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Can 3-D thermal and chemical structure bias 1-D seismic velocity profiles?

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Quantitative interpretation of seismic velocities in terms of temperature, pressure and composition can help our understanding of mantle dynamics. As the Earth is to a good first approximation spherically symmetric, seismic velocities are usually solved relative to a 1-D reference model. For interpretation, it is then assumed that the seismic reference corresponds to the mantle's average radial physical structure. However, it is not clear that this is valid.

Here we use forward spherical models of thermal and thermo-chemical mantle convection, to investigate whether 3-D variations in temperature, pressure, or chemistry can result in seismic reference profiles biased away from the physical reference profile. The physical structures of the convection models are converted into synthetic seismic structure by calculating elastic and anelastic parameters as a function of temperature, pressure, composition, phase. Averaged radial seismic profiles are compared with the seismic velocities calculated from the average radial physical structure.

In models of purely thermally-driven mantle convection, averaged seismic structure and seismic velocities of the physical average mostly correspond closely. Just in the upper 100-200 km, the effect of anelasticity means that the average radial velocities are biased by hot regions of the mantle. In addition, 3-D topography on major phase transitions causes localized anomalies. Furthermore, we find it is important to account for the radial gradient in dynamic pressure when calculating seismic velocities, even though dynamic pressure is only a small perturbation from the lithostatic background. To test the effect of variable seismic resolution, our synthetic seismic structures will be convolved with the resolution filter of global shear-wave models S20RTS and S40RTS.