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Partitioning of epistemic uncertainty and aleatory variability in site specific PSHA

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Conventional probabilistic seismic hazard analyses (PSHAs) assume that the ground motion variability (sigma) related to a given GMPE calibrated from a large data set of ground motions from various earthquakes recorded at multiple stations is an unbiased estimate of the variability at a single site. It is now recognized that part of the variability in the ground motion can be transferred into the epistemic uncertainty affecting the site behavior. Separating the repeatable components of the ground motion variability at a site from the total ground motion variability (ergodic sigma) has the benefit of reducing the ergodic standard deviation by introducing the use of the single-station sigma. On the other hand, the removal of the ergodic assumption implies incorporation of the epistemic uncertainty relative to the site amplification into the PSHA via logic tree. Generally, site-specific PSHAs account for soil amplification through amplification factors, AF(f), which are estimated via numerical ground response analysis. Analytical models for AF(f) (hereinafter, soil amplification functions – SAFs) can be determined by regression of AF(f) versus the spectral acceleration on rock relevant at the same frequency, f. Such predictive functions can be directly incorporated into the rock attenuation models selected for the PSHA, which are therefore transformed into site-specific GMPEs. Alternatively, one may want to keep the PSHA on rock decoupled from that on soil. In such a case, the hazard curve on rock is convolved with the probability density function of AF(f) to obtain the soil hazard. Independently of the computational approach adopted, the total standard error related to the site amplification term reflects both the uncertainty in the soil characteristics and the variability of the input ground motion used in the ground response analysis. While the latter has a pure aleatoric nature, the former is mainly epistemic (since it is related to the lack of knowledge about soil stratigraphy and soil parameter values), although it is commonly treated as aleatoric through Monte Carlo randomization of the soil properties. In this work, we will present a fully non-ergodic approach that separates the epistemic contribution related to the soil properties from the total variability in the soil amplification. The method consists of computing a SAF for each Monte Carlo realization of the soil column. Specifically, a SAF (and its related sigma) has to be determined via regression for each one of the n randomized soil samples at the base of which a number of accelerograms are driven. Each SAF can be therefore integrated into the selected rock GMPEs or, alternatively, can be used in the convolution approach with the rock hazard curves. For each single GMPE, this approach (termed as multi-SAF approach) leads to a bundle of site-specific hazard curves. The advantage of the multi-SAF analysis is clearly twofold. On the one hand, it allows distinction between the aleatoric and epistemic components of site amplification. Consequently, it allows direct incorporation of the epistemic uncertainty relative to site response into PSHA as required by the single-station sigma non-ergodic approach.