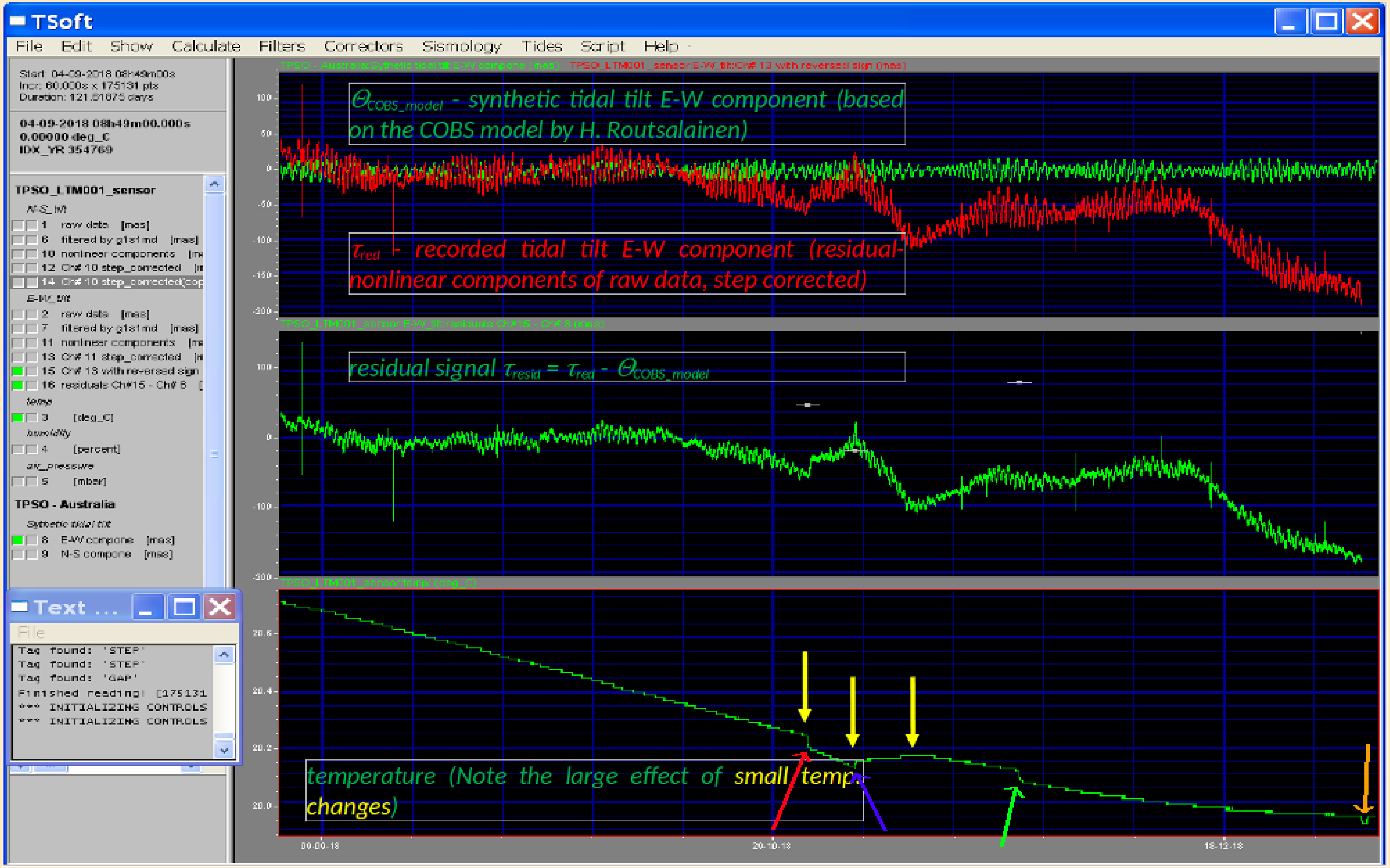
Temperature changes in TPSO

The seismic vault of TPSO buried 9 metres below ground level, has an approximate 1.5 Degrees C sinusoidal temperature change up and down during the year, with the temperature changes being some five months behind the season above ground level.
In December (summertime) the temperature has stopped dropping, is constant, at about 19.9 Degrees C. In June (wintertime) the temperature has stopped rising, is constant, at about 21.4 Degrees C. That is in both September (Springtime) the temperature is dropping some 0.01 Degrees C per day, and in March (Autumn) the temperature is rising at about some 0.01 Degrees C per day, the maximum daily rate of change in temperature inside TPSO seismic vault.

Not at all like the temperature constant year round 6.9 Degrees C inside the SGO of Conrad Observatory in Austria.

Enhancing the long term stability of the Lippmann High Resolution Tiltmeter

Image 7: Review of tilt data recorded by LTM001 at TPSO from 2018-09-04 to 2019-01-03. Sampling rate of displayed data: 1 min



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As can be seen in the temperature portion of Image 7 above, the temperature was steadily declining, and beginning to level off towards the end of December, when a temperature “disturbance” highlighted by the yellow arrows occurred in November 2018.

Question
If the seismic vault of TPSO is buried 9 metres below ground level, and TPSO has five insulated doorways in the tunnel leading into the seismic vault, then why would there be any sudden temperature change, any “disturbance” in temperature within the seismic vault, if no access was made into the tunnel, and no access was made into the seismic vault of TPSO.

It was assumed that the actual temperature inside the seismic vault of TPSO was not “disturbed”.

But then what would have caused the temperature sensor, on the PCB of the HRTM located inside the thick casing of the instrument, to record a change in temperature, to record a “disturbance” in temperature, when it could be reasonably assumed that the instrument itself was located in a gently steadily declining temperature inside the seismic vault of TPSO.

Answer
The answer was discovered by checking the actual voltage delivered to the HRTM during the supposed period of “disturbed” temperature change.

Image 8 on the following page, shows TPSO battery bank voltage as was measured by another seismic instrument, during the period highlighted by yellow arrows, in Image 7 above. Three seismic instruments (including the HRTM) all draw 12 volts off this lead acid battery bank. Which is charged by a 240 volt, 50 Hz regulated power supply which in effect kept the battery bank tickle charged at +13.1 volts. In addition Qty. two only 12 volt modems are powered from this battery bank, each modem broadcasting a data set, every minute.

Red arrow. 1st November 2018 at approx. 20:00 hrs UTC
The red arrow (as shown in both Image 7 and Image 8) shows the battery voltage dropping very quickly, at about 20:00 hrs, after the 240VAC power failure (probably due to a lightning strike induced failure) which tripped the battery charging circuit breaker. No other circuit breakers in TPSO were tripped at this time.

Battery dropped from some 13.1 volts to 12. 25 volts within an hour. The lead acid batteries (4 old truck batteries) are almost at end of their useful life.

From about 21:00 hrs UTC the battery bank voltage slowly falling from 12.25 volts over some 5 days down to some 11.7 volts as all three seismic instruments (including the HRTM) drew power from the battery bank uninterrupted for some 5 days.

All other systems within TPSO continued working uninterrupted.

Blue arrow. 6th November 2018 at about 23:00 hrs UTC.
The blue arrow (as shown in both Image 7 and Image 8). Some 5 days after battery charger tripped, I visited TPSO, and volts were 11.7. I reset the circuit breaker for the 12 volt battery charger and adjusted the regulated power supply voltage upwards somewhat, to enable a faster charge rate.

Enhancing the long term stability of the Lippmann High Resolution Tiltmeter

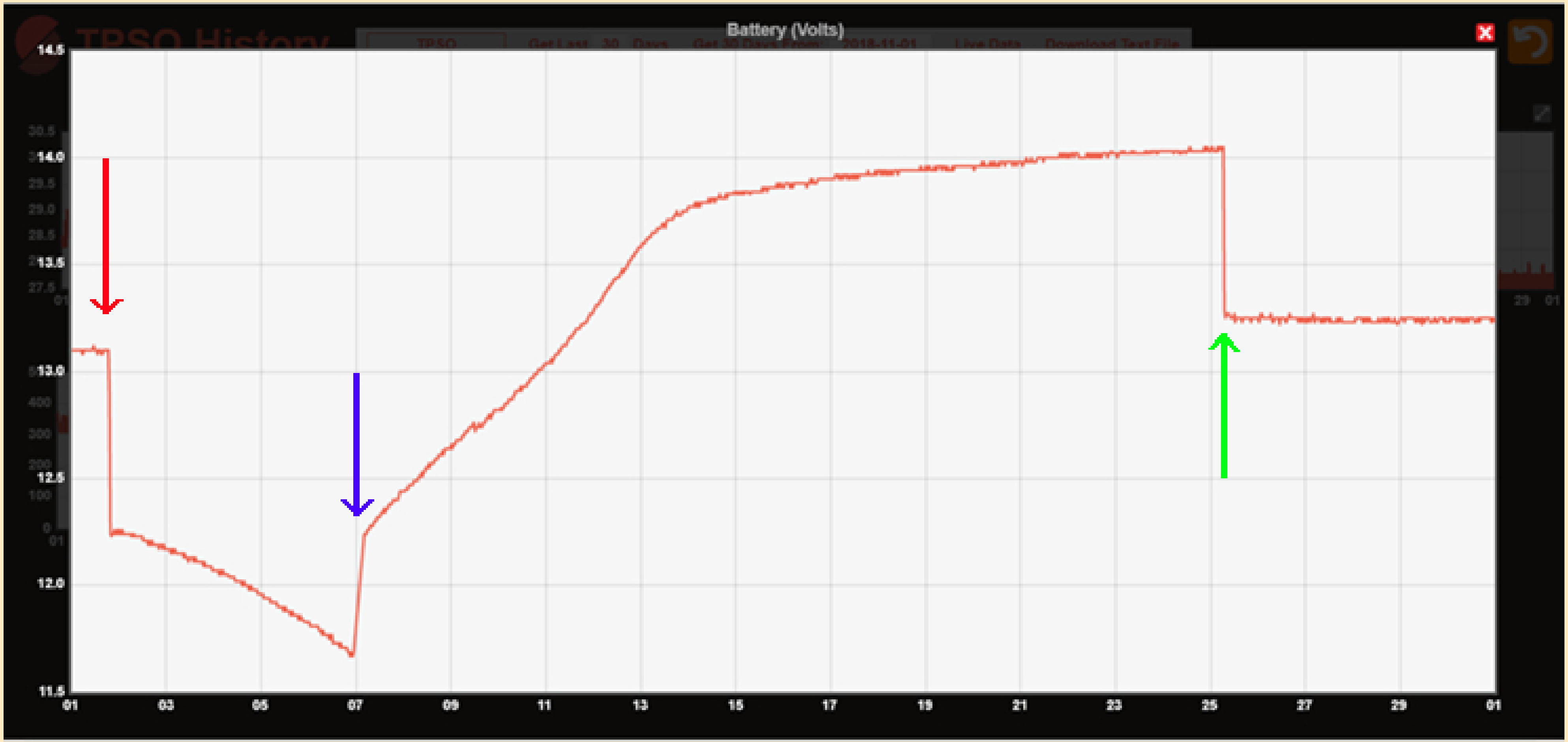

Image 8: The battery bank voltage in TPSO, during the period of the supposed temperature "disturbance". November 2018 [UTC time]

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Green arrow. 25th November 2018 at about 06:00 hrs UTC.
The green arrow (as shown in both Images 7 and Image 8) shows where about 18 days after the battery charger circuit breaker tripped, I again visited TPSO, and seeing that the voltage was a bit high at some 14.05 volts, I reset the trickle charger to some 13.25 volts. Voltage took some hours to drop from 14.05 volts to 13.25 volts, where the voltage remained at 13.25 volts before slowly creeping up to 13.35 volts.

Orange arrow.
The orange arrow (as only shown in Image 7) is where on the 2nd January 2019, at approx. 03:00 hrs UTC, the voltage dropped from 13.35 volts to 12.50 volts for some two hours before returning very quickly again to 13.35 volts. Due to a power outage.

Effect of voltage change on instrument traces.
So that is the story of how it came to be recognised that “disturbances” in the temperature trace of the HRTM on the seismic pier of TPSO, and “disturbances” in the E/W and in the N/S tilt traces of the HRTM on the seismic pier of TPSO, corresponded to significant step voltage changes in the power supply. NOT as previously thought, to changes in ambient temperature.

(It is to be noted that at the Conrad Observatory, the Lippmann HRTM does not have any voltage regulator immediately before the instrument, so any voltage fluctuations from the nominal power supply are passed straight through to the HRTM). How-be-it very small voltage fluctuations which made any correlations between voltage supply and trace “disturbance” well nigh be impossible to determine at the Conrad Observatory.
But the large supply voltage step changes at TPSO, of close to 1 volt, enabled the correlation between voltage supply and trace “disturbance” to be easily determined.

Lippmann HRTM instrument makeup.
The HRTM’s internal PCB is directly subjected to the supply voltage.

A relatively stable supply voltage [as at Conrad Observatory] still results in small changes in supply voltage, resulting is small changes in power dissipations within the instrument, resulting in small changes in actual temperature of the actual instrument itself, (measured in hundredths of a Degree C), but which result in different drift values, which for high accurate long term observatory grade tilt measurements, degrades the value of the recorded tilt data.

However, the HRTM has for the actual tilt sensors themselves, a first step voltage regulator followed by a second high precision voltage regulator giving a very stable voltage to the actual tilt sensors. So the scale factor of the instrument is not affected by slightly changing nominal voltage fluctuations, but changing supply voltages (even minutely) will affect drift values.

So a changing input voltage changes the energy dissipation in the input electronics on the PCB inside the solid aluminium instrument case. Since these circuits are inside the solid aluminium instrument case, the “extra” heat due to dissipation changes the temperature inside the box, “deforming” unevenly the mechanical parts of the sensor, and seeing as the tiltmeter is a real pendulum, then this uneven heating of the aluminium case causes REAL tilts eventually. Not tilts of the platform/ground, only the tilt of the sensor aluminium frame.

Enhancing the long term stability of the Lippmann High Resolution Tiltmeter

And any change in drift values of such a high precision observatory grade instrument such as the Lippmann HRTM is of great concern when attempting to measure minute long term changes in tilt.

The solution

Mr Eric Lippmann was informed of the effect that large step changes in the supply voltage at TPSO had upon theHRTM traces. He confirmed the scale factor would not be affected, due to the tilt sensors themselves being supplied power through a first step voltage regulator then through a second high precision voltage regulator.

But Mr. Lippmann confirmed that,
"changes of even some volts will not affect the scale factor but due to changes in internal temperature gradients will affect drift values."

So Mr Eric Lippmann suggested and designed a very stable voltage regulator, to be placed in the power supply line, just prior to the tiltmeter, so that regardless of changes in nominal supply voltage the Lippmann tiltmeter will always be receiving the same voltage.

This simple solution it is hoped, will allow for much more stable tilt traces, being particularly advantageous for the measurement of long term (years) tilt variations.

Ambient temperature compensation

With the SGO area within the Conrad Observatory having a constant ambient temperature of 6.9 Degrees C all year round, then now with the fitment of a high precision voltage regulator into the power supply just before the Lippmann tiltmeter, then it can be expected that the tilt traces now at Conrad Observatory, will have a very low drift.

With the fitment of a high precision voltage regulator, manufactured and supplied by SAA's Chairman, Mr Blair Lade, into the power supply just before the Lippmann tiltmeter, on the seismic pier of TPSO, then it can be expected that the TPSO Lippmann tilt traces now will have a very low internal drift. But because the seismic vault of TPSO has temperature changes throughout the year, (some +/- 0.8 Degrees C) then it is anticipated that a temperature compensation factor will be able to be determined, that effectively compensates for seismic vault ambient temperature fluctuations, thereby enabling a very accurate determination to be made of long term tilt.

The advantage of joint collaboration

So it just goes to show, how by joint collaboration, with instrument maker Mr Eric Lippmann, with Dr. Gabor Papp, Geodetic and Geophysical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Sopron, Hungary, with the Conrad Observatory (COBS), with the Seismological Association of Australia Inc (SAA) and with The Peters Seismological Observatory (TPSO), that a significant advancement has been made in improving the long term stability of the observatory grade Lippmann tiltmeter.

References

[1] https://en.wikipedia.org/wiki/Central_Institution_for_Meteorology_and_Geodynamics
[2] http://conrad-observatory.at/
[3] Ruotsalainen H, Bán D, Papp G, Leonhardt R, Benedek J (2016): Interferometric Water Level Tilt Meter at the Conrad Observatory. COBS Journal Nr. 4. pp. 11
[4] https://www.hindawi.com/journals/ijge/2012/954271/
[5] http://igets.u-strasbg.fr/2018workshop/3.2_04_gravi_tilt.pdf

Resources & useful links

Description	URL / Webpage	Notes
SAA Membership Application	https://www.assa.org.au/media/74629/saa-membership-	Join up with the SAA using this form
SAA Flier	https://www.assa.org.au/media/74629/saa-membership-	Our current brochure - flier, saying what we do
SAA Newsletters	https://www.assa.org.au/resources/technical-special-	Download any SAA Newsletter from this site
SAA EqServer	http://ade-eqserver.dyndns.org:8080/eqserver/	South Australian miniseed seismometers
Melbourne University EqServer	http://meiproc.earthsci.unimelb.edu.au/eqserver/	Australian miniseed seismometers
Regional Seismic Network	http://www.regional-seismic.net/	PSN seismometers - Aust. Centre for Geomechanics
Regional Seismic Users Website	http://www.rsuw.daleh.id.au/index.html	PSN seismometers - RSUW
Recent SA Earthquakes	http://earthquakes.mappage.net.au/q.htm	Data & summaries of recent SA quakes
Central QLD Seismology Research Group	http://www.cqsrg.org/	CQSRG - Kevin McCue
Astronomical Society of SA	https://www.assa.org.au/resources/technical-special-	ASSA - Seismology page
Geoscience Australia	http://www.ga.gov.au/earthquakes/initRecentQuakes.do	Our national authority on seismic events
QLD Uni Environmental & Earth Sciences	https://sees.uq.edu.au/	The University of Queensland - Col Lynham
Seismic Research Centre	https://www.src.com.au/	OEM of seismic instruments & software
symCDC	http://symcdc.com/	OEM of seismic instruments & software
IRIS Seismic Monitor	http://ds.iris.edu/seismon/	Global seismic events
Joint Australian Tsunami Warning Centre	http://www.bom.gov.au/tsunami/	Bureau of Meteorology site
Australian Earthquake Engineers Society	https://aees.org.au/	An organisation with similar interests
Atlas of the Underworld	http://www.atlas-of-the-underworld.org/	Mapping the Earth's mantle
Atlas of Living Australia	https://www.ala.org.au/	A Citizen Science initiative