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# QUANTIFYING UNCERTAINTIES IN GROUND MOTION SIMULATIONS FOR SCENARIO EARTHQUAKES ON THE HAYWARD-RODGERS CREEK FAULT SYSTEM USING THE USGS 3D VELOCITY MODEL AND REALISTIC PSEUDODYNAMIC RUPTURE MODELS

A. Rodgers, X.-B. Xie

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Arthur Rodgers
*Center for the Study of Imaging and Dynamics of the Earth,*
*University of California Santa Cruz, CA, 95064 and*
*Lawrence Livermore National Laboratory, Livermore, CA 94551, rodgers7@llnl.gov*
and Xiao-Bi Xie
*Institute of Geophysics and Planetary Physics, University of California Santa Cruz, CA,*
*xie@pmc.ucsc.edu*

## RESEARCH OBJECTIVES

This project seeks to compute ground motions for large (M>6.5) scenario earthquakes on the Hayward Fault using realistic pseudodynamic ruptures, the USGS three-dimensional (3D) velocity model and anelastic finite difference simulations on parallel computers. We will attempt to bound ground motions by performing simulations with suites of stochastic rupture models for a given scenario on a given fault segment. The outcome of this effort will provide the average, spread and range of ground motions that can be expected from likely large earthquake scenarios. The resulting ground motions will be based on first-principles calculations and include the effects of slip heterogeneity, fault geometry and directivity, however, they will be band-limited to relatively low-frequency (< 1 Hz).

## APPROACH

Ground motions will be computed with the recently developed *WPP* anelastic wave propagation code (Nilsson et al., 2007). This code computes the seismic response of a 3D seismic model to forcing, including finite ruptures built from a large number of sub-events. The *WPP* code reads the USGS 3D model in parallel using the *cencalvm* software developed by Brad Aagaard. This model was used for ground motion simulations of the 1906 San Francisco earthquake (Aagaard, et al., 2008). We have used the *WPP* code to evaluate the USGS 3D model by modeling broadband waveforms from moderate (M~ 4-5) earthquakes (Rodgers et al. 2008).

Pseudodynamic rupture models will be created using a method and codes developed by Liu et al. (2006). This method creates a suite of rupture models with stochastic variation of the slip, rise-time and rake with correlation properties consistent with dynamic modeling and empirical observations.

## ACCOMPLISHMENTS

This project has only just begun and we have not yet performed ground motion simulations for pseudodynamic ruptures. However, we did recently complete a series of runs using three different models of the January 17, Kobe Japan earthquake. These results were presented at the Fall AGU Meeting (Rodgers et al., 2007). We also ran simulations for two moderate earthquakes (July 20, 2007 M 4.2 Piedmont and October 31, 2007 M 5.6 Alum Rock) and compared the computed seismograms with observations. Results were consistent with our previous study (Rodgers et al., 2008) showing that the USGS model is about 5% too slow on average.

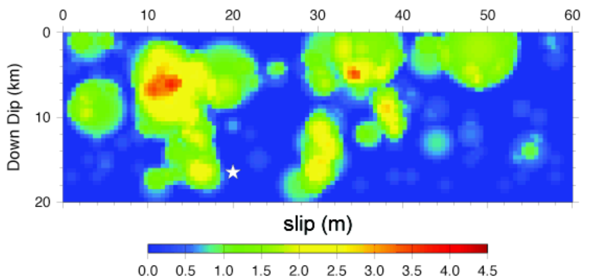


**Figure 1.** Slip model of the January 17, 1995 Kobe earthquake by Zeng and Anderson (2000).

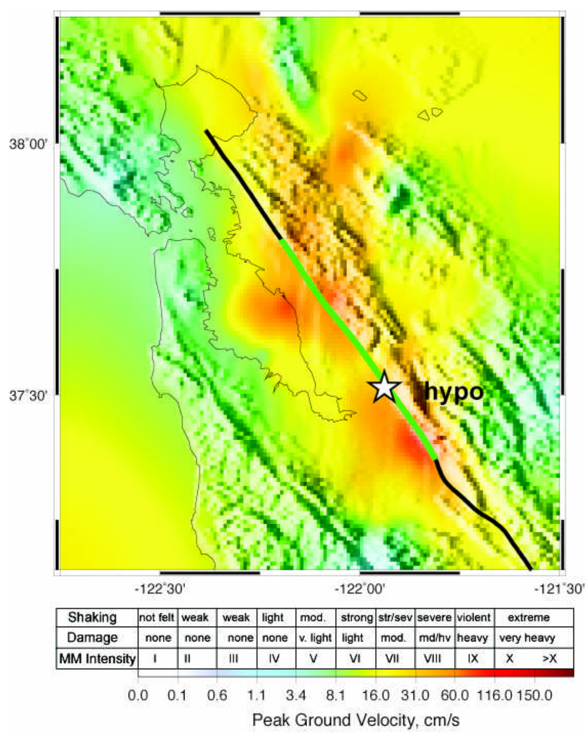


**Figure 2.** ShakeMap based on simulation of M 6.9 earthquake on the Hayward Fault using the rupture model of the Kobe earthquake from Zeng and Anderson (2000). The rupture extends on the green fault segment and the hypocenter is located at the star.

The 1995 Kobe earthquake is a good analog for the Hayward Fault because it occurred on a strike-slip fault with magnitude and fault length comparable to the October 21, 1868 Hayward event. We used three different models of the rupture published by different groups (Wald, 1996; Sekiguchi et al., 2000; and Zeng and Anderson, 2000). Figure 1 shows the slip model reported by Zeng and Anderson (2000), note the two shallow asperities.

This and other rupture models were rendered onto a ~60-km segment of the southern Hayward Fault. Ground motion simulations were performed with 100 m resolution at the surface and numerical accuracy to 0.5 Hz. Figure 2 shows the resulting ShakeMap for the Zeng and Anderson (2000) slip model on the southern Hayward Fault with a southern hypocenter. Note that the ground motions reach MMI values of IX-X, consistent with moderate to heavy damage and reported intensities for the 1868 event. Intense shaking is predicted in the Evergreen and San Leandro Basins and along the rupture. Shaking away from the rupture is strong to the northeast of the end of the rupture (Berkeley to Pittsburg) and in the Santa Clara and Tri-Valley areas. The other rupture models for the southern Hayward Fault with a southern hypocenter show a similar general pattern but differ in some details because of the different pattern of slip.

## SIGNIFICANCE OF FINDINGS

The Hayward Fault ruptured with a major earthquake on October 21, 1868. This event, estimated to have a magnitude, $M_W$, of approximately 7.0 (e.g. Boatwright and Bundock, 2007). Today the Hayward Fault is surrounded by the densely populated East Bay spanning the urbanized centers from Oakland to San Jose. The damage for a repeat of the 1868 event or similar event can be expected to be catastrophic (EERI, 1996). This fault is currently the most likely fault to experience a major earthquake, with a 27% chance of a magnitude 6.7 or greater event for the thirty-year period 2003-2032

(Working Group on California Earthquake Probabilities, 1999; 2003). This project will provide estimates of the expected ground motion levels and their range as well as ground motion time-series which can be used for evaluation of engineered structures.

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