Relations of USGS MM Intensity Versus Earthquake Ground Motion Indices Using the Three Recent California Earthquakes

The University of Tokyo, Institute of Industrial Science, Member Khosrow T. Shabestari
The University of Tokyo, Institute of Industrial Science, Member Fumio Yamazaki

1. Introduction

Recently many new intensity scales and correlation between earthquake ground motion indices and MM intensity scale proposed especially for the California region. Following the 1994 Northridge earthquake, Dengler and Dewey (1998) proposed a community (the geographical boundaries of ZIP codes) decimal intensity (CDI) scale. Their concept is based on the Humboldt Earthquake Education Center (HEEC) telephone survey to study the effect of individual household’ s responses and their observation of earthquake’ s effects as a function of independently assigned US Geological Survey (USGS) MM intensity for the same communities. Wald et al. (1999b) introduced an automatic rapid generation method of intensity map using the responses of the intensity survey questionnaires to the Internet users who felt the earthquake in southern California. They convert the individual answers of each community into numerous values as Community Internet Intensity (CII) using a modified version of the CDI (Dengler and Dewey 1998) algorithm. Since October 1996, the JMA developed a new instrumental seismic intensity scale (I_{JMA}) using three-component strong ground motion records. The new instrumental seismic intensity values are promptly obtained just after an earthquake occurs, as a real number, as well as other earthquake ground motion indices. In this study, since new instrumental JMA seismic intensity (I_{JMA}) can be used as an earthquake ground motion index, the I_{JMA} methodology is applied for the three California damaging earthquakes. The reported Modified Mercalli Intensities for the selected recording stations during the 1994 Northridge earthquake, the 1989 Loma Prieta earthquake, and the 1987 Whittier Narrows earthquake are collected. Using these strong ground motion records, the new JMA seismic intensities are calculated for the three earthquakes. Then the linear regression among the mean of PGA_L and PGV_L (larger of two horizontal components) for the each given limited range of MMI units and the nearest reported MM intensity values to the recording stations are obtained, respectively for the current data set. Also the linear relationship of PGA_L versus I_{JMA} is derived, then by combining these two equations the new relation between I_{JMA} and instrumental MMI (I_{MM}) seismic intensity is introduced. Finally, the linear regression of MM intensity with respect to the mean of I_{MM} (for given each MMI unit) is performed for the data set, and the result is compare with the Wald et al. (1999b) relation between MMI versus CII.

2. Relations of USGS MMI versus PGA and PGV

Before starting a regression analysis among the data, first the location of all stations and reported USGS MMI values were plotted for the three earthquakes. The corresponding MMI value for each recording station was selected, taken the nearest MMI value to that station (in some cases the local site geological condition was considered). In the primary regression of MMI versus earthquake ground motion indices (PGA_L, PGV_L, and I_{JMA}) some stations showed a large scatter from the mean relations. Hence they were excluded in the analysis further. Finally the linear relations between the USGS MMI and the geometric mean of the PGA_L (PGAm L) and PGV_L (PGVm L) values for a given MMI unit were derived, respectively. In case of PGA for the limited range of MMI (V $\leq$ MMI $\leq$ VIII), we found that our regression is closer to the Wald et al. (1999a) relation than the result when PGA values for the MMI IV were included. This might be explained by the lack of PGA in MMI IV unit, therefore the geometric mean of the PGA_L could not represent the actual MMI. However, this was not the observation case for the relation between MMI and PGV. To check the validity the obtained two equations, those were compared with the results of the Wald et al. (1999a), who introduced a linear regression of MMI versus PGA and PGV for the eight recent California damaging earthquakes and Trifunac and Brady (1975), who used 57 California earthquakes. As shown in Figures 1a and 1b, our relations are very close to the Wald et al. (1999a) relations and a significant difference compared with the Trifunac and Brady (1975) relationships was observed. The reasons to explain this difference may be the development of earthquake resistant structures and the improvement of sensitivity of instruments in the last two decades. Revising building codes after damaging earthquakes, make structures to resist to high-level ground shaking (Wald et al. 1999a).

The JMA seismic intensities (I_{JMA}) were calculated from the acceleration records, which consist of 105 three-component sets of three recent California earthquakes. Figure 2a indicates a linear regression between the PGA_L and obtained I_{JMA}. By substituting this relation into relation of Fig. 1a, a new relationship between the instrumental seismic intensity (I_{JMA}) and MMI was obtained as given by Eq. (1).

The proposed relation between I_{JMA} and MMI $$I_{MM} = 1.71\, I_{JMA} - 1.84 \quad (1)$$

Key words: Earthquake ground motion indices, Instrumental seismic intensity, Modified Mercalli Intensity
Contact Address: 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan.

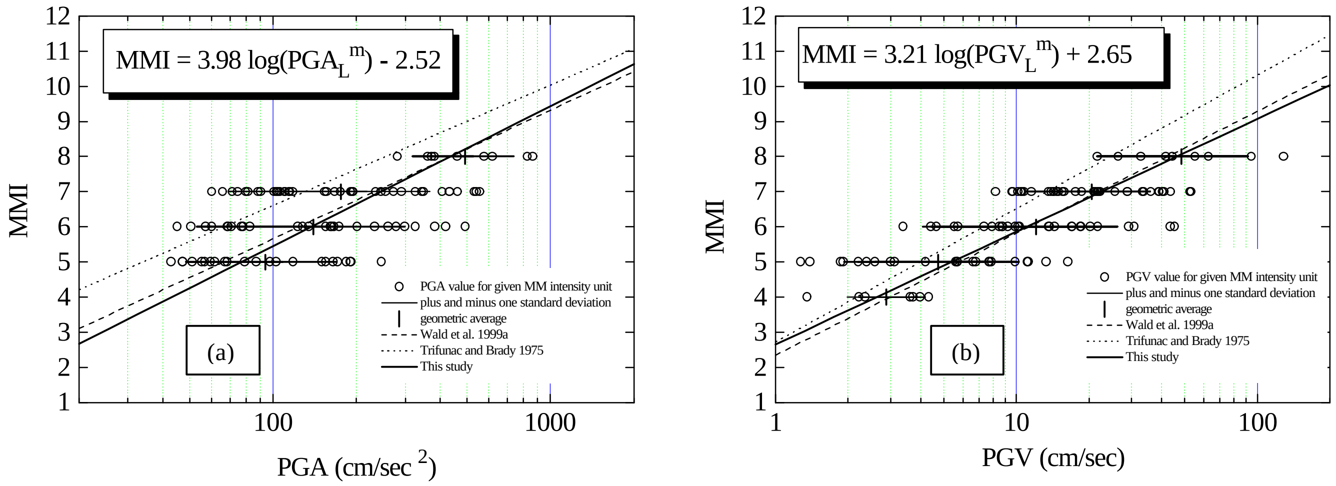

Fig. 1 The linear relations between MMI versus (a) PGA and (b) PGV for the three California earthquakes. The bars represent the geometric average of PGA and PGV for a given MMI unit, horizontal lines show the range of mean plus minus one standard deviation, and open circles denote the recorded PGA and PGV values.

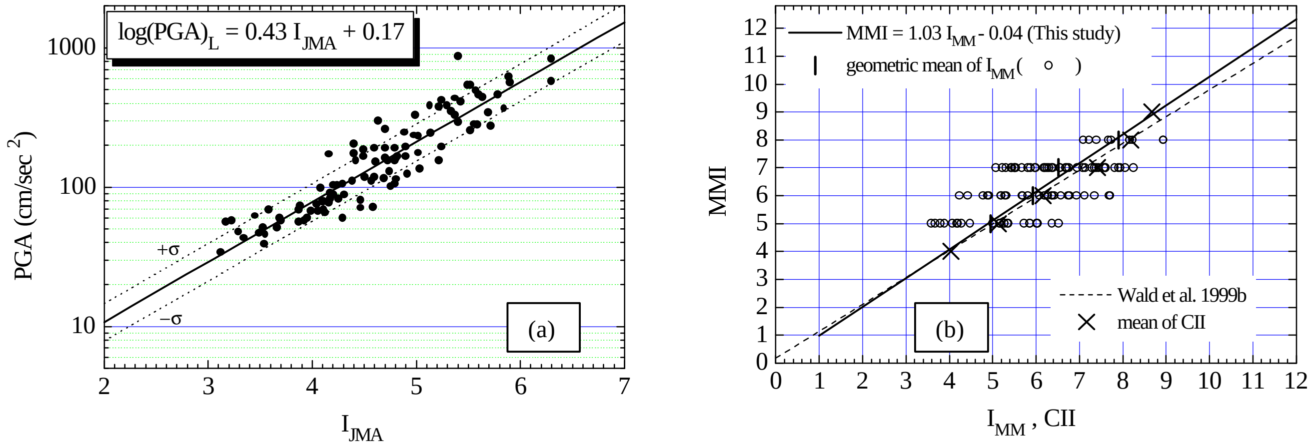

Fig. 2 The linear relations between (a) PGA and I_{JMA} and (b) MMI and I_{MM} (solid line) for the three California earthquakes.

Figure 2b shows the linear relation between the geometric mean of the new proposed intensity (I_{MM}) for a given USGS MMI unit, which calculated from Eq. (1) and the USGS MMI intensity (for the limited range of USGS MMI). We compared our result with the recent proposed CII mapping method’ s result of Wald et al. (1999b), who correlated CII of the Northridge, the Whittier Narrows, and Sierra Madre earthquakes with the USGS MMI and correspondence MM intensity values for the small to moderate events of California using TriNet ShakeMap instrumental intensity method (Wald et al. 1999c).

3. Conclusions

Since the USGS MMI value is not directly associated with PGA and PGV values, which are obtained from one point, relationships were obtained by a linear regression between the USGS MMI and the geometric average of PGA_L and PGV_L for a given MM intensity unit. Combining the obtained relation of PGA and the relation between I_{JMA} and PGA, the new linear relation between MMI and I_{JMA} was obtained for the three California significant earthquakes. We find that our proposed I_{MM} values are well correlated with the USGS MM intensities.

References

Dengler, L. A. and Dewey, J. W. 1998. An intensity survey of households affected by the Northridge, California, earthquake of 17 January 1994, *Bull. Seism. Soc. Am.*, Vol. 88, No.2, 441-462.

Trifunac, M. D. and Brady, A. G. 1975. On the correlation of seismic intensity scales with the peaks of recorded strong ground motion, *Bull. Seism. Soc. Am.*, Vol. 65, 139-162.

Wald, D. J., Quitoriano, V., Heaton, H. T., and Kanamori, H. 1999a. Relationships between peak ground acceleration, peak ground velocity, and Modified Mercalli Intensity in California, *Earthquake Spectra*, Vol. 15, No.3, 557-564.

Wald, D. J., Dengler, L. A., and Dewey, J. W. 1999b. Utilization of the Internet for rapid community intensity maps, *Seism.Research Letters*, Vol. 70, No.6, 680-697.

Wald, D. J., Quitoriano, V., Heaton, H. T., and Kanamori, H., Scrivner, C. W., and Worden, C. B. 1999c. TriNet “ ShakeMap” : Rapid generation of peak ground motion and intensity maps for earthquakes in southern California, *Earthquake Spectra*, Vol. 15, No.3, 537-555.