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On the Sensitivity of Seismic Hazard Estimates for North Iceland on the basis of Monte Carlo Methods

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The Tjornes Fracture Zone (TFZ) of North Iceland is one of the most active seismic zones in Iceland. The main structural components of the TFZ are two major faults, the Grimsey Lineament (GL) and the Húsavík–Flatey Fault (HFF) which both have a history of causing destructive earthquakes (*Stefansson et al*., 2008; *Thorgeirsson*, 2012). The HFF is the largest transform fault in Iceland and is for the most part offshore. On land however, it has an additional normal component of faulting, resulting in an extensional basin where Húsavík, the second largest town in North Iceland, is located, effectively directly on top of the fault. The diverse geology and topography under the town is likely to contribute to localized differences in site effects and spatially variable earthquake strong-motions, indicating possible significant relative differences in earthquake hazard to its inhabitants. The above feature of Húsavík, including dense population (rather than the other regions of Iceland), many infrastructural and industrial buildings and tourist industry indicate that seismic risk is significant in the town and it has suffered damaging earthquakes. For that purpose, the evaluation of earthquake hazard is very vital. Probabilistic seismic hazard analysis (PSHA) is an effective way to quantify the potential and expected level of earthquake ground shaking in a probabilistic framework. Based on the current nationwide seismic hazard estimation of Iceland, Húsavík is located in a zone of high earthquake hazard defined as having a 10% probability peak ground acceleration (PGA) exceeding 0.4g (referred to as ground motion level expected to be exceeded in a 475-year interval). This is a reference value that does not take into account local features that may vary ground motion levels e.g. due to geology, wave propagation, landscape, etc. Additionally, previous earthquake hazard estimates of this region have relied on a single ground motion model and incorporated uncertainties in a limited way, but nevertheless have pointed out several ways to improve the hazard estimates. For this reason it is both timely and important, especially in light of the fast growing heavy industry being developed in the region, to more accurately revise the earthquake hazard estimates. To provide more insight into the nature of earthquake hazard in a given region, PSHA should ideally quantify various sources of uncertainties which are usually categorized as either aleatory or epistemic. Aleatory uncertainty arises because of natural, unpredictable variation in the performance of the system where can not be eliminated with increasing knowledge and information while epistemic uncertainty is due to a lack of knowledge about the behavior of the system that is conceptually resolvable. Uncertainties can be found in all PSHA steps; characteristics of the seismic sources, distribution describing seismicity parameters and GMPEs. However, the uncertainty associated with GMPEs tends to exert a greater influence on the hazard results than other sources of uncertainty. In GMPEs, variability of amplitudes about a median values is aleatory in nature and the uncertainty about the correct value of the median is considered as epistemic. In PSHA, epistemic uncertainty has been modeled by either the use of alternative equations in a logic tree framework or the representative suite approach. However, in both approaches, selection of appropriate GMPEs is still a major challenge, particularly for regions where an appropriate local GMPE does not exist due to the low seismicity or limited observational data. Here, two data-driven methods, the likelihood-based and the Euclidean distance-based ranking are used to reduce epistemic uncertainties. Furthermore, a Bayesian posterior inference by Markov Chain Monte Carlo (MCMC) simulation is used to calibrate the selected GMPEs to the Icelandic data. After calibration, all models fit the recorded data very well in the distance and magnitude range where data is available. In this study, a PSHA in terms of PGA is presented using the Monte-Carlo (MC-PSHA) method. There are some advantages to the MC-PSHA in terms of flexibility and transparency and it is prefered to Cornell McGuire approach (CM-PSHA), due to uncertainty in the present Icelandic earthquake catalog. MC-PSHA takes a standard seismic source model and uses it to generate a very long synthetic catalog representing possible future outcomes of regional seismicity. The Monte Carlo draws follow the prescribed probability distributions for distance, magnitude and epsilon (the number of standard deviations by which an observation differs from the mean of prediction). One of the prominent advantages of MC-PSHA is its compatibility with different seismicity models. In other words, with the MC-PSHA approach, time-dependent, non-Poissonian, Markovian and other models can be adopted easily. In this study, the seismic source zones and related seismicity parameters proposed by *Björnsson et al*. (2007) are used which is shown in Fig. 1.

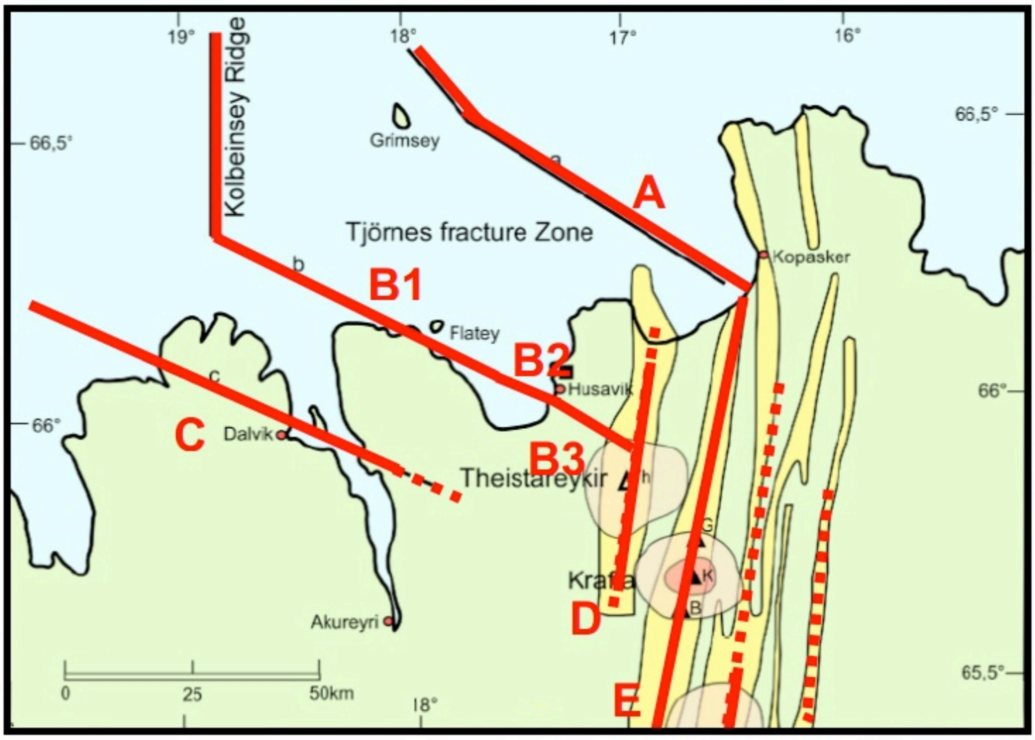

Figure 1. The seismic source zones applied in PSHA. The solid red lines indicate seismic source zones capable of producing earthquakes with magnitude greater than or equal to 4 and the dotted lines refer to source zones where event magnitude does not exceed 4 (Bjornsson et al. 2007). A, B and C are transform zones and the yellow areas indicate volcanic zones.

We applied both the original and updated GMPEs and carried out seismic hazard assessment for grid points over the TFZ. Hazard maps and the standard deviation of hazards show the sensitivity of results on different GMPEs. The obtained results indicate the imoprtance of the appropriate functional form of GMPEs for earthquake hazard and risk anlyses in North Iceland. Moreover, they highlight the shortcomings of the current approaches and provide clear insight into of the direction of future research efforts, namely incorporating near-fault effects as synthesized from calibrated finite-fault earthquake models into the PSHA.

References

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