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Velocity gradients in the Earth's upper mantle: insights from higher mode surface waves

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The majority of seismic tomographic models of the uppermost mantle beneath Precambrian regions show a positive velocity gradient from the Moho to depths of around 100 km. It is becoming increasingly well recognised that this gradient is not readily compatible with simple models of a craton with constant composition and a steady-state geotherm and more complex compositional variations are invoked to explain this feature.
At these depths most of the models are dominated by data from fundamental mode surface waves, and the combination of the sensitivity kernels alongside the choice of model parameterisation means that the velocity gradient could be an artefact of the particular inversion. Indeed, recent work using thermodynamically consistent velocity models suggests that in some cases there is not a requirement of this style of gradient.
We investigate this aspect of the mantle structure further by returning to the Sa phase. This phase can be considered as the build up of a wave packet due to the overlapping group velocities of higher modes at periods of around 8 – 30 s. Using the Australian shield as a test-case we compare waveforms built from three different styles of velocity model. Firstly, the 1D model AU3 (Gaherty & Jordan, 1995) which did incorporate the Sa phase as part of the waveform in their modelling. Secondly, recent tomographic models of the Australian continent are used, which include no a priori information from the phase. Thirdly, a thermodynamically consistent velocity model that fits the broad dispersion characteristics of the tomography is tested. Finally, these synthetic waveforms are compared to real data crossing the Australian shield.
The results illustrate small, but clear, variations in waveform dependent on the velocity structure. Complicating factors in any analysis involve the importance of having good knowledge of the crustal structure and a very accurate source depth (particularly if this is similar to the average crustal thickness).