Introduction

The goal of the UGMS committee, since its inception in the spring of 2013, has been to develop long-period response spectral acceleration maps for the Los Angeles region for inclusion in NEHRP and ASCE 7 Seismic Provisions and in Los Angeles City Building Code. The maps are to be based on 3-D numerical ground-motion simulations, and ground motions computed using latest empirical ground-motion prediction equations from the PEER NGA project. The work of the UGMS committee is being coordinated with (1) the SCEC Ground Motion Simulation Validation Technical Activity Group (GMSV-TAG), (2) other SCEC projects, such as CyberShake and UCERF, and (3) the USGS national seismic hazard mapping project. Significant progress toward developing the maps was made in 2014, and this summary report highlights the accomplishments and future work.

Background and Motivation for Long Period Ground Motion Maps

Section 11.4 in the current ASCE 7-10 (and forthcoming ASCE 7-16) standard specifies a general procedure for developing risk targeted Maximum Considered Earthquake (MCE$_R$) response spectral accelerations at intermediate and long periods. These long period accelerations depend on two parameters, $S_{M1}$ and $T_L$, where $S_{M1}$ is the MCE$_R$ response spectral acceleration at 1-sec period that accounts for the effect of the local site geology through the site coefficient, $F_v$, and $T_L$ is the period that defines the transition in the MCE$_R$ spectrum from constant spectral velocity to constant spectral displacement.

The $T_L$ parameter was introduced in the ASCE 7-05 standard to provide a more realistic estimate of the response spectrum at long periods. The values of $T_L$ vary from 4 sec to 16 sec depending on location in the US. During its development, deficiencies in the $T_L$ concept were recognized, but a better representation of the long period motions was not possible at the time because the existing ground motion prediction equations (GMPEs) did not extend to long periods.

The subsequent NGA West and NGA West2 projects, culminating in 2008 and 2013, produced GMPEs for computing response spectra to 10-sec period from shallow crustal earthquakes in the western US. Although these GMPEs were derived from an extensive world-wide ground-motion database, relatively few truly strong ground motion records in this database were from earthquakes in the Los Angeles area, where the effects of the complex 3-D basin structures were known to have significant influences on long period motions. Furthermore, the earthquakes on the local faults contributing to the MCE$_R$ motions in Los Angeles have not occurred during the last several decades when the region was populated with arrays of strong motion instruments.
The available ground motion data for southern California did suggest a correlation between long period ground motions and basin depth. Thus, NGA West, NGA West2, and a few previous generation GMPEs incorporated a basin depth term to model the effect of the basins. However, this parameterization ignores the 3-D effect, as well as the location and orientation of the fault rupture with respect to the basins. Recognizing this deficiency in the empirical GMPEs, SCEC launched a program to simulate ground motions numerically using a physics-based 3-D fault-rupture and wave-propagation model of Southern California. The computations were done with the CyberShake platform that utilized supercomputers to generate millions of simulations covering the range of potential moderate to large magnitude earthquakes on Southern California faults included in the Uniform California Earthquake Rupture Forecast (UCERF) models the USGS has used to develop the MCER ground-motion maps for the region.

The potential feasibility of using CyberShake to develop long period ground motion maps was demonstrated by SCEC (Graves et al., 2010; Wang and Jordan, 2014), and this eventually led to the formation of the SCEC UGMS committee.

**Results Generated by UGMS during 2014**

During its May 2014 meeting, the UGMS committee decided to conduct further tests of the feasibility of CyberShake at 14 sites in Southern California (Figure 1). These sites were selected to capture a representative range of different effects (i.e., deep basin, basin edge, directivity, near field). $M_{CER}$ response spectra were computed at these sites using the CyberShake simulations and the NGA West and NGA West2 GMPEs. (The Idriss GMPE was not used because it did not account explicitly for basin effects.) The NGA GMPEs required estimates of the $V_{S30}$, the average shear-wave velocity in the upper 30m, and the basin depth term, $Z_{1.0}$ or $Z_{2.5}$, the depth to the top of the layer with a shear-wave velocity of 1 km/sec or 2.5 km/sec, respectively. Values estimated for these parameters at the 14 sites are listed in Figure 1.

SCEC developed a web page containing the results of the $M_{CER}$ calculations, which involved computing the following at each site:

1. The 5% damped, horizontal component, response spectra in the direction of maximum shaking.

2. Probabilistic $M_{CER}$ at each site, which required the convolution with a generic fragility function, per Section 21.2.1.2 of the ASCE 7-10 standard.

3. Deterministic $M_{CER}$, including the Deterministic Lower Limit $M_{CER}$, per Section 21.2.2.

4. $M_{CER}$ response spectrum as the minimum of the Deterministic and Probabilistic $M_{CER}$, per Section 21.2.3.
The CyberShake-based and NGA-based MCE_R response spectra were computed at common periods of 2, 3, 4, 7.5, and 10 sec; the NGA-based spectra were also computed at 1 and 1.5 sec periods. After observing the results, it was quickly recognized that CyberShake underestimated the response spectra at 2-sec period (see Wang and Jordan, 2014, Fig. 6), a limitation that will be corrected in 2015.

The results of each step above were archived in various links in the SCEC web site, CyberShake MCE_R, at http://scec.usc.edu/scecpedia/CyberShake_MCE. The MCE_R response spectra from Step 4 were plotted on log-log graphs with the vertical axis being 5% damped, horizontal component, pseudovelocity [PSV = (T/2π) S_a, where S_a is the response spectral acceleration], and the horizontal axis being period, which ranged from 1 to 10 sec. Each plot presents the results for one of the 14 sites, and it compares the MCE_R response spectra from the CyberShake simulations, the 2013 NGA West2 GMPEs, and from the General Procedure of Section 11.4 of ASCE 7-10. The plots follow Figure 1, and the abbreviation at the top of each plot identifies the site in the figure.

Several observations are apparent from the MCE_R response spectra plots:

1. As noted above, the CyberShake spectral ordinate at 2-sec period was underestimated, and the amount of the underestimation was a factor of ~2.

2. The CyberShake-based and NGA West2 GMPE-based MCE_R response spectra were within a factor of 2 of each other in the 3 to 10-sec period band, and for some sites the two spectra were virtually identical.

3. An average of the CyberShake and GMPE-based MCE_R response spectra from 3 to 10 sec provided a curve that was a fairly smooth transition to the GMPE-based MCE_R response spectrum between 1 and 3 sec.

Conclusions

The results generated during 2014 are encouraging and indicate that the UGMS committee should continue its efforts toward generating long period ground motion maps for Southern California for possible inclusion in (1) the next edition of the Los Angeles City building code, which would be a variation to the ground motions for Southern California in the ASCE 7-16 standard, and (2) the 2020 NEHRP seismic provisions and the ASCE 7-22 standard. The code cycle for the latter has already begun.

A few technical issues will need to be addressed before draft maps can be prepared. One item was the placement of the hypocenter at the bottom of the thrust/reverse faults in the CyberShake rupture realizations, which would tend to introduce more directivity from upward propagating
ruptures than was considered realistic. It was agreed that a more more uniform distribution of hypocenters with depth for these faults should be made for future CyberShake runs.

Another issue was the effect of the near surface velocity model on the ground motions CyberShake generates at shorter periods ~ 2 sec. The sensitivity of ground motions will be checked at a few basin sites resulting from (1) a finer mesh of the near surface geology over a depth ~200m, and (2) a more realistic velocity structure over this depth. Depending on the results, some refinements may be made.

The UGMS committee must also decide how to include the CyberShake simulations in the preparation of the ground-motion maps. The MCE\textsubscript{R} response spectra at the 14 sites indicates both the 2013NGA West2 GMPEs and the CyberShake simulations should be used, but the exact procedure will probably be determined toward the end of 2015.

References


Acknowledgements

The work done by Scott Callaghan, Kevin Milner, and Philip Maechling of SCEC to compute the MCE\textsubscript{R} response spectra and prepare the CyberShake MCER web site with these and other data related to the calculations, is greatly appreciated, as well as the contributions of the UGMS committee members and corresponding members.
**Figure 1**
Locations of 14 Sites and Their Vs30, Z1.0, Z2.5 Values

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Vs30 (Wills 2006)</th>
<th>Z1.0 (CVM-S4.26)</th>
<th>Z2.5 (CVM-S4.26)</th>
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* CVM-S4.26 has a Vs30 larger than the Z-value, so the depth is essentially 0.
The graph illustrates the relationship between period (s) and Peak Strong-Vertex (PSV) velocity (cm/s) for different ground motion models. The models include:

- ASCE 7-10 Det Lower Limit
- ASCE 7-10 Ch 11.4
- GMPE MCER
- CyberShake MCER

The x-axis represents the period (s), while the y-axis represents the PSV velocity (cm/s). The graph shows how the PSV velocity changes with varying periods for each model.