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Effects of Surface Scattering in Waveform Inversion

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In full waveform inversion of seismic body waves, the free surface is often ignored on grounds of computational efficiency. We perform a synthetic study to investigate the effects of this simplification. In terms of size and frequency our test model and data conform to a real long-offset survey of the upper crust across the San Andreas Fault. Random fractal variations are superimposed on a background model with strong lateral and vertical velocity variations ranging from 1200 to 6500 m/s. We compute and invert synthetic data for this model and different topographies. We use a fully elastic time-domain image method code to synthesize the seismograms, and a visco-acoustic frequency-domain code to invert them. Our results show that the loss of resolution from neglecting the free surface in the inversion is not very significant when compared to other approximations and sources of error, particularly when the subsurface structure is dominated by spatial gradients. In contrast, if the subsurface contains major discontinuities that give rise to coherent multiples and reverberations, the inversion becomes more sensitive to modeling the free surface. In addition, non-linearity and sensitivity to erroneous attenuation increase. Surprisingly, the loss of resolution from neglecting the free surface is smaller when the topography is irregular. We explain this by the fact that a rough surface strongly affects the coherency of multiples.