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An alternative SCEC community velocity model (CVM) and pathway to a Unified Structural Representation (USR) based on the Community Block Model (CBM)

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TECHNICAL REPORT

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Summary

This past year's efforts were highlighted by the delivery of a new Community Block Model (CBM) and alternative Community Velocity Model (CVM-H) for southern California. CVM-H is a new velocity parameterization based on extensive petroleum well and seismic reflection data (e.g., Suess & Shaw, 2003), and is currently being used by SCEC investigators for numerical simulations of seismic wave propagation to predict strong ground motions (Komatitsch et al., 2004; Olsen et al., 2004 – TeraShake) and other seismology applications. The CBM is a completely new SCEC product, consisting of major fault surfaces from the Community Fault Model (CFM) extrapolated and connected with topographic, base-of-seismicity, and Moho surfaces, to define closed blocks (Figure 1). The CBM is currently being used to generate volumetric meshes that will be used by SCEC's Crustal Deformation Modeling Group through 3D quasi-static codes to model crustal motions. In addition, the CBM will serve as the basis for integrating the SCEC fault (CFM) and property models (CVM, CVM-H) into a Unified Structural Representation.

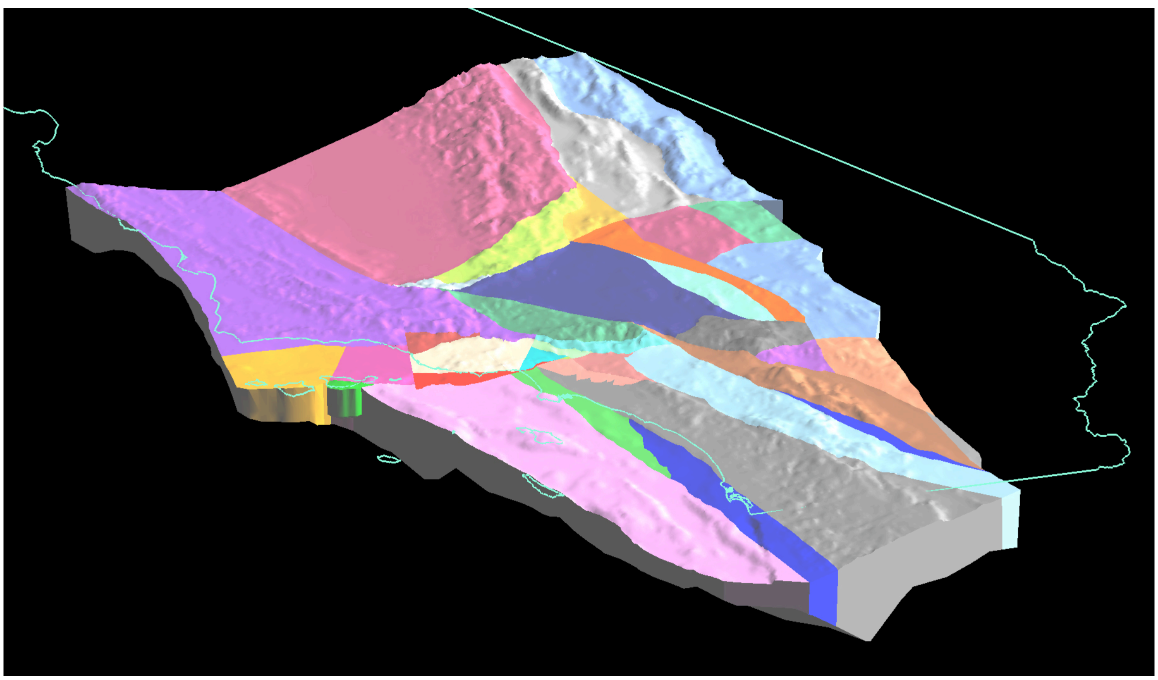

Figure 1: Perspective view of the new SCEC Community Block Model (CBM), which consists of more than 75 tectonic blocks bounded by major faults, derived from the CFM, and regional topography, base-of-seismicity, and Moho surfaces.

Alternative Velocity Model (CVM-H)

The current SCEC Community Velocity Model was developed using a rule-based approach (Magistrale et al., 2001), where velocities in sedimentary basins are specified based on the ages and depths of stratigraphic horizons. Thus, the model consists of a set of stratigraphic horizons (Wright, 1991) and 1-D velocity functions to interpolate velocities between these surfaces. In the Los Angeles and San Fernando basins, these functions have been calibrated using a set of eleven sonic logs. The CVM has been widely used by SCEC researchers in strong ground motion simulations, earthquake relocations, and seismic hazard assessment.

In an unrelated NEHRP-funded effort (1999-2002), the Harvard structure group developed an alternative velocity model of the greater Los Angeles basin. The Harvard model describes three-dimensional velocity (Vp) structure based on a large array of direct velocity measurements, including more than 200 sonic logs, 5 checkshots, 7000 stacking velocities, and 35,000 km of seismic reflection profiles. Sediment velocities were interpolated using a *kriging with trend* approach, where a modeled variogram function of the data was used to define how distributed data points were weighted in interpolating a velocity value for each grid cell. Regional trends observed in the stacking velocity values were used to guide the interpolation of borehole velocities in areas with limited well control. The top basement surface was mapped in the central basin using more than 100 wells that penetrate crystalline rock, and seismic reflection profiles that imaged the basement-sediment interface. The new basement surface roughly corresponds with that of Wright (1991) in areas with dense well control; however, more complex basement structure is resolved in the seismic reflection data across other parts of the basin. The resulting model contains variable grid spacing, with as small as 50 m cells in the shallow sediments and coarser spacing in the deeper sediments and basement. Co-registered Vs and density models were developed based on simple theoretical relations between these parameters and Vp.

In 2004, we made several important upgrades to the Harvard model, including extending its borders to encompass the entire current CVM. We also developed software enabling SCEC users to access the code (http://wacke.harvard.edu:8080/HUSCV/). This tool allows users to populate arbitrary point sets with v_P and derived shear wave velocity and density values. SCEC CME is currently planning the development of a graphical interface for this model.

Community Block Model (CBM)

In 2004, we developed a new three-dimensional description of major fault blocks in southern California, termed a Community Block Model (CBM), in collaboration with Brad Hager (MIT) and the Fault Systems Focus Area Group. The CBM will be used by 3D quasi-static codes for simulating crustal motions, and by codes that simulate earthquake catalogs over multiple rupture cycles. The block model is based on the Community Fault Model (CFM) (http://structure.harvard.edu/cfm). However, unlike the CFM where faults can terminate laterally or at depth in free space, "fault surfaces" in the CBM must extend to connect with other faults or the model boundaries. Extending fault surfaces required careful consideration of geology in order to produce meaningful block representations.

The CBM includes 52 faults that define approximately 100 major fault blocks. The fault blocks are also bounded by topography and bathymetry, and surfaces representing the regional base of seismicity and the Moho. The faults in the CBM are a subset of the more than 120 faults currently comprising the CFM, that were selected based on size, slip rate, and continuity. The completed blocks are defined by closed triangulated surfaces (t-surfs) that precisely fit together without gaps or overlaps. We are in the process of working with the SCEC Crustal Deformation Modeling Group (Gable, 2004) to produce tetrahedral meshes of these CBM volumes. Notably, the block model yielded geometries and topologies that are highly complex and difficult to mesh, even though it considered only a subset of the CFM faults. Working with a Mohave sub-region of the model, we developed a method of re-meshing the original block-bounding surfaces to facilitate their use as a starting point for developing volumetric meshes.

For fault systems studies, nodes within these meshed volumes will be assigned rheologic properties. However, the fault blocks also define volumes in which other properties, such as velocity or density, may be parameterized. Thus, the CBM will also serve as a natural framework for developing the next generation of SCEC property models. Specifically, these new models will employ current (CVM, CVM-H) and future parameterization schemes to populate models (meshes and grids) that defined by the CBM. Because the CBM is based on the CFM, all of the resultant property models will be consistent with the geometries and positions of major faults. Thus, the integration of these property models with the CFM through the CBM will comprise the Unified Structural Representation (USR). The USR Working Group, which held a mini-workshop at the SCEC Annual Meeting, developed a plan to implement this USR, through a flexible software portal that will allow users to access compatible model components (CFM, CVM, and CBM) for designing and populating their own computational grids, meshes, and other models. In effect, this tool will allow users to query the CBM to define the relative position of surfaces, including both faults and major property boundaries, such as the top-of-basement or Moho. This will help in the construction of finite element meshes, and will allows all users to define regions of their grids or meshes where different property models (e.g., CVM, CVM-R, tomographic models) may apply. In this way, users can query the USR to both construct their meshes and grids, as well as to define property (velocity, density) structure using one or a combination of the SCEC suite of alternative velocity and density parameterizations.

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