A study of applicability of NGA models in Taiwan

Po-Shen Lin[1], Chyi-Tyi Lee[1,2], Brain Chiou[3], Chin-Tung Cheng[4], Jin-Chin Chern[4]
[1]Institute of Geophysics, National Central University
[2]Institute of Applied Geology, National Central University
[3]Caltrans' Geo-Research Group, Division of Research and Innovation
[4]Geotechnical Engineering Research Center, Sinotech Engineering Consultants, INC

Abstract

The purpose of this study is to investigate if there is significant difference between earthquake strong-ground motions in California and in Taiwan. A large set of strong ground-motion records from Taiwan is compiled and compared to the NGA (Next Generation Attenuation of Ground Motions) models developed for California. Comparison is made via two types of residuals, the inter-event and intra-event residuals. The results suggest, overall, the magnitude, distance, and soil (V_{S30}) scaling of the four NGA models examined in this study work well for Taiwan. There is a significant trend or bias in the inter-event residual against the depth to the top of rupture. At large distances (> 150 km), NGA models without crustal damping tend to over predict the Taiwan data at short periods.

Introduction

The high-quality earthquake recordings from Taiwan offer a unique opportunity to advance the knowledge of strong-motion seismology. About half of the data in the NGA dataset are from six Taiwan earthquakes with magnitude greater than 5.9 (Chiou and Youngs, 2006). However, so far there isn't a published study that systematically investigates the difference in strong-ground motion between Taiwan and California. The main objective of this study is to provide such an investigation. A strong-motion database similar to the NGA database is developed and used in this study. We summarizes the development of this database and residuals with respect to four NGA models are used as the primary data for comparison. A model-by-model summary of the comparison results is given in this study.

Data

This section describes the compilation of a spectral acceleration dataset that includes 7722 records from 71 crustal (hypocentral depth < 35 km) earthquakes in Taiwan. The magnitude and distance distribution of the dataset is shown in Figure 1.

The raw strong-motion records were obtained from the Central Weather Bureau

(CWB) of Taiwan. All the records were processed by baseline correction and by band-pass filtering with a causal 4-pole Butterworth filter, channel by channel. The high-cut frequency was set to 50 Hz for convenience. The selection of low-cut corner frequency was based on the shape of pseudo spectral velocity (PSV) spectra and Fourier amplitude spectral.

Ground motion parameters examined in this study are the peak ground acceleration and 5%-damped pseudo-spectral accelerations at 0.1, 0.3, 0.5, 1.0, 3.0 and 5.0 seconds. The ground-motion parameters were computed for each of the two horizontal components, orientated in the E-W and N-S directions. The geometric mean of the two horizontal components is taken directly from the as-recorded values. This is different from the GMRotI (Boore at al., 2006) used by NGA models. However the difference between the two is not expected to be large and therefore is not expected to impact the conclusion reached in this study.

The moment magnitude (M_W) published in the earthquake catalog of BATS (Broadband Array in Taiwan for Seismology) is the main source for the M_W used in this study. If an earthquake is not in the BATS catalog, then the M_W from Harvard's CMT catalog was adopted. If neither is available, the empirical relationship of Tsai and Wen (1999) was used to estimate M_W using M_L published by CWB.

Depth to the top of rupture (Z_{TOR}), fault width (W), the shortest distance from the recording site to the ruptured fault plane (R_{Rup}), Joyner-Boore distance (R_{JB}) are derived from the available finite fault model. When a finite fault model is not available, the following substitutions were used: hypocentral depth for Z_{TOR}, the predicted fault width from Well and Coppersmith (1994) for W, hypocentral distance for R_{Rup}, and epicentral distance for R_{JB}.

Three resources are available for obtaining the V_{S30} at a CWB strong-motion site: the NGA database, the 3rd letter (C3) of Geomatrix's classification, and the site classification of Lee et al. (2001). A large number of CWB sites are already included in the NGA database. For these sites, NGA's V_{S30} is adopted. For sites that are not in the NGA database, an estimate of V_{S30} is obtained using the same approach as was used by NGA. Specifically, when V_{S30} computed from NCREE's logging data is not available, V_{S30} is inferred from the 3rd letter of Geomatrix's classification and the site elevation using the empirical model developed by Chiou and Wen (a summary of that model is given in Appendix C of Chiou and Youngs, 2006). There are about 224 stations whose Geomatrix classification has not been assigned yet. For these stations, V_{S30} is inferred from Lee et al. classification and elevation using the (unpublished) model developed by Chiou and Wen. Finally, both site classifications are not available for a few recently installed stations and a V_{S30} vs. elevation model was used to provide an estimate of V_{S30} at these sites.

Comparison of Taiwan Data to NGA Attenuation Models

The comparison of Taiwan data to four NGA models for PGA, 5%-damped pseudo spectral accelerations at 0.1, 0.3, 0.5, 1, 3, and 5 second period is made by examining the residuals against several key predictors (moment magnitude, distance, depth to top of rupture, and V_{S30}) of the NGA models.

Residuals are calculated as observed value minus predicted value in the natural logarithm domain (i.e. residual = *ln*(observe) - *ln*(predict)). Assumptions regarding the values of a few predictors are made. Because focal mechanism is still missing for many earthquakes, vertical strike-slip faulting is assumed for all earthquakes. As a result, the effects of style of faulting and foot wall/hanging wall are not captured for records from dip slip earthquakes. Furthermore, because information of basin depth in Taiwan is still under development, the default value of $Z_{2.5}$ suggested by Campbell and Bozorgnia is used for all sites. In order to check the accuracy of depth, We re-estimate the depth of earthquakes with hypocentral depth between 15~35km, using P and S arrival times picked from several strong-motion records close to the epicenter. This exercise does not result in large changes in focal depth of these earthquakes; in fact some earthquakes become even deeper.

Result

The results suggest the magnitude, distance, and soil (V_{S30}) scaling of the four NGA models examined in this study work well for Taiwan, in general. There is a trend or a bias in the inter-event residual against the depth to the top of rupture for all four NGA models. Also, NGA models without crustal damping tend to over predict the Taiwan short-period data at large distances (> 150 km). A distance trend at 50 km is seen in several NGA models. Further study is needed to understand and correct this trend

Reference

Boore D. M., J. Watson-Lamprey and N. A. Abrahamson, 2006: Orientation-independent measures of ground motion, *Bull. Seism. Soc. Am.*, **96**, 1502–1511.

Boore D. M. and G. M. Atkinson, 2006: Boore-Atkinson Provisional NGA Empirical Ground-Motion Model for the Average Horizontal Component of PGA, PGV and SA at Spectral Periods of 0.05, 0.1, 0.2, 0.3, 0.5, 1, 2, 3, 4, and 5 Seconds, *PEER report,* http://peer.berkeley.edu/products/rep_nga_models.html

Campbell K. W. and Y. Bozorgnia, 2006: Campbell-Bozorgnia NGA Empirical Ground Motion Model for the Average Horizontal Component of PGA, PGV, PGD and SA at Selected Spectral Periods Ranging from 0.01–10.0 Seconds, *PEER report,* http://peer.berkeley.edu/products/rep_nga_models.html

Chiou B. S.-J. and R. R. Youngs, 2006: Chiou and Youngs PEER-NGA Empirical Ground Motion Model for the Average Horizontal Component of Peak Acceleration and Pseudo-Spectral Acceleration for Spectral Periods of 0.01 to 10 Seconds, *PEER report,* http://peer.berkeley.edu/products/rep_nga_models.html

Chiou, B. S-J. and K.L. Wen, 2006: Estimation of Vs30 at CWB's Free-Field Sites, unpublished document.

Lee, C. T., C. T. Cheng, C. W. Liao, and Y. B. Tsai, 2001: Site Classification of Taiwan Free-field Strong-Motion Stations, *Bull. Seism. Soc. Am.*, **91**, 1283-1297.

Liu, K. S., T. C. Shin, and Y. B. Tsai, 1999: A free field strong motion network in Taiwan: TSMIP, *TAO*, **10**, 377-396.

Tsai, Y. B., and K. L. Wen, 1999: Compilation of a uniform catalog of earthquakes in Taiwan and development of motion attenuation relationships, *Report of national science and technology program for hazards mitigation*, **87-07**, 79 pp.

Well, D. L. and K. J. Coppersmith, 1994: New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement, *Bull. Seism. Soc. Am.*, **84**, 974-1002.

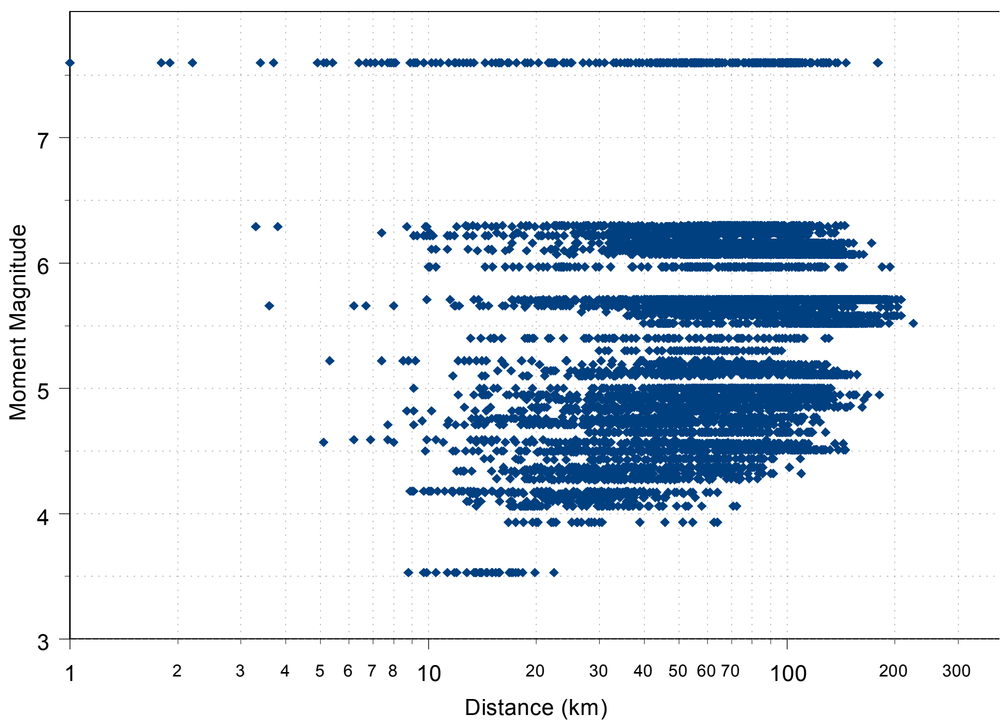

Figure 1. Magnitude-distance distribution of strong motion data used in this study

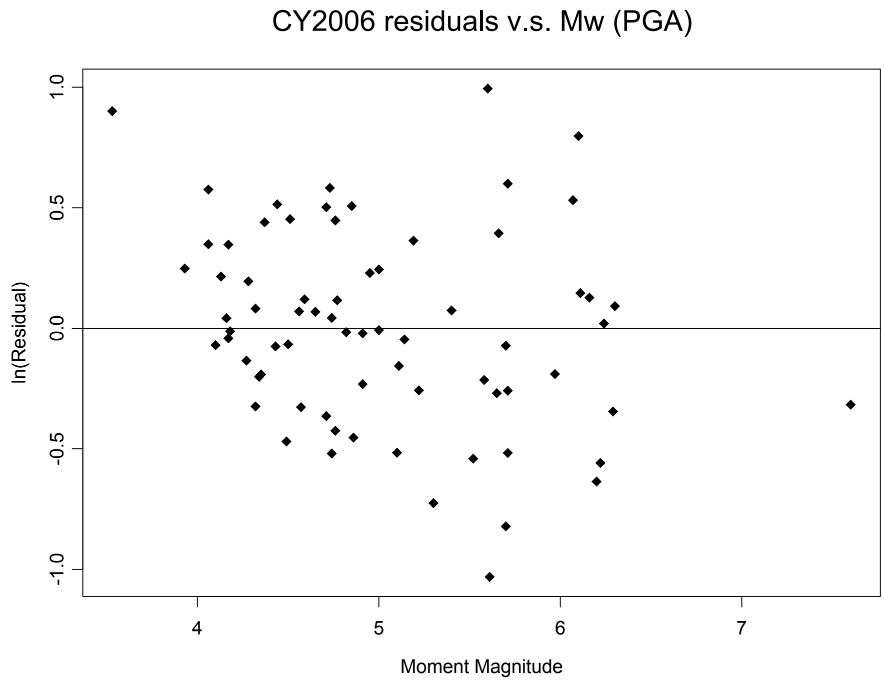

Figure 2. Inter-event residual for Chiou and Youngs' 2006 model versus moment magnitude (for PGA)

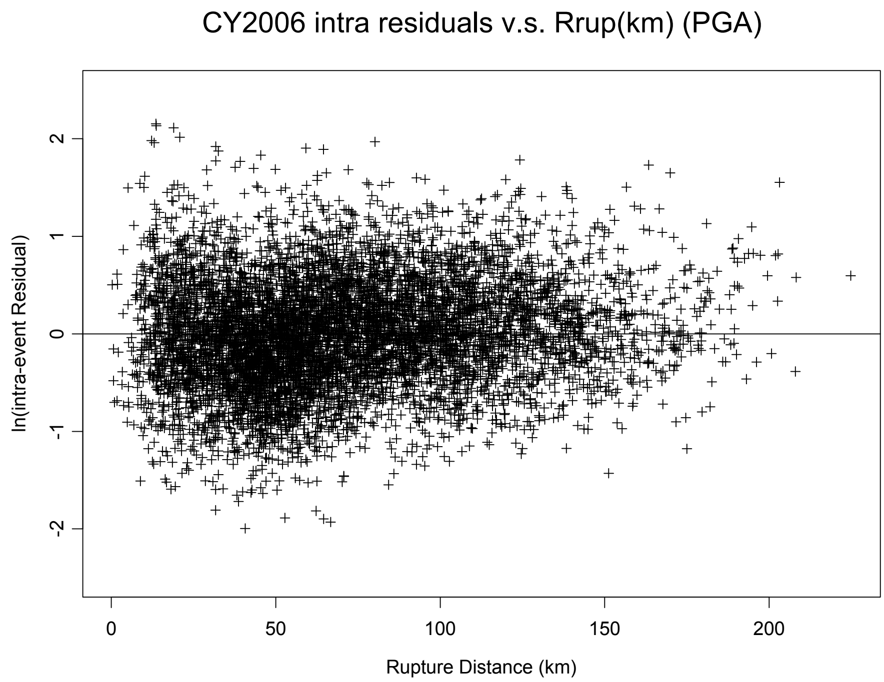

Figure 3. Intra-event residual for Chiou and Youngs' 2006 model versus rupture distance (for PGA)