SCEC Community Fault and Velocity Models

... and how they might contribute to the DCPP seismic hazard assessment

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The SCEC USR is a 3D description of crustal and upper mantle structure in California that integrates many forms of data and model results. Models and supporting datasets are evaluated and vetted by the SCEC community.

The USR serves a broad range of science and hazards assessment efforts, including strong ground motion prediction and PSHA.

The USR consists of
- Community Fault Models (CFM, CFM-R, SCFM)
- Community Velocity Models (CVM, CVM-H)
SCEC Community Velocity Models (CVMS, CVMH)

3D descriptions of velocity and density structure in southern California

- SCEC maintains two model versions (CVM-S 4.0; CVM-H 11.9)
- Basin descriptions are based on constraints from seismic reflection and wellbore data, including tens of thousands of direct velocity measurements.
- Compatible with the CFM
- Includes a refined Moho
- Crust and upper mantle velocity structures are based on travel-time tomography and teleseismic surface wave models, which are then evaluated and enhanced using 3D tomographic waveform inversions
- $V_S30$ based geotechnical layer
Volumetric description of basin sediments

Süss & Shaw (2003)
Basement structure is defined by surface geology, seismic reflection and refraction surveys, wellbore data, and potential field measurements.
Basement structure in the SCEC CVM-H

Basement structure is well resolved in marine seismic reflection data. Example from the Santa Maria basin (McIntosh et al., 1991)
USR in DCPP study area

Basement surface from SCEC CVM-H 11.9.
Basement surfaces in the CVM-H include displacements of major faults represented in the Community Fault Model (CFM).

Basement structure in the SCEC CVM-H

w/o faults

w/ faults

CVM-H (LA basin)
Community Fault Model (CFM)

- 3D triangulated surface representation of active faults in California
- integrates many types of data that constrain fault geometries
- interpolated and extrapolated fault patches
- alternative fault representations

Plesch et al., 2005
Community Fault Model (CFM)

From fault trace and dip

A trace is digitized from a geo-referenced map or assembled from Qfaults and projected to the topographic/bathymetric level.

A length (eg. 2000m) filtered trace is shifted along the dip to a first depth level (eg. 3km), and a coarser trace to a deep level (eg. 10km).

All traces are then connected to a continuous fault surface.

View from below towards the seafloor
Alternatives represent substantially different geometric definitions of a fault surface

Varying degrees of detail ...

Different styles of fault interaction at depth ...

Whittier & Chino faults
Statewide Community Fault Model (SCFM)

- New statewide community model composed for UCERF3
- More than 300 fault representations, both as tsurfs (SCFM) and rectangles (SCFM-R)
- Seismogenic thickness surface as base of model
- Model evaluation through virtual workshop in 2011
SCFM includes 3D representations of major faults in the DCPP study area.
**Sediment Velocity Structure - Industry sonic logs**

**Standard Murphy-Whittier 101**

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**Standard Otto Community #1**

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**Compensated Sonic Log Tool**

- Upper Transmitter
- Receivers
- Lower Transmitter

*after Sheriff (1982)*

Süss & Shaw (2003)
Industry velocity data

- Well with sonic velocities
- Shotpoint with stacking velocities

Map showing industry velocity data with marked wells and shotpoints.
Industry velocity data

- 14,000 log samples
- 72,000 stacking samples

Los Angeles Velocity Model

SP - Sonic velocities

- Stacking Velocities
- Sonic Log Velocities

Depth [m]

Interval Velocities [m/sec]
Velocity measures at different scales

Yellow: model vp
Blue: well vp
Dark blue: log vp (0.5 ft resolution)

Residual: vp of log minus vp in model

Minimum: -882.343
25th percentile: -266.5
Median: -153.99
75th percentile: -50.3627
Maximum: 1486.28
Samples: 16927
Mean: -134.8
Std. deviation: 203.885
Variance: 44051.6
Basin structures embedded in regional tomographic model

CVM-H
- Basin velocities used as input for P and S wave travel-time tomography model (after Hauksson, 2000).
- Defines Vp, Vs, and density to depth of Moho.
Moho and upper mantle models

CVM-H

- Moho is defined using receiver functions, reflection/refraction surveys, and seismologic and potential field studies.

- Upper mantle velocity structure is defined using teleseismic surface wave models (T. Tanimoto).
Adjoint, spectral element method enhancement of CVM-H

Snapshot of a wavefield simulation generated by SPECFEM3D using mesh ECHR with model CVMH6.3. The red regions denote amplification of wavefield due to sedimentary basins.

Various meshes have 5 million to 1 billion elements

1. CVM-H 6.3: three surfaces + volumetric fields

2. Mesh using GEOCUBIT

3. SEM wavefield simulations in SPECFEM3D_SESAME

4. Iterative inversion using adjoint methods

5. Assessment with 300+ validation earthquakes (on-going)
CVM-H 6.3 and subsequent versions include 3D adjoint waveform tomography updates.

Full inversion uses more than 200 events, requiring 6800 wavefield simulations, implemented in 16 tomographic iterations.

6–30 s period
Evaluation of models is moving to higher frequency and precision.

Comparison of recorded data (black traces) and synthetics (red traces) for station RUS representing ‘early’ SCEC validations.

Recent SCEC validations.

Average goodness-of-fit (perfect fit = 100) at 0.1-0.5 Hz for synthetics relative to data.

K. Olsen
USR in DCPP study area

Vp in Santa Maria and Ventura basins (CVM-H 11.9): 0m depth
USR in DCPP study area

Vp in onshore and offshore Santa Maria basin (CVM-H 11.9): 300m depth
USR in DCPP study area

Vp in onshore and offshore Santa Maria basin (CVM-H 11.9): 1000m depth
Potential uses of USR/CVM’s in DCPP seismic hazard analysis

- Precise earthquake relocations
- Seismic reflection data processing
- Provides regional context for integration of local studies
- Model and supporting data can be used in various aspects of deterministic hazards assessment, including strong ground motion calculations.
- Other potential applications…
• Thank you for your attention
Nazareth & Hauksson (2004) use the depth where 99.9% of the total moment in a vertical column was released.

Steps:
- Selection of events
- Gridding and computation
- Filtering of low quality cells
- Smooth interpolation
CFM includes 3D representations of major fault in the DCPP study area.
Depth slices through high-res model

Süss & Shaw (2003)
Lithologic control on velocity

- Vp low in shales
- Vp high in sands
Depositional systems

Basinfloor fan deposits resolved in velocity model of the LA basin
USR in DCPP study area

Vp in onshore and offshore Santa Maria basin (CVM-H 11.9).
USR in SONGS study area

Vp in onshore and offshore Santa Maria basin (CVM-H 11.9)