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Small-scale lithospheric heterogeneity characterization using Bayesian inference

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Heterogeneities on the scale of the seismic wavelength in the Earth's crust and mantle cause complex wavefield fluctuations in time and amplitude which are known to affect velocity and source inversions, as well as other seismic characterisations. However, many seismic models ignore these heterogeneities for simplicity. As part of our longer-term goal to account for these, we attempt to rigorously and probabilistically characterise these lithospheric small-scale heterogeneities by combining a single-layer and a multi-layer energy flux models with a new Bayesian inference algorithm. The first technique characterizes energy losses to the ballistic arrival as intrinsic, diffusion and scattering quality factors, which allows us to compare the effects of these attenuation mechanisms on our data. With the second method, we can obtain synthetic coda envelopes for 1- and 2- layer models with different values of the correlation length and fractional velocity fluctuations in each layer. We then use the Metropolis-Hastings algorithm to sample the likelihood space and obtain the posterior probability distributions for each parameter and layer in the model. Our thorough testing of these methods reveals complicated trade-offs between the parameters and highly non-unique solutions, thus highlighting the importance of the Bayesian approach for scattering studies. Previous studies applying these methods used a more traditional grid search for their coda inversion, which may have affected their results. We applied this approach to a data set of over 300 events from three seismic arrays in Australia: Alice Springs array (ASAR), Warramunga Array (WRA) and Pilbara Seismic Array (PSA). The results from the single-layer energy flux model show that all quality factors take higher values for PSA than for the other two arrays, indicating that the structure beneath this array is less attenuating and heterogeneous than for the other arrays. Intrinsic and diffusion attenuation are strongest for ASAR, while scattering and total attenuation are similarly strong for ASAR and WRA. Our multi-layer model results show the crust is more heterogeneous than the lithospheric mantle for all arrays, with crustal values of the correlation length and velocity fluctuations being lower for PSA than for the other arrays, indicating the presence of weaker and smaller scale heterogeneity beneath this array. We attribute these differences and similarities in the attenuation and heterogeneity structure beneath the arrays to variations in the tectonic history of the areas they are located on. This new Bayesian approach to the multi-layer energy flux model, in combination with the single-layer model, not only allows us to determine and compare the different quality factors, but also gives us detailed information about the trade-offs and uncertainties in the determination of the

scattering parameters, making it a useful tool for future scattering and small-scale structure studies.