Lithospheric scattering and structure beneath seismic arrays from teleseismic P waveforms

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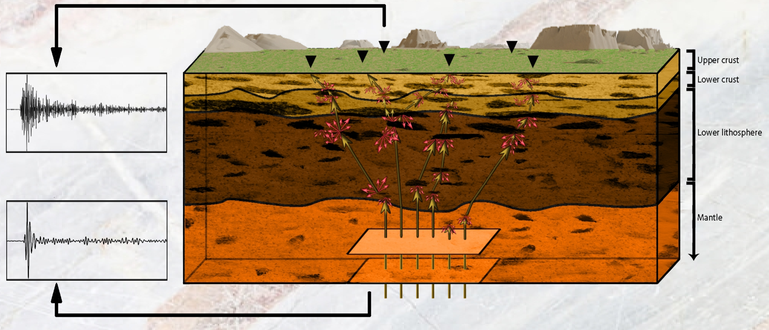
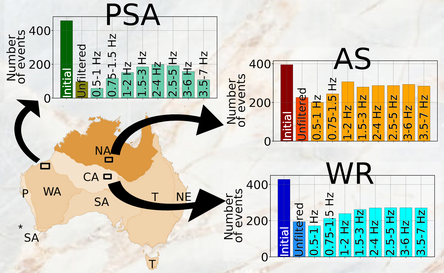
D51-0590

1. Seismic scattering

- Discontinuities and heterogeneities within the Earth's structure reflect, refract and scatter the energy seismic waves carry.
- Inhomogeneities:
  - are more abundant in the crust and upper mantle.
  - the size of the wavelength have the biggest effect on seismic waves.
- Incoherent scattered energy arrives later, and is the origin of seismic codas, whose shapes and amplitudes can vary from station to station.

The object of this study is to determine the stochastic small-scale structure of the lithosphere beneath three seismic arrays, which allows us to quantify scattering strength and compare it with other physical mechanisms that also cause amplitude attenuation in seismic waves.





***MAJOR TECTONIC ELEMENTS**
CA - Central Australia; **NA** – North Australia; **NE** - New England; **P** – Pinjarra; **SA** - South Australia;
T – Tasman (orogenic system/ fold belt); **WA** - Western Australia. Map modified from Shaw, R.D. Wellman, P., Gunn, P., Whitaker, A.J., Tarlowski, C., and Morse, M., 1996, Australian Crustal Elements based on the distribution of geophysical Domains, (1:5 000 000 scale map; version 2.4, ArcGIS dataset). Geoscience Australia, Canberra.

2. Dataset and Methods

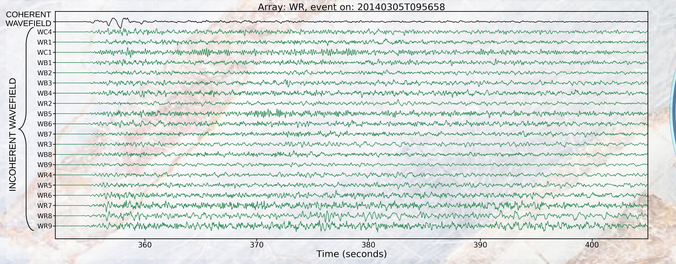
Largest dataset ever used in a study like this. Earthquakes from 2012 to 2017:
●30º to 80º away from the arrays ●200 km minimum depth
●Magnitude 5 to 7

Teleseismic Fluctuation Wavefield Method (TFWM) + Energy Flux Model (EFM) → **Structural parameters:** *Correlation length:* ***a,*** *Velocity variations:* ***ε,*** *Layer thickness:* ***L***

3. Teleseismic Fluctuation Wavefield Method Results

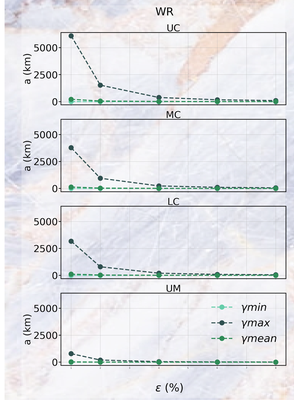
The TFWM uses the ratio between the spectra of the coherent and incoherent wavefields to obtain the structural parameters.
The coherent wavefield is obtained by stacking all the traces for a given event and array. The incoherent wavefield for each station is the subtraction of the coherent wavefield from individual traces.

Coherent vs. Incoherent wavefield



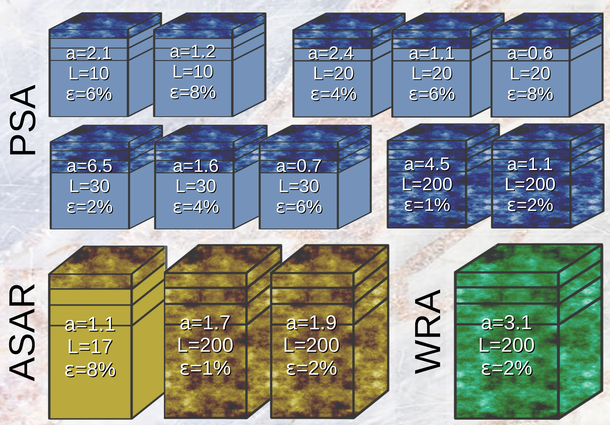
Trade off curves

Correlation length (a) and RMS velocity variations can't be solved separately in the TFWM



Structural parameters values

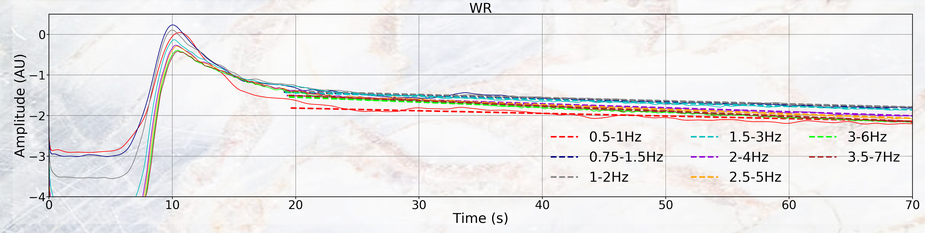
Possible combinations of values of the structural parameters that fit the data for each array. Lengths are given in kilometres.



4. Energy Flux Model Results

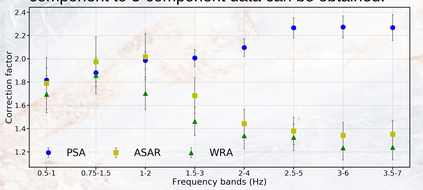
Coda decay fit

A linear function is used to fit the coda decay for each frequency band. A least squares fit of the intercept values allow to obtain scattering Q (Q_s), while the slope ones are used to obtain diffusion and intrinsic Q (Q_{diff}, Q_0).

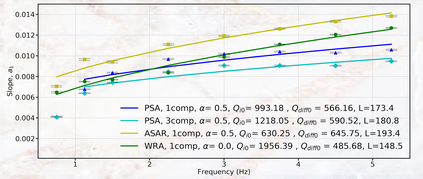


3-to-1 component data correction factor

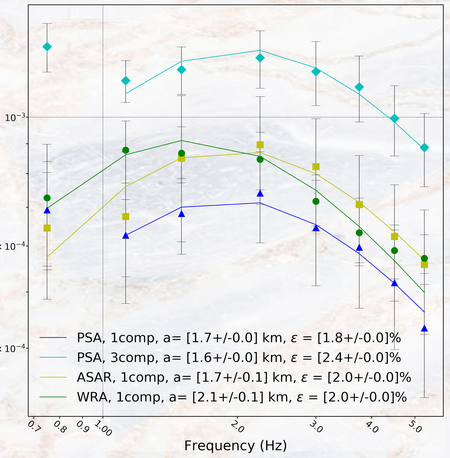
The EFM underestimates the values of the structural parameters when applied to 1-component data. However, a correction factor to convert from 1-component to 3-component data can be obtained.



Diffusion and intrinsic Q

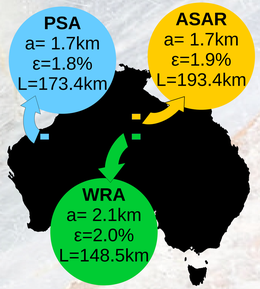


Scattering Q



5. Conclusions

- The structural parameters for all three arrays are similar and in agreement between the two applied methods. They suggest scattering is the main cause of amplitude attenuation of seismic waves and that the lithosphere is the largest contributor of scattered energy for all three arrays.
- The EFM is not able to resolve changes in a multi-layer scattering medium. We will apply a modified Energy Flux model (Korn, 1997) to these data to resolve the differences in crustal heterogeneities.



References: **1. Shapiro, S.A. and Kneib, G., 1993.** Seismic attenuation by scattering: theory and numerical results. Geophysical Journal International, 114(2), pp.373-391. **2. Korn, M., 1990.** A modified energy flux model for lithospheric scattering of teleseismic body waves. Geophysical Journal International, 102(1), pp.165-175. **3. Korn, M., 1997.** Modelling the teleseismic P coda envelope: depth dependent scattering and deterministic structure. Physics of the earth and planetary interiors, 104(1-3), pp.23-36.