ADJOINT-BASED INVERSION FOR STRESS AND FRICTIONAL PARAMETERS IN EARTHQUAKE MODELING

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We present an adjoint-based inversion method for stress and frictional parameters in earthquake modeling. The forward problem is linear elastodynamics with nonlinear rate-and-state frictional faults. The misfit functional quantifies the difference between simulated and measured displacements/velocities at receiver locations and may include windowing or filtering operators. We derive the corresponding adjoint problem, which is linear elasticity with linearized rate-and-state friction with time-dependent coefficients derived from the forward solution. The gradient of the misfit is efficiently computed by convolving forward and adjoint variables on the fault. The method thus extends the framework of full-waveform inversion to include rate-and-state frictional faults.

Additionally, we present a dual-consistent discretization of a dynamic rupture problem with a rough fault in antiplane shear, using high-order accurate summation-by-parts finite differences in combination with explicit Runge–Kutta time integration. The dual consistency of the discretization ensures that the discrete adjoint-based gradient is the exact gradient of the discrete misfit functional as well as a consistent approximation of the continuous gradient. Our theoretical results are corroborated by inversions with synthetic data. Figure 1 present results inverting for the direct effect parameter, showing that it is well-constrained within slipped parts of the fault, but unconstrained outside. Similar results hold for initial fault stress. We anticipate that adjoint-based inversion of seismic and/or geodetic data will be a powerful tool for studying earthquake source processes; it can also be used to interpret laboratory friction experiments.

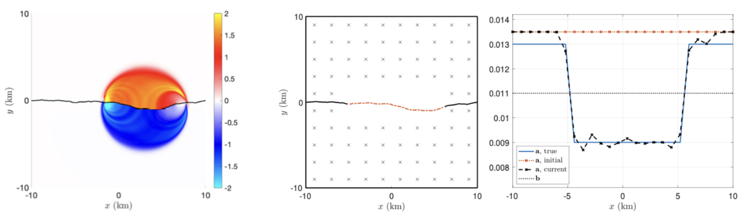

Figure 1: **Left:** Snapshot of high-resolution forward velocity wavefield. **Center**: Receiver locations ($\times$) and unstable part of fault ($--$). **Right**: Direct effect parameter $\mathbf{a}$ after 200 optimization iterations in an inverse crime setting. State evolution parameter $\mathbf{b}$ indicates velocity-weakening ($\mathbf{a}-\mathbf{b}<0$) and velocity-strengthening ($\mathbf{a}-\mathbf{b}>0$) regions.