International Workshop on Earthquakes in North Iceland
Húsavík, North Iceland, 31 May - 3 June 2016

On the Sensitivity of Ground-Motion Prediction Equations for Earthquake Strong-motions in the South Iceland Seismic Zone

Milad Kowsari[1], Benedikt Halldórsson[1], Birgir Hrafnkelsson[2], Jónas Þór Snæbjörnsson[3], Símon Ólafsson[1] and Sigurjón Jónsson[4]

[1]*Earthquake Engineering Research Centre, School of Engineering and Natural Sciences, University of Iceland, Iceland (milad@hi.is; skykkur@hi.is; simon@hi.is)*
[2]*Faculty of Physical Sciences, School of Engineering and Natural Sciences, University of Iceland, Iceland (birgirhr@hi.is)*
[3]*School of Science and Engineering, Reykjavík University, Iceland (jonasthor @ru.is)*
[4]*King Abdullah University of Science and Technology (KAUST), Saudi Arabia (sigurjon.jonsson@kaust.edu.sa)*

Seismic hazard analysis requires a reliable estimate of the expected earthquake ground motion at the site of interest. The most common way to assess the expected ground motion is to use a mathematical function that includes source, path and site parameters, commonly referred to as ground motion prediction equation (GMPE). Sensitivity and uncertainty analyses have been carried out in different parts of the world and have consistently shown that GMPEs play an important role in seismic hazard (*Cramer*, 2001; *Giner et al*., 2002; *Sabetta et al*., 2005; *Lombardi et al*., 2005; *Atkinson and Goda*, 2011). However, the development of reliable GMPEs in regions with scarce earthquake strong-motion data is challenging. To overcome this problem, GMPEs from other regions similar to the region of interest from geological and seismological point of view have been tested and in some cases improved by updating the GMPE parameters with local data. For this purpose, Bayesian statistical analysis can be applied to calibrate GMPEs by combining prior information on ground motion parameters with recorded earthquakes. The methodology is an effective approach when new observations become available. In this study, nine GMPE models are selected from three categories: local models calibrated to the strong-motion database of South Iceland, regional models corresponding to European and Middle Eastern data and finally, models from other regions which had been proposed in the SHARE project as being suitable models for the seismitectonic environment of Iceland. Bayesian posterior inference by Markov Chain Monte Carlo (MCMC) simulation is used to calibrate the selected GMPEs to the Icelandic data, consisting of 96 records from the Icelandic Strong-motion Network with the magnitude range of 5.1-6.5 and distance range of 4.4-82 km what is classified as “rock” vs. “stiff soil” types. The peak ground acceleration (PGA) has been chosen as an intensity measure because of its acceptability and applicability in seismic codes worldwide. Moreover, the Gelman–Rubin statistic and the autocorrelation analysis are used to assess the convergence of simulations and the reliability of the results. After updating, all models seem to fit the recorded data very well in the distance range where data is available. In GMPEs, the residuals are generally assumed to be normal with a mean zero and a standard deviation. The residual of all updated models are decreased and normally distributed with the mean values very close to zero. The standard deviation of GMPE as an aleatory uncertainty has a significant impact on the seismic hazard results. It has remained fairly stable over the past 50 years, with values between 0.10 and 0.40 log10 units and its resistance to reduce is a matter of concern to seismic hazard studies (*Douglas*, 2010). The calibration has resulted in new standard deviation of residuals which expresses the variability of amplitudes about the median prediction equations for earthquakes in South Iceland. In all models, the standard deviations have been reduced to 0.2 in log10 units after the applied method which is shown in Fig. 1.

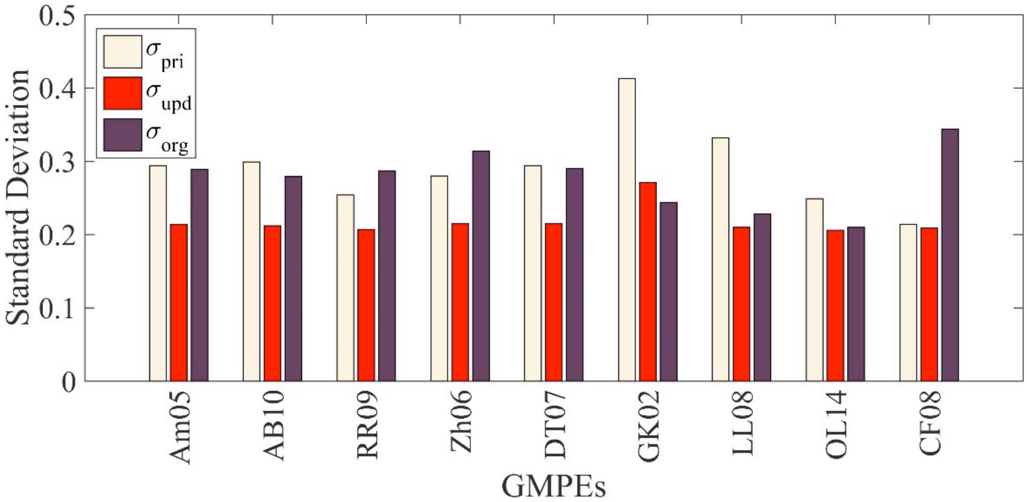

Figure 1. Standard deviation (in log-10 units) of the selected GMPEs, before updating (σ_{pri}), after updating (σ_{upd}) and the original model (σ_{org}).

The difference between the updated and original standard deviations, emphasize the importance of calibration in probabilistic seismic hazard analysis (PSHA). In PSHA the uncertainty about the correct value of the median considered as epistemic that can be handled by considering alternative GMPEs in a logic tree format. Proponents of the logic-tree approach argue that use of multiple models with alternative functional forms is required to properly capture uncertainties in form as well as amplitude (*Atkinson et al*., 2014). The advantage of the method proposed in this study is the use of the posterior probability distribution for each parameter of a given GMPE, instead of using constant regression coefficients in the classical approach.

References

Atkinson, G.M. and K. Goda, Effects of seismicity models and new ground-motion prediction equations on seismic hazard assessment for four Canadian cities, *Bull. Seismol. Soc. Am.* **101**, 176–189, 2011.

Atkinson, G.M., J.J. Bommer and N.A. Abrahamson, Alternative Approaches to Modeling Epistemic Uncertainty in Ground Motions in Probabilistic Seismic-Hazard Analysis, *Seismol. Res. Lett.* **85**, 1141–1144, 2014.

Cramer, C.H., A seismic hazard uncertainty analysis for the New Madrid seismic zone, *Eng. Geol.* **62**, 251–266, 2001.

Douglas, J., Consistency of ground-motion predictions from the past four decades, *Bull. Earthq. Eng.* **8**, 1515–1526, 2010.

Giner, J.J., S., Molina and P. Jauregui, Advantages of using sensitivity analysis in seismic hazard assessment: a case study of sites in southern and eastern Spain, *Bull. Seismol. Soc. Am.* **92**, 543–554, 2002.

Lombardi, A.M., A. Akinci, L. Malagnini and C.S. Mueller, Uncertainty analysis for seismic hazard in Northern and Central Italy, *Ann. Geophys* **48**, 853-865, 2005.

Sabetta, F., A. Lucantoni, H. Bungum and J.J. Bommer, Sensitivity of PSHA results to ground motion prediction relations and logic-tree weights, *Soil Dyn. Earthq. Eng.* **25**, 317–329, 2005.