Benchmarking passive seismic estimates of cover-thickness

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Purpose of the study

- Evaluate capabilities of passive seismic methods used for engineering purposes (depth <30 m) to map deep structures up to ~500 m depth.
- Benchmark precision of basement depth determination against known drilling data.
- Establish survey methods and logistic strategies for efficient field campaigns.
Seismic wave propagation from explosion
Shallow strong reflector shadows structures underneath.
Seismic wave propagation from distant source
seismic noise case
Source of the ambient noise

After Boese et al. [2015]
Ambient noise seismology based on assumption of diffuse seismic wavefield
We use two methods: HVSR and SPAC

**HVSR**
Spectral ratio between horizontal and vertical particle movement

**SPAC**
Known Distance/measured time of wave propagation

Discontinuity
Horizontal to Vertical ratio of surface waves
Seismic sensor selection – broad band?

- Broad-Band 120 sec
- Short Passive 0.22 sec
- Short Active 1 sec
High distortion
That could correspond to the error of \(~30\) m.

Peak HVSR = \(\frac{V_s}{4H}\)
Why so many stations?
Seismic Array configurations

Map view

Interstation vector

Map view

Interstation vector

E-W array element offset, m

Azimuth, deg

E-W array element offset, m

Azimuth, deg

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Example of SPAC processing
Example of recorder timing error

Ring 4: 166–186 m

Ring 8: 169.2–187.4 m
However some ambient noise sources can pose problems such as wind at the site

Wind speeds

Coughlin and Harms [2012]
H/V stabilization occurs after ~3 hours
Effect of wind on H/V survey (15 hours)
Ability to probe below the surface reflectors
Density measurements are important
Testing confidence limits

99.7% of the data are within 3 standard deviations of the mean.
95% within 2 standard deviations.
68% within 1 standard deviation.
Sources of uncertainty

• Our results are not direct measurements but process of non-linear multi-dimensional fitting

• Measurement errors are multisource: “unwanted” noise and instrumental

• Theory approximation error

• Measurement error propagation into parameter space can not be reliably estimated

• Benchmarking against known drilling logs give us an estimate that interface depth can be recovered with an error of 10–20%
Comparison to the drill log depth to the basement

(a) HVSR depth, m
(b) SPAC depth, m
(c) Joint HVSR and SPAC depth, m

Drilled depth, m

n=10
n=10
n=8
How can we improve our results?

- Accurate measurements and account for unwanted noise such as weather effects over seismic station
- Realistic physical models
- More sophisticated inversion strategies
Realistic physical model

Diffuse field theory vs pure Rayleigh wave approximation
Trans-dimensional inversion algorithm
Pre-defined parameterization of conventional nonlinear inversion

Courtesy of Rhys Hawkins, RSES, ANU
Inversion-driven parameterization
Field work suggestions

- For **benchmarking** spiral arrays are ideal
- If acquiring HVSR data at a single site deploy more than one instrument.
- Instrument response is important, suggest ≥20s instruments.
- Deploy for at least 3 hours
Conclusions

Key findings:

• Application of inversion algorithms provides robust results

• Surprisingly HVSR data seems to provide more information on earth structure than SPAC data at the sites we have tested

Current efforts:

• Implementation of trans-dimensional HVSR & SPAC inversions

• Adoption of realistic multi-mode physical models of wave field into inverse algorithms

• Continuation of benchmarking across the range of Australia’s cover materials
Thank you!

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