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# Sensitivity analysis of seismic waveforms to upper-mantle discontinuities using the adjoint method

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Using the spectral element method, we investigated the sensitivity of transversely recorded seismic waveforms to upper-mantle discontinuities in 1-D and 3-D background models. These sensitivity kernels or Fréchet derivatives illustrate the spatial sensitivity to particular model parameters, of which the shear wave speed and the surface topography are shown in this paper. We show kernels for consecutive time windows at three characteristic epicentral distances. *SS* precursors in the distance range of 110-160 degrees have frequently been used to infer the topography of upper mantle discontinuities. This distance range is chosen to minimise the interference from other waves. From our simulations we can draw three main conclusions: i) Our exact Fréchet derivatives show that there is always interference from other waves, which explains the difficulty reported in the literature to correct for 3-D elastic structure, even if it is perfectly well known. ii) All studies to date assume that travel times of precursors can be linearly decomposed into a 3-D elastic and a topography part. We recently showed that such a linear decomposition is not possible for *SS* precursors, and the sensitivity kernels presented in this paper explain why. iii) We show that other parts of the seismograms have far more sensitivity to upper-mantle discontinuities than *SS* precursors, especially multiply bouncing *S* waves exploiting the *S*-wave triplications due to the mantle transition zone.