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FULL WAVEFORM TOMOGRAPHY FOR SEISMIC VELOCITY AND ANELASTIC LOSSES IN HETEROGENEOUS STRUCTURES INCLUDING MODEL UNCERTAINTY

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ABSTRACT

We present a least squares optimization method for solving the nonlinear full waveform inverse problem of determining the crustal velocity and intrinsic attenuation properties of sedimentary valleys in earthquake-prone regions. Given a known earthquake source, and a set of seismograms generated by the source, the inverse problem is to reconstruct the anelastic properties of a heterogeneous medium with possibly discontinuous wave velocities. We formulate the inverse problem as a constrained optimization problem where the constraints are the partial and the ordinary differential equations describing the anelastic wave propagation from the source to the receivers.

We employ a wave propagation model in which the intrinsic energy-dissipating nature of the soil medium is modeled by a set of standard linear solids. We encounter the usual two problems inherent issues in inverse wave propagation schemes: rank deficiency and multiple minima. To overcome rank deficiency and ill-posedness, we include total variation regularization functional in the objective function, which annihilates highly-oscillatory material property components while preserving discontinuities in the medium. To treat multiple minima, we use a multilevel algorithm that solves a sequence of subproblems on increasingly finer grids with increasingly higher frequency source components to remain within the basin of attraction of the global minimum.

We initially assume that no information is available on the target shear wave velocity distribution, and begin the inversion process with a homogeneous shear wave velocity profile as the initial guess. In practice, however, some information on the target wave velocity distribution is usually available. To treat such cases, we modify our nonlinear inversion method to start from an initial velocity model, by including a-priori information regarding the initial model parameters in the misfit (objective) function. To represent model uncertainties, given an initial velocity model, in addition to the data

misfit term in our objective function, we include an L2-normed weighting term, which quantifies the model estimation errors, independently of the measured data.

We illustrate the methodology with pseudo-observed data from two-dimensional sedimentary models of the San Fernando Valley, using a source model with an antiplane slip function.

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