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Site-Specific MCE_R Response Spectra for Los Angeles Region based on 3-D Numerical Simulations and the NGA West2 Equations

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ABSTRACT

The Utilization of Ground Motion Simulation (UGMS) committee of the Southern California Earthquake Center (SCEC) developed site-specific, risk-targeted Maximum Considered Earthquake (MCE_R) response spectra for the Los Angeles region. The long period ($T \geq$ 2-sec) MCE_R response spectra were computed as the weighted average of MCE_R spectral accelerations derived from (1) 3-D numerical ground-motion simulations using the CyberShake computational platform, and (2) empirical ground-motion prediction equations (GMPEs) from the Pacific Earthquake Engineering Research (PEER) Center NGAWest2 project. The short period ($T <$ 2-sec) MCE_R response spectra were computed exclusively from the NGAWest2 GMPEs. A web-based lookup tool was also developed so users can obtain the MCE_R response spectrum for a specified latitude and longitude and for a specified site class or 30-m average shear-wave velocity, V_{S30}. The tool provides acceleration ordinates of the MCE_R response spectrum at 21 natural periods in the 0 to 10-sec band.

Introduction

The UGMS committee was formed in the spring of 2013 with the goal of utilizing the CyberShake simulation platform to improve the determination of long period ground motion in the Los Angeles region for use in seismic design. Details of the CyberShake methodology are provided in Graves et al. [1] and Wang & Jordan [2], and the computational process is described by Callaghan et al. [3]. The CyberShake probabilistic seismic hazard model used here (CS-LA15.4) simulated the ground motions for ~40,000 fault ruptures of moment magnitude $M \geq 6$ in Southern California from the Uniform California Earthquake Rupture Forecast, UCERF2 [4], generating ~440,000 pairs of orthogonal horizontal component time histories for each of 336 regional sites. This ensemble is large enough to sample the aleatory variability of the rupture process, including hypocenter and slip variations [5]. The time histories were computed using the high-resolution 3-D crustal model CVM-4.26 [6]. Other details on the background and motivation for the project can be found in Crouse and Jordan [7].

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MCE_R Response Spectra for Southern California

As described in Crouse and Jordan [7], MCE_R response spectra were computed separately for the NGA West2 GMPEs and the CS-LA15.4 model by following the site-specific procedures for probabilistic and deterministic seismic hazard analysis (PSHA and DSHA) in Chapter 21 of the ASCE 7-16 standard. Initially, these spectra were computed for 14 sites outside and within the basins of the Los Angeles region to obtain indications of the characteristics and differences in the spectra. The GMPE-based MCE_R response spectra were computed by substituting the values of the basin-depth terms, $Z_{1.0}$ and $Z_{2.5}$ (the depths to the tops of the layers with shear-wave velocities of 1.0 km/sec and 2.5 km/sec), taken from CVM-S4.26, and the V_{S30} value from Wills et al. [8], into the Abrahamson et al. [9], Boore et al. [10], Campbell and Bozorgnia [11], and Chiou and Youngs [12] GMPEs.

Based on MCE_R response spectra computed from the two approaches, the UGMS committee developed an averaging procedure to combine the spectra in the period band, 2.0 to 10 sec. The procedure is illustrated in the logic tree shown in Figure 1.

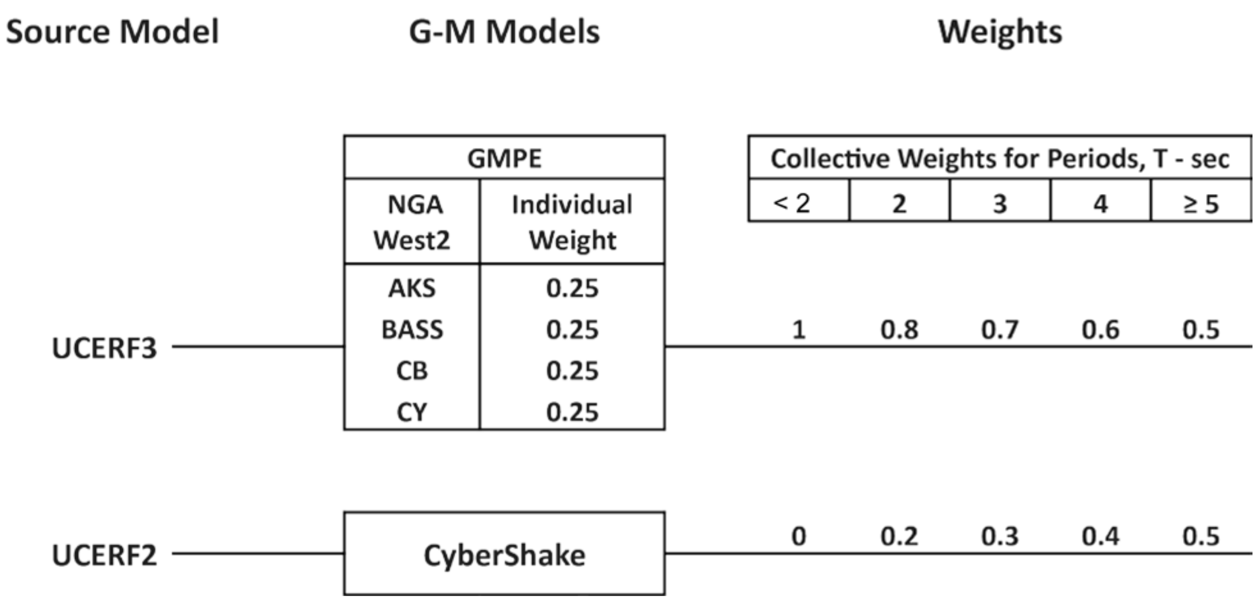

Figure 1. Logic tree illustrating the collective weights applied to MCE_R response spectra from the NGA West2 and CS-LA15.4 models.

The final MCE_R response spectra are the weighted geometric average of the MCE_R response spectra from the NGA West2 GMPEs and from the CyberShake simulations; the weights assigned to each vary depending on the natural period, T, with the MCE_R response spectra from the NGA West2 GMPEs receiving all the weight for $T < 2.0$ sec. As T increases, the weights for the MCE_R response spectra from the NGA West2 equations decrease, and the weights for the CyberShake MCE_R response spectra increase such that, for $T \geq 5.0$ sec, the weights are equal. An additional requirement, namely that these "averaged" MCE_R response spectra cannot be less than the MCE_R response spectra from NGA West2 equations, was imposed to account for the underestimation of the CyberShake MCE_R response spectra at $T < \sim 3$ sec. A color-coded plot of the "averaged" 5-sec MCE_R spectral accelerations for the region is presented in Figure 2, which also shows the locations of the 336 sites where the CyberShake motions were simulated.

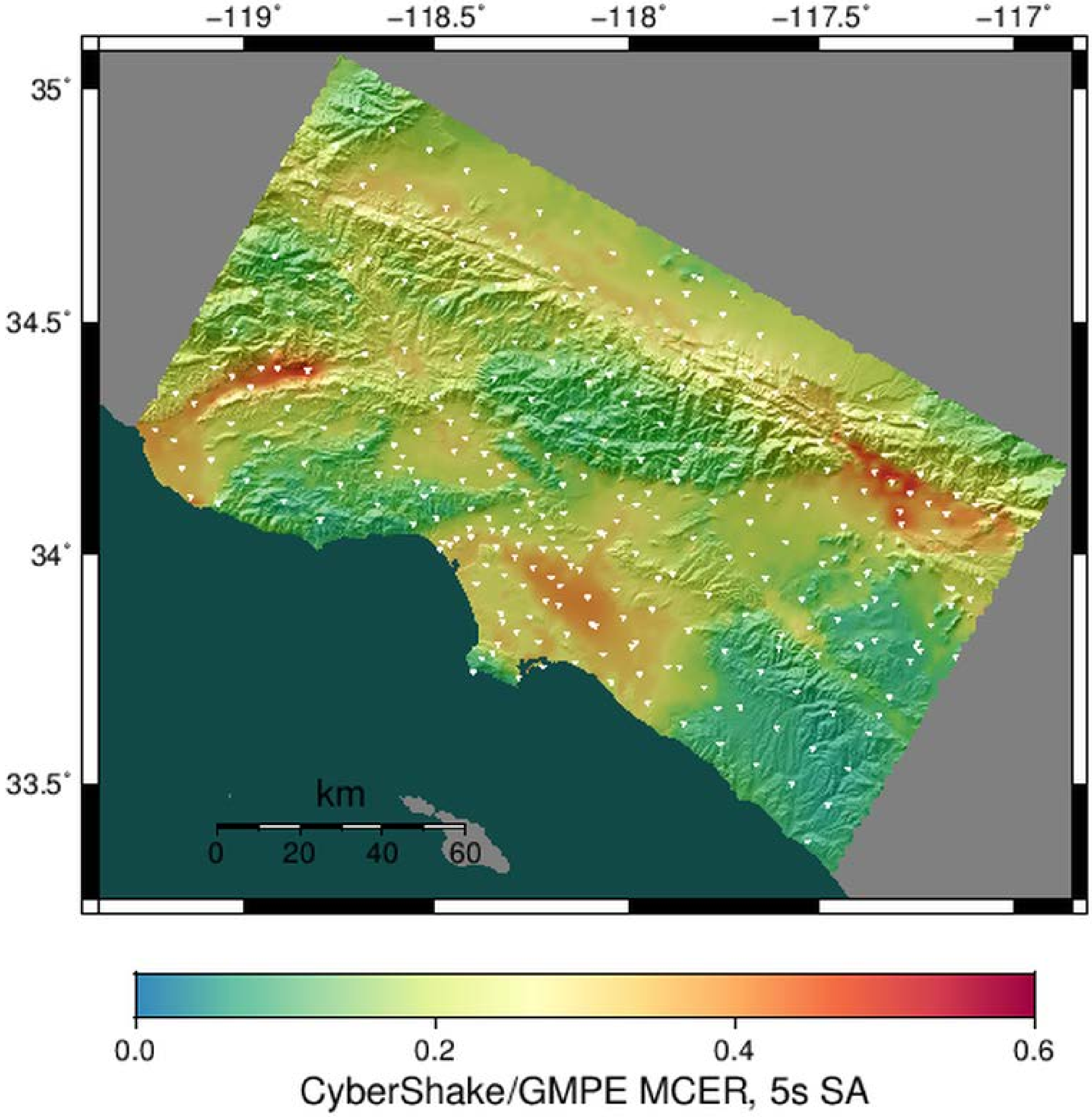

Figure 2. Regional MCE_R spectral acceleration map for 5-sec period. The 336 CyberShake sites are solid inverted white triangles. Acceleration scale in g.

The decision to compute the final MCE_R response spectra as the weighted geometric average of the MCE_R response spectra from the NGA West2 GMPEs and the CyberShake simulations, rather than weight the total mean hazard curves from both approaches (which was initially considered because it is the standard approach), was as follows. The MCE_R response spectra from weighting the hazard curves were not much less than the MCE_R response spectra from the simulations at deep soil basin sites, where the simulation-based MCE_R response spectra were significantly greater than the GMPE-based MCE_R response spectra by up to a factor of ~2. Because the simulations were generated from a linear model, the concern was that they overestimated these site ground motions due to nonlinear responses in the local soils and within the fault zones generating the motions. Limited 1-D nonlinear site-response analysis conducted by the UGMS indicated that the long period motions would be reduced, and further reductions might be expected from nonlinear response within the fault zone [13, 14]. Thus, weighting the MCE_R response spectra was a convenient way to judgmentally account for nonlinear effects and produce smoother looking final MCE_R response spectra that were not significantly greater than the GMPE-based MCE_R response spectra. This latter observation was considered important to gain acceptance and use of the MCE_R response spectra by the structural engineering community, which would be reluctant to accept such spectra if they were significantly greater than MCE_R response spectra from the traditional site-specific approach using the NGA West2 GMPEs.

Web-Based Lookup Tool

A web-based lookup tool, similar to the USGS lookup tool, was developed by SCEC under the UGMS direction and released for public use in early 2018. The web address to access the tool is as follows: https://data2.scec.org/ugms-mcerGM-tool_v18.4. This tool enables users to obtain the MCE_R response spectrum for a specified latitude and longitude and for a specified site class or V_{S30}. If either of these local geologic parameters is not known, the tool automatically selects a default value of V_{s30} from Wills et al. [8]. The Summary output consists of a table of acceleration ordinates of the MCE_R response spectrum at multiple natural periods in the 0 to 10-sec band; a plot of the spectrum is also included. The Detailed output also presents the simulation-based and GMPE-based MCE_R response spectra; values of S_{DS}, S_{D1}, S_{MS}, and S_{M1}, per the requirements in Section 21.4 of ASCE 7-16, are also listed, as well as the PGA_M, per Section 21.5.

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