2006 SCEC Annual Report

Improvements to the SCEC community velocity (CVM-H) and block (CBM) models, and implementation of a Unified Structural Representation (USR)

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TECHNICAL REPORT

Summary
In 2006, we developed and delivered a new version of the SCEC Community Velocity Model (CFM-H version 4.0, Figure 1), which included enhanced descriptions of the Salton Trough and Santa Barbara and Ventura basins (http://structure.harvard.edu/cfm-h/). This new model version has a basement surface compatible with the positions and offsets of major faults represented in the SCEC Community Fault Model (CFM 3.0). Thus, the CFM 3.0 and CVM-H 4.0 represent a unified structural representation, or USR. In addition, we develop a series of new fault representations in the Mohave Desert region, including fault planes that ruptured in the 1992 Landers earthquake. These new fault representations were used to enhance the Mohave region by the SCEC Community Block Model (CBM), which is currently being meshed for the SCEC crustal deformation group in preparation for its use in modeling fault system behavior in southern California.

Figure 1: Perspective view of the SCEC Community Velocity Model (CVM-H 4.0). Significant improvements were made this past year in the structural representations of the Salton Trough and Santa Barbara and Ventura basins. Vp in m/sec shown just below sea level.

CVM-H 4.0
In 2005, this research project provided SCEC with a new Community Velocity Model termed CVM-H, (Süss et al., 2005), that served as an alternative to the longstanding SCEC CVM. The CVM-H is based on tens of thousands of direct velocity measurements from petroleum well and seismic reflection data (e.g., Suess & Shaw, 2003), and includes basin representations constrained by surface geology, seismic profiles, well tops, and gravity modeling. Comparisons of synthetic and observed waveforms in the simulation
studies have demonstrated that the new model (CFM-H) performs well at 2 second and longer periods in the greater Los Angeles basin, where the velocity structure and basin shapes are directly constrained by well and seismic data (Komatitsch et al., 2004). Some other regions of the model, however, did not perform as well (Figure 1), owing to the fact that velocity descriptions in these regions are derived solely from regional tomographic models (Hauksson, 2000) that lack sufficient resolution to simulate ground motions at shorter periods.

This past year, we continued to make improvements to the CVM-H by updating basin representations and velocity parameterizations in the poor performing regions. In particular, we focused on improving the model in the region of the Salton Trough, Santa Barbara basin, and Ventura basin. The new Salton Trough model includes constraints from seismic refraction profiles, gravity modeling, and both oil and geothermal wells. Based on velocity patterns observed in the data, Vp was parameterized as a function of both absolute depth and basin depth. In the Santa Barbara and Ventura basins, our efforts focused on updating the top basement surface and re-calibrating the sediment velocity functions. These improved regional models were combined with the high-resolution Los Angeles basin model and the coarser resolution southern California model of Suess & Shaw, (2003) to form the CVM-H 4.0 (Figure 2).

Figure 2: Perspective view of the SCEC Community Velocity Model (CVM-H 4.0), showing a new version of the contoured basement surface that defines basin shapes.

Through collaboration with Jeroen Tromp at the Caltech Seismological Laboratory, the new CVM-H has been used in a series of earthquake wave-propagation simulations to
assess the impact of the model refinements. Simulation of the 3 November 2002 Mw 4.2 Yorba Linda earthquake demonstrated that the new model provides accurate simulation of strong ground motion amplification effects in the Salton Trough sedimentary basin, offering substantial improvements over previous model versions (Figure 3, Lovely et al., 2006). We are currently in the process of performing other simulations to assess the impact of updates in other regions of the model. Ultimately, enhanced velocity CVM’s will help to improve estimates of strong ground motions resulting from large earthquakes in southern California.

![Figure 3: Maps showing seismograms in and around the Salton Trough from the 3 November 2002 Mw 4.2 Yorba Linda earthquake. Black waveforms represent the recorded data and red waveforms represent the synthetic simulations. The left plot shows simulations using the Los Angeles Basin high-resolution velocity model (Süss and Shaw, 2003) embedded in a regional tomography model (Hauksson, 2000) after Komatitsch et al., 2004); whereas, the right plot shows simulations incorporating the new Salton Trough velocity model in CFM-H 2.0 (Süss et al., 2005) based on the SEM method. The two figures illustrate the improved accuracy of ground motion simulations produced with the new velocity model. Both the data and the synthetic seismograms were subsequently bandpass filtered between 6 and 35 sec with a four-pole two-pass Butterworth filter. (From Lovely et al., 2006).](image)

**SCEC science employing the CVM-H and CVM**

The Community Velocity Models are being used in a variety of SCEC sponsored research projects. These include effort to develop fully 3D, waveform tomographic inversion models of crust and upper mantle structure (Chen et al., 2006; Liu et al., 2006). These studies are able to assess the accuracy of the SCEC CVM’s based on comparisons of observed and synthetic waveforms, and offer the promise of significantly improving the structural representations particularly in regions of poor data control. Moreover, the CVM’s are being used in a series of scenario simulations (e.g., TeraShake; Minster [2004], CyberShake; Callaghan et al., [2006]) to quantify expected strong ground motion that will result from future large earthquakes in southern California. These simulations offer the potential of significantly improving regional seismic hazards assessment, and
through the SCEC Implementation Interface will be used in collaboration with the earthquake engineering community to assess the impacts of expected ground motions on building and structures.

**Refinement of the Community Block Model (CBM)**

In 2004, we developed a Community Block Model (CBM) of southern California, which consists of major fault surfaces from the CFM extrapolated and connected with topographic, base-of-seismicity, and Moho surfaces, to define closed blocks. The CBM is currently being used to generate volumetric meshes that will be employed by SCEC’s Crustal Deformation Modeling Group through 3D quasi-static codes to model crustal motions (Williams et al., 2006). In order to move forward in testing and applying their various deformation codes, the working group has recommended that we develop a new version of the Mohave micro block model that incorporates a detailed representation of the 1992 Landers and 1999 Hector Mine ruptures. We developed this model in 2006 (Figure 4), and continue to improve (smooth and resample) structural elements of the CBM to assist with the meshing process. This model will ultimately serve a variety of studies to examine geodetic and seismologic constraints on pre-, co-, and post-seismic deformation.

![Image of the CBM](image.png)

**Figure 4:** View of a portion of the Mohave region of the CBM, showing original block boundaries in the Landers region (left), and the refined block boundaries based on the more detailed fault representation in CFM 3.0 (right). The green area in the revised model represents a new fault block required to accommodate the Landers rupture trace.
References
Hauksson, E., 2000, Crustal structure and seismicity distribution adjacent to the Pacific and North American plate boundary in southern California, JGR, 105, 13,875-13,903.