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Lithospheric scattering and structure beneath seismic arrays from teleseismic P waveforms

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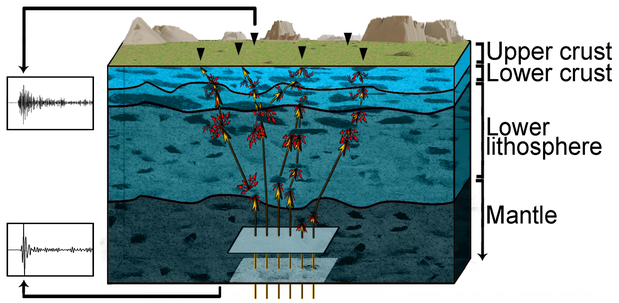
Seismic scattering

Discontinuities and heterogeneities within the Earth's structure reflect, refract and scatter the energy seismic waves carry, thus being the origin of seismic codas.

Inhomogeneities:

- are more abundant in the crust and upper mantle.
- the size of the wavelength have the biggest effect on seismic waves.

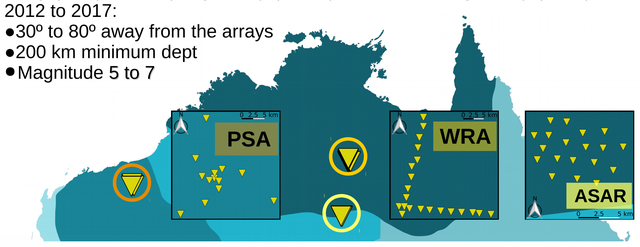
The object of this study is determine the stochastic small-scale structure of the lithosphere beneath three seismic arrays, which allows us to quantify scattering strength and compare it with other physical phenomena that also cause amplitude attenuation in seismic waves.



Dataset and Methods

Largest dataset ever used in a study like this.
Earthquakes recorded at three Australian seismic arrays (Pilbara Seismic Array (PSA), Alice Springs Array (ASAR) and Warramunga Array (WRA) from 2012 to 2017:

- 30º to 80º away from the arrays
- 200 km minimum dept
- Magnitude 5 to 7



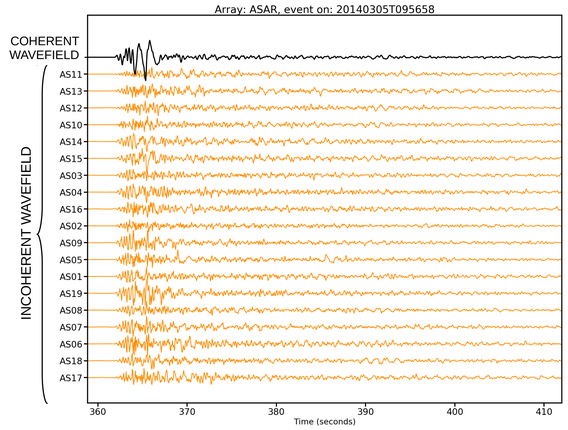
Teleseismic Fluctuation Wavefield Method (TFWM)

Energy Flux Model (EFM)

Structural parameters:
Correlation length: **a**
Velocity variations: **ε**

Teleseismic Fluctuation Wavefield Method

Coherent vs. Incoherent wavefield



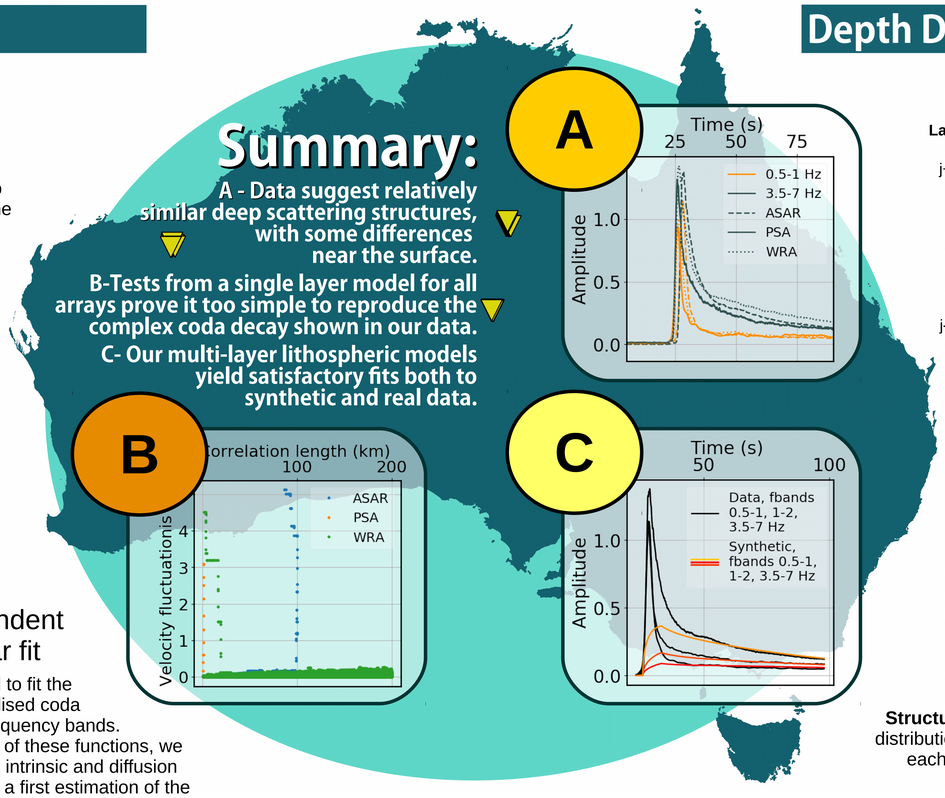
The TFWM uses the ratio between the spectra of the coherent and incoherent wavefields to obtain the structural parameters. The coherent wavefield is obtained by stacking all the traces for a given event and array. The incoherent wavefield for each station is the subtraction of the coherent wavefield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

Summary:

A - Data suggest relatively similar deep scattering structures, with some differences near the surface.

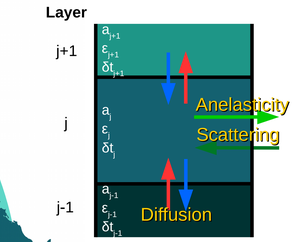
B-Tests from a single layer model for all arrays prove it too simple to reproduce the complex coda decay shown in our data.

C- Our multi-layer lithospheric models yield satisfactory fits both to synthetic and real data.



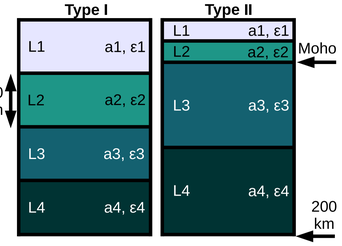
Depth Dependent Energy Flux Model

Energy flux

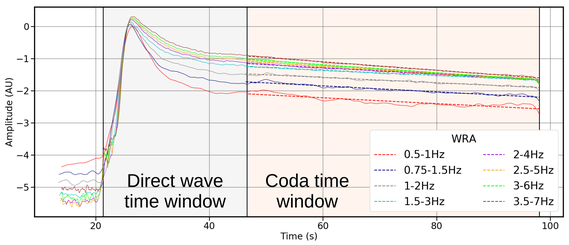


Lithospheric models

Model type I, with four equally thick layers, allows us to compare lithospheric scattering structures for all arrays. Model type II, on the other hand, can be used to obtain the specific scattering structures for each array.

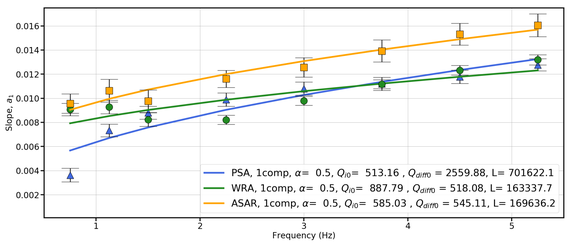


Energy Flux Model



Frequency dependent coda decay linear fit

Linear functions are used to fit the coda decay of the normalised coda envelopes for all eight frequency bands. From the two coefficients of these functions, we can obtain the scattering, intrinsic and diffusion quality factors, as well as a first estimation of the values of the structural parameters and thickness of the scattering layer.

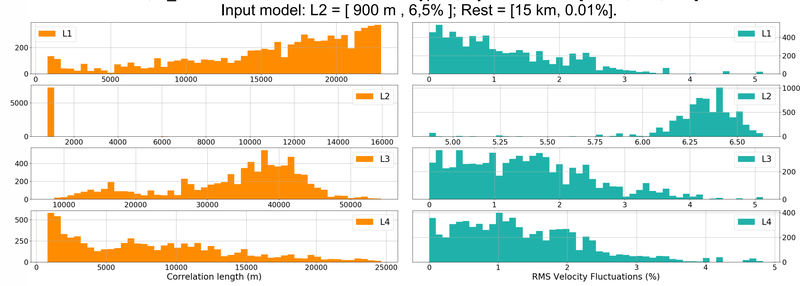


Scattering, diffusion and intrinsic quality factors

The EFM developed by Korn (1990) gives us an estimation of both the diffusion and intrinsic (anelastic) quality factors, as well as the scattering quality factor. By comparing these three values, we can evaluate the magnitude of the impact each one of these mechanisms has on seismic waves. We use the intrinsic quality factor as an input for the depth-dependent EFM, as diffusion is implicit and we invert for scattering Q values.

Synthetic tests results

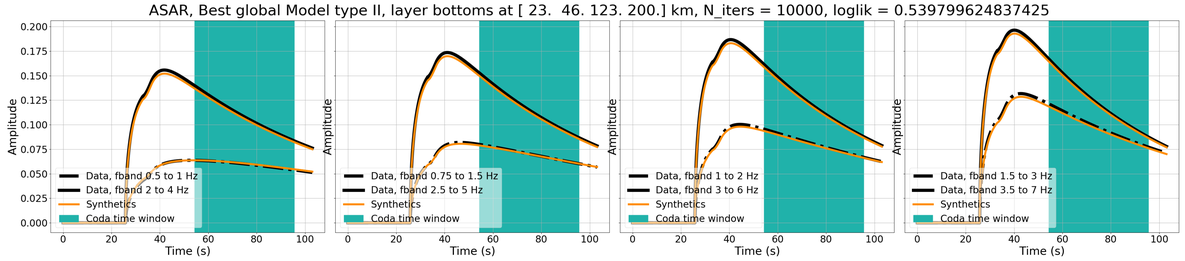
ASAR, N_iters = 10000, 74.12% A.R., Model type II, layer bottoms at [23, 46, 123, 200] km.
Input model: L2 = [900 m , 6,5%]; Rest = [15 km, 0.01%].



Structural parameters calculation. A Bayesian inversion allowed us to sample the posterior probability distribution for each parameter and model layer. Parameters were updated randomly and the likelihood of each new model of explaining the data was compared with the one from the last accepted model, in a Markov Chain Monte Carlo fashion.

Normalised coda envelope fitting

ASAR, Best global Model type II, layer bottoms at [23. 46. 123. 200.] km, N_iters = 10000, loglik = 0.539799624837425



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.

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