Solid Earth
Discussions

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Interactive
comment

Interactive comment on "The relative contributions of scattering and viscoelasticity to the attenuation of S waves in Earth's mantle" *by* Susini deSilva and Vernon F. Cormier

Susini deSilva and Vernon F. Cormier

vernon.cormier@uconn.edu

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Reviewer: Does the 2D analysis of the wave propagation bias the estimated intensity of scattering by ignoring scattering into and out of the plane of the calculation?

Few tests of 2-D vs 3-D scattering effects exist. Wu and Irving (GJI, 2017, doi: 10.1093/gji/ggx047), who compared 3-D to 2.5D numerical simulations, show an example test. Their 2.5D simulations do not remove the energy of out-of-plane scattering, but they did not find significant differences between the simulations for smoothed PKiKP coda.

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Discussion paper

At any given velocity and density perturbation, however, 3-D scattering in principle should remove more energy from the direct arriving pulse than 2-D scattering in a plane containing the source, receiver, and center of the earth. Thus the assumption of 2-D scattering at a given perturbation level will potentially overestimate the true perturbation level needed to produce that apparent attenuation. Any overestimate of the perturbation level just reinforces our conclusion that intrinsic attenuation is also needed to explain the observed apparent attenuation combined with coda levels.

Reviewer: To what degree are the results of this analysis influenced by the assumption of constant Q within the absorption band, rather than the mild frequency dependence (Q f 1/3) consistently revealed by laboratory studies?

Resolving the frequency dependence of intrinsic attenuation from seismic data is a notoriously difficult problem, complicated by depth dependence, and the need to compare observations over a very frequency broad band. Using observations of free-oscillations low frequency surface waves (0.001 to 0.005 Hz), a study by Lekic et al. (EPSL, 2009, doi:10.1016/j.epsl.2009.03.030) found a power of 0.3 frequency dependence of Qs, diminishing to 0 as frequency increased. A body wave study by Choy and Cormier (JGR, 1986, doi: 10.1029/JB091iB07p07326) found small or no frequency dependence of attenuation in the upper and lowermost mantle but attenuation decreasing with frequency as a power of -1 above a corner frequency in the mid-mantle. The frequency band of our observations and simulations, however, is too narrow (0.01 to 0.25 Hz) to observe a difference between the effects of a power of 0 or - 0.3 for the frequency dependence of attenuation (1/Q). Our study also did not consider the complication of depth dependent changes in the shape of the relaxation spectrum, which would require both multiple S and ScS observations over a series of ranges

Reviewer: How was the thermodynamic model of mantle heterogeneity derived? In particular, what range of variability of chemical composition and temperature was allowed?

Except for a peak in heterogeneity power associated with a post-perovskite phase change in the lowermost mantle our test "maximum plausible" heterogeneity model was derived from a study of P wave coherence beneath the USArray (Cormier et al., Commun. Comp. Phys., preprint, doi: 10.4208/cicp.OA-2018-0079) , assuming dlnVs/dlnVp = 2. The peaks in the heterogeneity model inferred from P wave coherence closely coincide with predictions from thermodynamic models by Stixrude and Lithgow-Bertelloni, with which we were initially surprised. These thermodynamic models considered a range of mantle compositions and mixing scenarios. Details are given in several of their papers. Models of mantle compositions included both pyrolite and depleted MORB mantle, assumed both mechanical mixing and equilibrium assemblages, and considered variations in potential temperature between 1000 to 2000 deg K. Most of the differences between the models were their predictions for 1-D averages of mantle seismic velocities. There were not large differences between models for the size and position of predicted peaks of heterogeneity power at different depths, which are most important to seismic scattering.

Reviewer: What is the explanation for the conclusion that the heterogeneity from the tomographic wavespeed model is insufficient to explain the amplitude of the ScS coda? Does this potentially reflect the fact that spatial smoothing tends to mean that the amplitudes of wavespeed anomalies are underestimated?

The heterogeneity power in these models is too weak to explain the observed ScS coda power even when we assumed a white spectrum between the scale lengths (>200 km) they can resolve and the scale length corresponding to the smallest scale (25 km) that will produce significant scattering the frequency pass band we observed and modeled. Yes, images from global tomography underestimate wavespeed anomalies by smoothing fluctuations in travel time picks. These fluctuations are due to a combination of picking errors and the effects of unresolvable small-scale structure observed over paths limited in spatial density. Regularizing parameters in tomographic inversion damps these fluctuations. To explain multi-pathing that has been observed in

body waveforms some studies have multiplied the velocity perturbations in large-scale structures imaged by tomograms by factors up to 2 to explain the observed waveform complexity (e.g., Romanowicz et al., EPSL 233, 137-153, 2005).

C4