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Mode Coupling of Surface Waves: Evidence of Occurrence and Impact on Surface Waveform Inversions

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We investigate the surface wave mode coupling problem in terms of actual energy transfer from one overtone branch to another due to scattering by lateral heterogeneities in Earth structure. Focusing on surface waves in the period range 15-50 seconds, a series of synthetic tests for the 2D case are conducted wherein a single heterogeneity embedded in a 1D background model is illuminated by a single mode and the wavefield in the far field from the heterogeneity is analysed. The scattered wavefield is decomposed into its constituent modes by projecting it onto the modal eigenfunctions of the background model. This allows the calculation of mode participation factors which indicate the contribution of each mode to the total wavefield, and which are corroborated by a simple energy conservation constraint. We also extract dispersion curves for the individual mode branches using a frequency domain slant stack method. The dispersion curves obtained are in excellent agreement with the modal content of the wavefield as inferred from the mode participation factors. We perform this analysis separately for Love and Rayleigh waves on the incidence side, and find that in each case there is strong scattering into modes up to two branches away, for heterogeneities of the order of 5-10% over the background structure. These results are compared with predictions by Maupin's (2001) multiple-scattering scheme for modelling surface wave propagation in three dimensional structures. By using different classes of heterogeneity in our simulations we identify the frequencies at which mode coupling becomes negligible. Finally, for the frequencies at which mode coupling is not negligible, we demonstrate the perils of using a mode-summation based inversion scheme to invert surface waveforms for path average shear velocity structure.