ShakeOut: 1 Hz Ground Motion Simulations for the Southern San Andreas Fault

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Objective

Compute 0-1 Hz ground motion from the M7.8 kinematic SoSAFE (Southern San Andreas Fault Evaluation) ShakeOut scenario.

ShakeOut Scenario

The M7.8 ShakeOut rupture scenario initiates near Bombay Beach by the Salton Sea and propagates unilaterally 300 km toward the northwest up to near Lake Hughes.

ShakeOut Velocity Model

A 600 km by 300 km by 80 km area from the CMU etree representation of the SCEC Community Velocity Model (CME) version 4 was extracted at a constant grid spacing of 100 m into 14.4 billion grid points. The lowest S-wave velocity was truncated at 500 m/s, and Qp and Qs values were based on the Qp-Vp and Qp-Vp regression formulas by Brocher (2006).

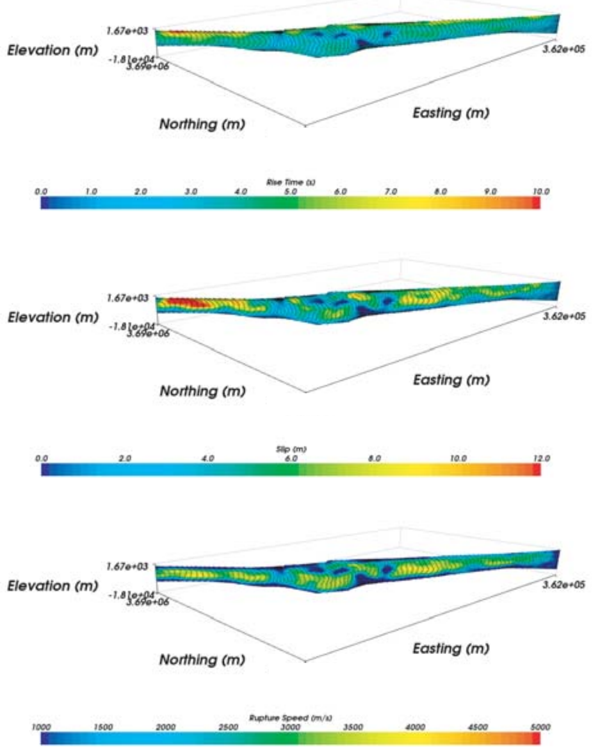
ShakeOut Source Description

The source description (Aagaard) contains slip that combines a long length scale background distribution with short length scale random variations, and a spatially-variable distribution of rake, rise time, peak slip rate, and rupture speed. The source is specified on non-planar fault geometry derived from the SCEC Community Fault Model (CFM) version 3 and mapped onto a regular grid.

Location Map

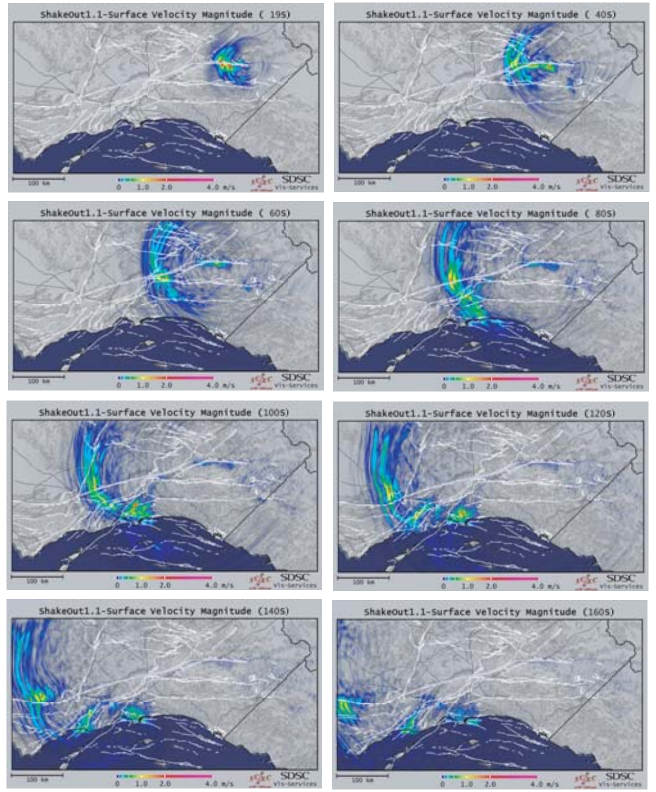
Location map for the ShakeOut simulations. The red rectangle depicts the simulation area (same as for the TeraShake simulations) , which is rotated 40 degrees clockwise from North.

ShakeOut V1.1 Source Characterization



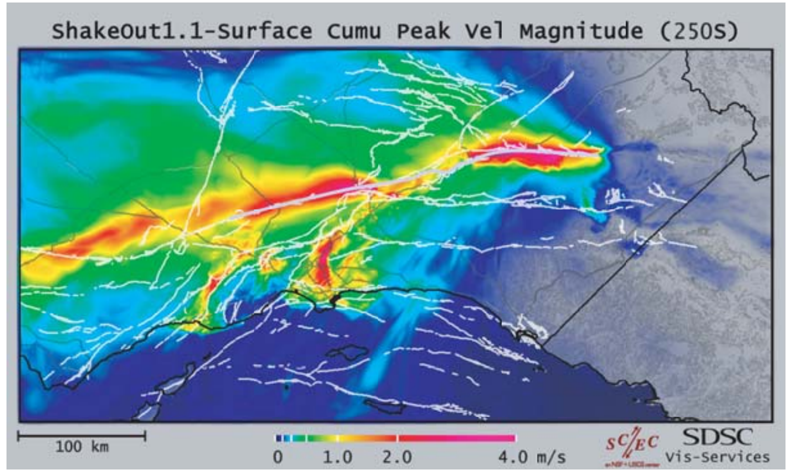
Distributions of (top) risetime, (middle) slip, and (bottom) rupture speed for the ShakeOut V1.1 scenario (from B. Aagaard).

ShakeOut V1.1 Wave Propagation



Snapshots of instantaneous velocity magnitude for the 1 Hz ShakeOut simulation. Notice the strong forward directivity effect, as well as the wave guide effects from the chain of sedimentary basins (the San Bernardino, Chino, San Gabriel, and Los Angeles basins) running westward from the northern terminus of the rupture to downtown Los Angeles. Also notice the multi-pathing effect, where the Puente Hills divides the wave guide up into two branches, with the largest amplification for the northernmost branch.

ShakeOut Peak Ground Motion Pattern



Cumulative peak ground velocities for the ShakeOut simulation. The maximum PGV (root-sum-of squares of the three components) away from the fault (365 cm/s) is generated by the northern wave guide, near Whittier Narrows. The maximum near-fault PGV occurs in the Coachella Valley area (546 cm/s).

Related Efforts: SCEC DynaShake Platform

The kinematic ShakeOut scenario source used here was designed to mimic the expected moment magnitude and the final surface slip distribution resulting from such event. However, the kinematic ShakeOut source is likely one of many models that match these proposed source parameters. To characterize the ensemble of source models that fit the constraints, the SCEC DynaShake Platform has developed a “slip-matching” technique for constraining initial (shear and normal) stress conditions in simulations such that they conform to scenarios defined in this form. The slip-matching method iteratively performs kinematic and dynamic simulations at low resolution to find initial stress distributions that (i) have stochastic irregularities compatible with seismological observations, (ii) satisfy frictional strength limits at shallow depth, (iii) are slip-matched to surface displacement scenarios, and (iv) rupture the full length of the specified scenario. Preliminary results at low resolution show a wide variety of complex rupture patterns, which all closely reproduce the target surface-slip distribution and moment magnitude (Mw 7.8). The models vary greatly in their fault-plane distributions of stress drop, peak slip velocity, final slip and rupture time, even though averages are nearly identical. Once extended to a higher resolution the ensemble of rupture models will be used to simulate wave propagation in theTeraShake/ShakeOut domain, and ground motions will be compared to those from the kinematic source descriptions. These efforts are expected to limit the uncertainty of the ground motions associated with a large earthquake on the southern San Andreas fault.

Preliminary Results

We have simulated 250 s 0-1 Hz ground motion in the SCEC CVM V4.0 for the SoSAFE ShakeOut V1.1 scenario in a 600 km by 300 km area of southern California. The wave propagation shows strong amplification effects in the basin areas, including the Salton Trough, Los Angeles and Ventura. The ground motions are strongly focused in the direction of rupture. Similarly to the results of the TeraShake simulations, this rupture directivity effect is dramatically modified by interactions with the chain of sedimentary basins (the San Bernardino, Chino, San Gabriel, and Los Angeles basins) running westward from the northern terminus of the rupture to downtown Los Angeles. This chain of basins forms a low-velocity structure that acts as a waveguide, trapping seismic energy along the southern edge of the San Bernardino and San Gabriel Mountains and channeling it into the Los Angeles region. Also similarly to the TeraShake results the Love waves are wrapped around the Puente Hills, channeling seismic energy not just into the Whittier Narrows area, but also into the southern part of the LA basin (see snapshots of the instantaneous velocity magnitude). This multi-pathing effect separates the seismic energy into two branches, with the (northern) wave guide through Whittier Narrows generating the strongest amplification. The maximum PGV (root-sum-of squares of the three components) away from the fault (365 cm/s) is generated by the northern wave guide, near Whittier Narrows. The maximum near-fault PGV occurs in the Coachella Valley area (546 cm/s).

Computational Aspects

We used the Olsen-AWM (fourth-order staggered-grid finite-difference method) for the ShakeOut simulation. The Olsen-AWM is parallellized using Message-Passing-Interface (MPI) and has been optimized large-scale simulations (see scaling figure below). The ShakeOut simulation used 2000 TACC Dell linux Lonestar processors and took 58 hours to compute 250 seconds of wave propagation. The pre-processing input partition was carried out on the SDSC IBM Datastar p655 nodes. Approximately 1 Terabyte of surface synthetics was generated by the simulation.