Soil structure impact on site effects and modeling spatial strong-motion variability across Icelandic strong-motion arrays

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In earthquake engineering the estimation of the impact of subsoil characteristics on site effects, and modeling the distribution of ground motion amplitudes are known as key elements in accurate seismic hazard assessment programs. Recently, the deployment of Icelandic strong-motion arrays, ICEARRAY I in the SISZ and ICEARRAY II in the TFZ, has enhanced the Icelandic strong-motion database and made such detailed studies possible. That is of importance in particular because the site response in standard earthquake engineering practice in Iceland is generally assumed to be uniform across a small area. However, significant variability in relative earthquake ground motion amplitudes as well as prominent different site responses can be detected using recent strong-motion recordings across Icelandic arrays. In this study we quantify the localized site effects across ICEARRAY I and ICEARRAY II considering empirical methods (i.e. Horizontal to Vertical Spectral Ratio, HVSR, and Standard Spectral Ratio, SSR) using both strong-motion data and microseismic recordings. The results between different methods and data sets are consistent and show systematic variation between stations which are highly correlated to geological structures. In particular, we find that the standard modeling of vertically incident body waves is not practical for lava-rock stations characterized by velocity reversals due to recurring lava-sediment stratigraphy. Instead, we model the sub-soil structural as a multi-degree-of-freedom, MDOF, dynamic system to obtain the observed predominant frequencies of site amplification.

Moreover, we present a Bayesian Hierarchical Model, BHM, for spatial distribution of Peak Ground Acceleration, PGA, across both Icelandic arrays. Our proposed model considers a flexible probabilistic framework for multi-level modeling of PGA that accounts for the source and site effects as well as quantifying the uncertainties over multiple hierarchy levels. The main goal of the proposed BHM lies in combining different main factors which directly influence the ground-motion intensities. We find that the total uncertainty is a bit larger in comparison with the calibrated local ground motion prediction equations' standard deviation obtained for south Iceland. Moreover, the results indicate that inter-station variability can be considerable even over a very small area. In addition, the comparison of the obtained site term across ICEARRAY I and ICEARRAY II explicitly indicates that more complex subsoil structure causes more unreliable results with higher uncertainties. Our investigations notably emphasize on the importance of detailed micro-scale studies for seismic hazard assessment specifically for dense urban areas or spatially distributed infrastructures (e.g. pipeline systems, transportation networks, power systems). Therefore, developing our understanding of the main factors which affect the variation of the relative strong-motion amplitude can be critical for seismic hazard assessment or planning insurance rates for the areas under studying.