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Full Waveform Inversion in the Time-Frequency Domain with Applications to the Australian upper Mantle

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We present a novel approach to full waveform tomography based on misfits in the time-frequency domain and adjoint methods. Our focus is on theoretical developments and synthetic inversions for heterogeneities in the Australian upper mantle.

The centrepieces of our methodology are envelope and instantaneous phase misfits defined on time-frequency transforms of the seismograms. These misfits allow us to extract the maximum robust information from seismograms for the purpose of high-resolution tomography.

We derive Fréchet kernels for different definitions of the envelope and phase misfits using adjoint methods. Only in the special – though unrealistic – case of monochromatic waves the Fréchet kernels for instantaneous phase measurements coincide with those obtained from waveform cross-correlation. Examples of Fréchet kernels for data collected during the SKIPPY project are computed by means of a recently developed spectral element method.

Since our final objective is a full waveform tomography for upper mantle structure under Australia, we intensively study synthetic inversions. We demonstrate that lateral heterogeneities can be determined efficiently by using instantaneous phase measurements of S waves and surface wave trains without explicitly dissecting the seismograms. Special attention is given to the following questions relating to the inversion, i.e., the misfit minimisation algorithm: 1) determination of the optimal step length for

gradient methods, 2) acceptance/rejection criteria for the updated models and 3) the pre-conditioning of the steepest descent direction. Finally, we examine the possibility of using enevelope or amplitude measurements and their corresponding Fréchet kernels for seismic waveform tomography.